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ITU INTERNET REPORTS 2005

The Internet of Things



International
Telecommunication
Union

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ITU Internet Reports

The Internet of Things

November 2005



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FOREWORD

“The Internet of Things” is the seventh in the series of “ITU Internet Reports”, originally launched in 1997 under the title “Challenges to the Network”. This edition has been specially prepared for the second phase of the World Summit on the Information Society, to be held in Tunis from 16-18 November 2005. Technological advances in “always on” communications promise a world of networked and interconnected devices that will provide relevant content and information to users, wherever they may be located. Machine-to-machine communications and person-to-computer communications will be extended to things, from everyday household objects to sensors monitoring the movement of the Golden Gate Bridge or detecting earth tremors. Everything from tyres to toothbrushes will fall within communications range, heralding the dawn of a new era, one in which today’s internet (of data and people) gives way to tomorrow’s Internet of Things.

The first chapter, *Introducing the Internet of Things*, explains the technical visions underlying the Internet of Things in ubiquitous networks, next-generation networks and ubiquitous computing. Chapter two, *Enabling Technologies*, examines the technologies that will drive the future Internet of Things, including radio-frequency identification (RFID), sensor technologies, smart things and nanotechnology and miniaturization. Chapter three, *Shaping the Market*, explores the market potential of these technologies, as well as factors inhibiting their market growth, and illustrates changing business models in three representative industries. Chapter four, *Emerging Challenges*, considers the wider implications of the Internet of Things for society, in standardization, privacy and socio-ethical challenges. Chapter five, *Opportunities for the Developing World*, examines the benefits these technologies offer to developing countries to address their concerns. Chapter six, *The Big Picture*, concludes by describing how a user might conduct their life in 2020 and summarizes the key interactions described in the book. The Statistical annex presents the latest data and charts for 206 economies worldwide in their use of ICTs.

ITU, the United Nations specialized agency for telecommunications, is committed to playing a positive role in the development of the information society and to extending the benefits of advances in telephony and information and communication technologies (ICTs). This is in line with the Resolution of the highest administrative organ of ITU (Resolution 101 of the Plenipotentiary Conference (Minneapolis, 1998)), which calls upon ITU to “fully embrace the opportunities for telecommunication development that arise from the growth of IP-based services”, and ongoing calls from ITU’s Member States to continue to actively pursue this objective. The ITU Internet Reports are one contribution towards this commitment.

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The statistical tables were drawn from the ITU World Telecommunication Indicators Database and compiled by Phillipa Biggs. The report was edited by Phillipa Biggs and Lara Srivastava. Special thanks go to Jean-Jacques Mendez for the cover design, and to Isabelle Lucas for assistance with the overall formatting.

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Some of the data contained in this report is taken from the ITU World Telecommunication Indicators Database, managed by the Market, Economics and Finance Unit (formerly the Telecommunication Data and Statistics Unit) of the ITU Telecommunication Development Bureau (BDT). The Database is available on CD-ROM, or via the internet as a subscription service. All of ITU's indicator reports and databases are available for purchase, on the internet, at <http://www.itu.int/indicators>. For more information on ITU Internet Reports, including a summary of this edition, visit <http://www.itu.int/internetofthings/>.

The views expressed in this report are those of the authors and do not necessarily reflect the opinions of ITU or its membership.

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DATA NOTES

A number of economic and regional groupings are used in the report. Economic groupings are based on gross national income (GNI) per capita classifications used by The World Bank. Economies are classified according to their 2003 GNI per capita in the following groups:

Gross National Income (GNI) per capita of:

- Low Income USD 735 or less
- Lower middle USD 736–2'935
- Upper middle USD 2'936–9'075
- High USD 9'075 or more

See the *Statistical Annex* for the income classification of specific economies.

The classification *developed* and *developing* is also used in the report. *Developed* economies are classified as: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. *Advanced* economies include *Developed*, plus Hong Kong, China; Republic of Korea; Singapore and Taiwan, China as well as Cyprus and Israel. All other economies are considered *developing* for the purposes of this report. The classification *least developed countries* (LDCs) is also employed. The LDCs are Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen, and Zambia. *Emerging* is also sometimes used in the report. These are countries that are neither developed nor LDCs. The grouping *Organisation for Economic Co-operation and Development* (OECD) is also used. Members include all the developed countries plus the Czech Republic, Hungary, Republic of Korea, Mexico, Poland, Slovak Republic and Turkey. A number of regional groupings are used in the report. The main regional groupings are *Africa*, *Asia*, *Americas*, *Europe* and *Oceania*. Note that *Pacific* is also used in the report to refer to the Oceania region. See *List of economies* in the *Statistical Annex* for the primary regional classification of specific economies. The following sub-regional groupings are also used in the report:

- *Arab region* – Arabic-speaking economies;
- *Asia-Pacific* – refers to all economies in Asia east of, and including Iran, as well as Pacific Ocean economies;

- *Central and Eastern Europe* – Albania, Bosnia, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Serbia and Montenegro, Slovak Republic, Slovenia and The Former Yugoslav Republic of Macedonia;
- *Commonwealth of Independent States* – 12 republics emerging from the former Soviet Union excluding the Baltic nations;
- *Latin America and the Caribbean* – Central (including Mexico) and South America and the Caribbean;
- *North America* – Generally, Canada and the United States, although in some charts, Mexico is also included (if so, this is noted);
- *Southern Europe* – Cyprus, Malta and Turkey;
- *Western Europe* – refers to the member states of the European Union, Iceland, Norway and Switzerland.

Other conventions

- Billion is one thousand million.
- Dollars are current United States dollars (US\$) unless otherwise noted. National currency values have been converted using average annual exchange rates (unless stated otherwise in the Technical Notes; two tables of current prices use most recent exchange rates). Growth rates are based on current prices, unless otherwise noted.
- Thousands are separated by an apostrophe (1'000).
- Totals may not always add up due to rounding.

Additional definitions are provided in the technical notes of the *ITU World Telecommunication Indicators*. Note that data in some charts and tables referring to the same item may not be consistent and may also differ from the tables shown in the *Statistical Annex*. This can happen due to revisions to data that occurred after sections of the report were written, as well as different estimation techniques and/or exchange rates. Such variations tend to be insignificant in their impact on the analysis and conclusions drawn in the report. Finally, it should be noted that data generally refer to fiscal years as reported by countries.

GLOSSARY

2G: *Second-generation mobile network or service.* Generic name for second generation networks, for example GSM.

2.5G: *Second-generation enhanced.* Name given to enhanced 2G networks, for example GPRS and cdmaOne.

3G: *Third-generation mobile network or service.* Generic name for third-generation networks or services under the IMT-2000 banner, for example W-CDMA.

3GPP: *Third-Generation Partnership Project.* A cooperation between regional standards bodies to ensure global interworking for 3G systems.

ADSL: *Asymmetric digital subscriber line.* A technology that enables high-speed data services to be delivered over twisted pair copper cable, typically with a download speed in excess of 256 kbit/s, but with a lower upload speed. Corresponds to ITU Recommendation (standard) ITU-T G.992.1

Analogue: Transmission of voice and images using electrical signals. Analogue mobile cellular systems include AMPS, NMT and TACS.

ARPU: *Average Revenue Per User.* Usually expressed per month but also per year.

Bandwidth: The range of frequencies available to be occupied by signals. In analogue systems, it is measured in terms of Hertz (Hz) and in digital systems in bit/s per second (bit/s). The higher the bandwidth, the greater the amount of information that can be transmitted in a given time. High bandwidth channels are referred to as broadband which typically means 1.5/2.0 Mbit/s or higher.

Bit (binary digit): A bit is the primary unit of electronic, digital data. Written in base-2, binary language as a “1” or a “0”.

Bit/s: *Bits per second.* Measurement of the transmission speed of units of data (bits) over a network. Also kbit/s: kilobits (1'000) per second; Mbit/s: megabits (1'000'000) per second, and Gbit/s: Gigabits (1'000'000'000) per second.

Bluetooth: A radio technology that enables the transmission of signals over short distances between mobile phones, computers and other devices. It is typically used to replace cable.

Broadband: Although there exist various definitions of broadband that have assigned a minimum data rate to the term, it may be defined as transmission capacity with sufficient bandwidth to permit combined provision of voice, data and video, with no lower limit. Effectively, broadband is implemented mainly through ADSL, cable modem or wireless LAN (WLAN) services.

Browser: Application that retrieves WWW documents specified by URLs from an HTTP server on the internet. Displays the retrieved documents according to the Hypertext Markup Language (HTML).

Byte:

- (1) A set of bits that represent a single character. A byte is composed of 8 bits.
- (2) A bit string that is operated upon as a unit and the size of which is independent of redundancy or framing techniques.

CAGR: *Compound annual growth rate.* See the Technical Notes in Annex.

Cellular: A mobile telephone service provided by a network of base stations, each of which covers one geographic cell within the total cellular system service area.

Channel: One of a number of discrete frequency ranges utilized by a base station to transmit and receive information from cellular terminals (such as mobile handsets).

Circuit-switched connection: A temporary connection that is established on request between two or more stations in order to allow the exclusive use of that connection until it is released. At present, most voice networks are based on circuit-switching, whereas the Internet is packet-based. See also *Packet-based*.

Connectivity: The capability to provide, to end-users, connections to the internet or other communication networks.

Coverage: Refers to the range of a mobile cellular network, measured in terms of geographic coverage (the percentage of the territorial area covered by mobile cellular) or population coverage (the percentage of the population within range of a mobile cellular network).

Data mining: The use of data search capabilities and statistical algorithms to search existing databases for patterns and correlations between them that give new meaning to their data content.

Digital: Representation of voice or other information using digits 0 and 1. The digits are transmitted as a series of pulses. Digital networks allow for higher capacity, greater functionality and improved quality.

DSL: *Digital subscriber line.* DSL is a technology for bringing high-bandwidth information to homes and small businesses over ordinary copper telephone lines. See also *xDSL*, which refers to different variations of DSL, such as ADSL, HDSL, and RADSL

E-commerce: *Electronic commerce.* Term used to describe transactions that take place online where the buyer and seller are remote from each other.

E-mail: *Electronic mail.* The exchange of electronic messages between geographically dispersed locations.

End-user: The individual or organization that originates or is the final recipient of information carried over a network (i.e. the consumer).

Encryption: The process of converting plain text into code to secure information from being read by unauthorized persons or those without special computing knowledge.

EPC: *Electronic Product Codes.* A unique number used by suppliers to identify specific items in the supply chain. The code is stored in an RFID tag and when retrieved, it can be linked to a database with information on the selected item, such as its type, manufacturer, origin, and date of production.

Ethernet: A protocol for interconnecting computers and peripheral devices at high speed. Recently Gigabit Ethernet has become available which enables speeds up to 1 Gbit/s. Ethernet can run on several types of wiring including: twisted pair, coaxial, and even fibre-optic cable.

Fixed line: A physical line connecting the subscriber to the telephone exchange. Typically, *fixed-line network* is used to refer to the PSTN (see below) to distinguish it from mobile networks.

Frequency: The rate at which an electrical current alternates, usually measured in Hertz (see Hz). It is also used to refer to a location on the radio-frequency spectrum, such as 800, 900 or 1'800 Mhz.

Gbit/s: *Gigabit per second.* See also bit/s.

GDP: *Gross domestic product.* The market value of all final goods and services produced within a nation in a given time period.

GNI: *Gross national income.* The market value of all final goods and services produced in a nation's economy, including goods and services produced abroad. GNI in constant prices, differs from GNP in that it also includes a terms of trade adjustment; and gross capital formation which includes a third category of capital formation: net acquisition of valuables.

GNP: *Gross national product.* The market value of all final goods and services produced in a nation's economy, including goods and services produced abroad.

GPRS: *General Packet Radio Service.* It refers to a standard for wireless communications that supports a wide range of bandwidths. It runs at speeds up to 115 kilobits per second and is particularly suited for sending and receiving small bursts of data, such as e-mail and Web browsing, as well as large volumes of data.

GPS: *Global positioning system.* Refers to a "constellation" of 24 "Navstar" satellites launched initially by the United States Department of Defense, that orbit the Earth and make it possible for people with ground receivers to pinpoint their geographic location. The location accuracy ranges from 10 to 100 metres for most equipment. A Russian system, GLONASS, is also available, and a European system, Galileo, is under development.

Grey Goo: A term introduced by Eric Drexler in his 1986 seminal book on nanotechnology *Engines of Creation*. It describes a pessimistic future scenario in which, due to advances in nanotechnology, tiny molecular machines can replicate themselves at a phenomenal rate, beyond human control.

GSM: *Global System for Mobile communications.* Digital mobile standard developed in Europe, and currently the most widespread 2G digital mobile cellular standard. GSM is available in over 170 countries worldwide. For more information, see the website of the GSM Association at: <http://www.gsmworld.com/index.html>.

Host: Any computer that can function as the beginning and end point of data transfers. Each internet host has a unique internet address (IP address) associated with a domain name.

HTML: *Hypertext Markup Language.* A hypertext document format used on the World Wide Web. Mark-up languages for translating Web content onto mobile phones include cHTML, WML and xHTML.

HTTP: *Hypertext Transfer Protocol.* Hypertext is any text that cross-references other textual information with hyperlinks.

Hz: *Hertz.* The frequency measurement unit equal to one cycle per second.

IM: *Instant Messaging.* It refers to programs such as AOL Instant Messenger and ICQ that allow users to exchange messages with other users over the internet with a maximum delay of one or two seconds at peak times.

IMS: *IP Multimedia Subsystem.* Framework originally developed by the Third Generation Partnership Projects (3GPP and 3GPP2) for their third-generation mobile networks.

IMT-2000: *International Mobile Telecommunications-2000.* Third-generation (3G) “family” of mobile cellular standards approved by ITU. For more information see the website at: <http://www.itu.int/imt>.

Infotainment: The combination of information on current event and entertainment content or of their formats.

Internet: Interconnected global networks that use the Internet Protocol (see *IP*).

IP Telephony: *Internet Protocol telephony.* IP telephony is used as a generic term for the conveyance of voice, fax and related services, partially or wholly over packet-based, IP-based networks. See also *VoIP* and *Voice over broadband*.

IPv4: *Internet Protocol version 4.* The version of IP in common use today.

IPv6: *Internet Protocol version 6.* The emerging standard, which aims to rectify some of the problems seen with IPv4, in particular the shortage of address space.

ITU: *International Telecommunication Union.* The United Nations specialized agency for telecommunications. See <http://www.itu.int/>.

LAN: *Local Area Network.* A computer network that spans a relatively small area. Most LANs are confined to a single building or group of buildings. However, one LAN can be connected to other LANs over any distance via telephone lines and radio waves. A system of LANs

connected in this way is called a wide-area network (WAN).

LBS: *Location-based services.* LBS make use of information on the location of a mobile device and user, and can exploit a number of technologies for the geographic location of a user. Some of these technologies are embedded in the networks and others in the handsets themselves. Location capability is already available to some level of accuracy (approx. 150 m) for most users of cellular networks. Increased accuracy can become available through location technologies such as GPS. See *GPS*.

Main telephone line: Telephone line connecting a subscriber to the telephone exchange equipment. This term is synonymous with the term ‘fixed line’ used in this report.

Mbit/s: *Megabit per second.* See also bit/s.

Middleware: Software that connects two otherwise separate applications. In the case of RFID, it forwards data that an RFID reader has extracted from an RFID tag to another system, such as a database, a personal computer or a robot control system.

MMS: *Multimedia Message Service.* MMS will provide more sophisticated mobile messaging than SMS or EMS. A global standard for messaging, MMS will enable users to send and receive messages with formatted text, graphics, audio and video clips. Unlike SMS and most EMS, it will not be limited to 160-characters per message.

Mobile: As used in this report, the term refers to mobile cellular systems.

MP3: MPEG-1 Audio Layer-3 (MPEG stands for Moving Pictures Experts Group). A standard technology and format for compression of a sound sequence into a very small file (about one-twelfth the size of the original file) while preserving the original level of sound quality when it is played.

Nanoscience: Interdisciplinary fields of science dedicated to the study of phenomena on length scales between the molecular and micron size. One nanometre equals one thousandth of a micrometre or one millionth of a millimetre.

Nanotechnology: Emerging engineering discipline that applies methods from nanoscience to develop technologies on the nanometre scale, usually 0.1 to 100 nm.

NGN: *Next-Generation Networks.* These are packet-based networks in which service-related functions are independent from underlying transport-related technologies. They are able to provide telecommunication services and make use of multiple broadband transport technologies.

Packet: Block or grouping of data that is treated as a single unit within a communication network.

Packet-based: Message-delivery technique in which packets are relayed through stations in a network. See also *Circuit-switched connection*.

PDA: *Personal digital assistant.* A generic term for handheld devices that combine computing and possibly communication functions.

Penetration: A measurement of access to telecommunications, normally calculated by dividing the number of subscribers to a particular service by the population and multiplying by 100. Also referred to as *teledensity* (for fixed-line networks) or *mobile density* (for cellular ones), or *total teledensity* (fixed and mobile combined).

PETS: *Privacy enhancing technologies.* Either stand alone solutions helping individuals and companies protect their privacy or add-on features designed to enhance the privacy of an existing system.

PPP: *Purchasing power parity.* An exchange rate that reflects how many goods and services can be purchased within a country taking into account different price levels and cost of living across countries.

Profiling: The practice of identifying a particular group of people or predicting their potential behaviour, based on the analysis of their past actions, psychological characteristics or physical features.

Protocol: A set of formal rules and specifications describing how to transmit data, especially across a network.

PSTN: *Public Switched Telephone Network.* The public telephone network that delivers fixed telephone service.

RFID: *Radio-frequency identification.* A system of radio tagging that provides identification data for goods in order to make them traceable. Typically used by manufacturers to make goods such as clothing items traceable without having to read bar code data for individual items.

RFID reader: A device that communicates via radio waves with RFID tags and delivers the information in a digital format to a computer system.

RFID tag: A transponder or tag carrying data and located on the object to be identified. It normally consists of a coupling element (such as a coil, or microwave antenna) and an electronic microchip, less than 1/3 millimetre in size.

Robot: A mechanical device that performs a variety of often complex human tasks on command or through advanced programming.

Robotics: A branch of engineering that involves the conception, design, manufacture, and operation of robots.

Sensor: A device, such as a photoelectric cell, that receives and responds to a signal or stimulus.

Server:

(1) A host computer on a network that sends stored information in response to requests or queries.

(2) The term server is also used to refer to the software that makes the process of serving information possible.

SIM: *Subscriber identity module* (card). A small printed circuit board inserted into a GSM-based mobile phone. It includes subscriber details, security information and a memory for a personal directory of numbers. This information can be retained by subscribers when changing handsets.

Skimming: Refers to the unauthorized capture by an intruder of electronic information contained in a chip or tag, such as a passport chip.

Smart dust: Miniaturized sensor/transmitters used to analyze the environment. Their size is expected to reach 1 cubic millimetre in size.

SMS: *Short Message Service.* A service available on digital networks, typically enabling messages with up to 160 characters to be sent or received via the message centre of a network operator to a subscriber's mobile phone.

Spectrum: The radio-frequency spectrum of hertzian waves used as a transmission medium for cellular radio, radiopaging, satellite communication, over-the-air broadcasting and other services.

TCP: *Transmission Control Protocol.* A transport layer protocol that offers connection-oriented, reliable stream services between two hosts. This is the primary transport protocol used by TCP/IP applications.

Teledensity: Number of main telephone lines per 100 inhabitants within a geographical area. *Effective teledensity* reports fixed-line teledensity or mobile density—whichever is higher—in a particular geographical region. See *Penetration* and *Total teledensity*.

Total teledensity: Sum of the number of fixed lines and mobile phone subscribers per 100 inhabitants. (See Technical Notes in Annex). See *Penetration*.

Transmission Control Protocol/Internet Protocol (TCP/IP): The suite of protocols that defines the internet and enables information to be transmitted from one network to another.

Universal Access: Refers to reasonable telecommunication access for all. Includes universal service for those that can afford individual telephone service and widespread provision of public telephones within a reasonable distance of others.

URL: *Uniform Resource Locator.* The standard way to give the address or domain name of any internet site that is part of the World Wide Web (WWW). The URL indicates both the application protocol and the internet address, e.g. <http://www.itu.int>.

UWB: *Ultra-Wide Band.* Wireless communication technology that can currently transmit data at speeds between 40 to 60 megabits per second and eventually up to 1 gigabit per second. It uses ultra-low power radio signals.

VoIP: *Voice over IP.* The generic term used to describe the techniques used to carry voice traffic over IP (see also *IP telephony*).

VPN: *Virtual private network.* A method of encrypting a connection over the internet. VPNs are used extensively in business to allow employees to access private networks at the office from remote locations. VPNs are especially useful for sending sensitive data.

W-CDMA: *Wideband code division multiple access.* A third-generation mobile standard under the IMT-2000 banner, first deployed in Japan. Known as UMTS in Europe. See also *CDMA*.

Website / Webpage: A website (also known as an internet site) generally refers to the entire collection of HTML files that are accessible through a domain name. Within a website, a webpage refers to a single HTML file, which

when viewed by a browser on the World Wide Web could be several screen dimensions long. A “home page” is the webpage located at the root of an organization’s URL.

Wi-Fi: *Wireless fidelity.* A mark of interoperability among devices adhering to the 802.11b specification for Wireless LANs from the Institute of Electrical and Electronics Engineers (IEEE). However, the term Wi-Fi is sometimes mistakenly used as a generic term for wireless LAN.

WiMAX: Fixed wireless standard IEEE 802.16 that allows for long-range wireless communication at 70 Mbit/s over 50 kilometres. It can be used as a backbone internet connection to rural areas.

Wireless: Generic term for mobile communication services which do not use fixed-line networks for direct access to the subscriber.

WLAN: *Wireless local area network.* Also known as *Wireless LAN* or *Radio LAN*. A wireless network whereby a user can connect to a local area network (LAN) through a wireless (radio) connection, as an alternative to a wired local area network. The most popular standard for wireless LANs is the IEEE 802.11 series.

WLL: *Wireless local loop.* Typically a phone network that relies on wireless technologies to provide the last kilometre connection between the telecommunication central office and the end-user.

WMAN: *Wireless Metropolitan Access Network.* Refers to a wireless communications network that covers a geographic area, such as a city or suburb.

WSIS: *World Summit on the Information Society.* The first phase of WSIS took place in Geneva (hosted by the Government of Switzerland) from 10 to 12 December 2003. The second phase will take place in Tunis (hosted by the Government of Tunisia), from 16 to 18 November 2005. For more information see: <http://www.itu.int/wsisi>.

WWW: *World Wide Web.*
(1) Technically refers to the hypertext servers (HTTP servers) which are the servers that allow text, graphics, and sound files to be mixed together.
(2) Loosely refers to all types of resources that can be accessed.

xDSL: While DSL stands for digital subscriber line, xDSL is the general representation for various types of digital subscriber line technology, such as ADSL (asynchronous digital subscriber line), HDSL (high bit-rate digital subscriber line), or VHDSL (very high bit-rate digital subscriber line).

ZigBee: Open industry specification that operates in the 2.4 GHz (ISM) radio band, the same band as 802.11b standard, Bluetooth, microwaves and some other devices. This specification is a combination of HomeRF Lite and the 802.15.4 specification, and it can connect up to 255 devices per network. Although Zigbee supports slower data transmission rates (up to 250 kbit/s) than its competing specifications, it consumes significantly less power.

List of Abbreviations and Acronyms

Note: This list includes abbreviations and acronyms not otherwise mentioned in the glossary. The list aims to cover the main terms used in this report, but is not exhaustive.

3GPP	Third-Generation Partnership Projects
ASTAP	APT Standardization Program
APNF	Asia-Pacific Nanotechnology Forum
APT	Asia-Pacific Telecommunity
CASPIAN	Consumers Against Supermarket Privacy Invasion and Numbering
CCTV	Closed caption television
CEN	European Committee for Standardization
DARPA	Defense Advanced Research Projects Agency
DMB	Digital multimedia broadcasting
DSL	Digital subscriber line
DSRC	Dedicated short-range communications
DVD	Digital videodisc
EAS	Electronic article surveillance
EC	European Commission
EFF	Electronic Frontier Foundation
EPIC	Electronic Information Privacy Organization
ETRI	Electronics and Telecommunications Research Institute
ETSI	European Telecommunications Standards Institute
EU	European Union
EV-DO	Evolution data only
EV-DV	Evolution data and voice
GHz	Gigahertz
GPS	Global positioning system
GSM	Global system for mobile communications
H2H	Human-to-human
H2T	Human-to-thing
HAN	Human area network
HDTV	High definition television
HF	High frequency
IC	Integrated circuit
ICT	Information and communication technologies
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMS	IP multimedia subsystem
IMT-2000	International mobile telecommunications-2000
IP	Internet protocol

IPR	Intellectual property rights
ISO	International Organization for Standardization
ISP	Internet Service Provider
ITU-D	ITU Development Sector
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Standardization Sector
kHz	kiloHertz
LAN	Local area network
LDC	Least developed countries
LEDs	Light-emitting diodes
LF	Low frequency
MDGs	Millennium Development Goals
MEMS	Micro electro-mechanical systems
MHz	MegaHertz
MIT	Massachusetts Institute of Technology
MMS	Multimedia message service
MP3	MPEG-1 Audio Layer-3
MVNO	Mobile virtual network operator
NFC	Near Field Communication
Nm	Nanometre
OECD	Organisation for Economic Co-operation and Development
OPA	Online Privacy Alliance
P3P	Platform for privacy preferences
PAN	Personal area network
PDA	Personal digital assistant
PSTN	Public switched telephone network
PTO	Public telephone operator, <i>also</i> public telecommunication operator
ROM	Read-only memory
SPU	ITU Strategy and Policy Unit
SRAM	Static random access memory
T2T	Thing-to-thing
UHF	Ultra-high frequency
UN	United Nations
US	United States
USD	United States dollars
W3C	World Wide Web Consortium
WMS	Warehouse management system
XML	Extensible markup language

1 CHAPTER ONE: INTRODUCING THE INTERNET OF THINGS

1.1 Towards ubiquity

In the fifth century before the Christian era, the Greek Philosopher Empedocles argued that the whole of creation could be reduced to the four basic elements of earth, air, fire and water. In the nineteenth century, the development of the Dewey decimal classification system recognized ten basic classes that could each be divided into ten divisions, which could each be divided into ten sections, creating 1'000 categories for human knowledge, each with decimal sub-divisions.

Although such addressing systems might be sufficient for our foreseeable future connectivity needs, history teaches us that we can never be sure. Humanity's approach to trying to understand the world around us has been characterized by a move from simplicity to increasing complexity. As the internet grows, it needs to encompass more and more elements of the real world, and therefore the abstraction has to be more complex too. Simplicity is no longer an option. Communications will become increasingly ubiquitous in daily life, increasingly requiring identifying and addressing systems. Our attempts to develop a structure for the internet will more intensely map the real world onto cyberspace in increasing detail. In this context, technological ubiquity and complexity will drive the future communication landscape.

1.1.1 A dynamic internet

The internet began in the late 1960s as a link between a handful of university computer centres. In the 1970s and 1980s, the use of the internet was dominated by e-mail and file transfer, and the number of users was counted in thousands. In the 1990s, web browsing became dominant and users were denominated in millions. The internet as we know it today will radically change over the next decade. As of the end of 2004, there were some 875 million internet users worldwide (Figure 1.1). Moreover, mobile phones, of which there were over 1.75 billion at the end of 2004, are being used more and more as devices for internet access. This creates new applications and services hitherto unknown, through both 2G systems and a growing subscriber base for IMT-2000 (3G) systems. The internet and other data transmission services (e.g. SMS, MMS), initially the purview of the developed world, are also gaining market share in developing economies, boosting information and communication access and increasing demand for bandwidth.

Today, in the 2000s, we are heading into a new era of ubiquity, where the “users” of the internet will be counted in billions and where humans may become the minority as generators and receivers of traffic. Instead, most of the traffic will flow between devices and all kinds of “things”, thereby creating a much wider and more complex “Internet of Things”, the core subject of this report.

If humans are the only internet users of the future, then the total user base cited above might conceivably double, but is unlikely to go beyond two billion active users in the near future. On the other hand, if “things” become active internet users on behalf of humans, then the number of active connections could be measured in terms of tens or hundreds of billions. By connecting the world’s things, the internet would truly achieve ubiquity in every sense of the word.

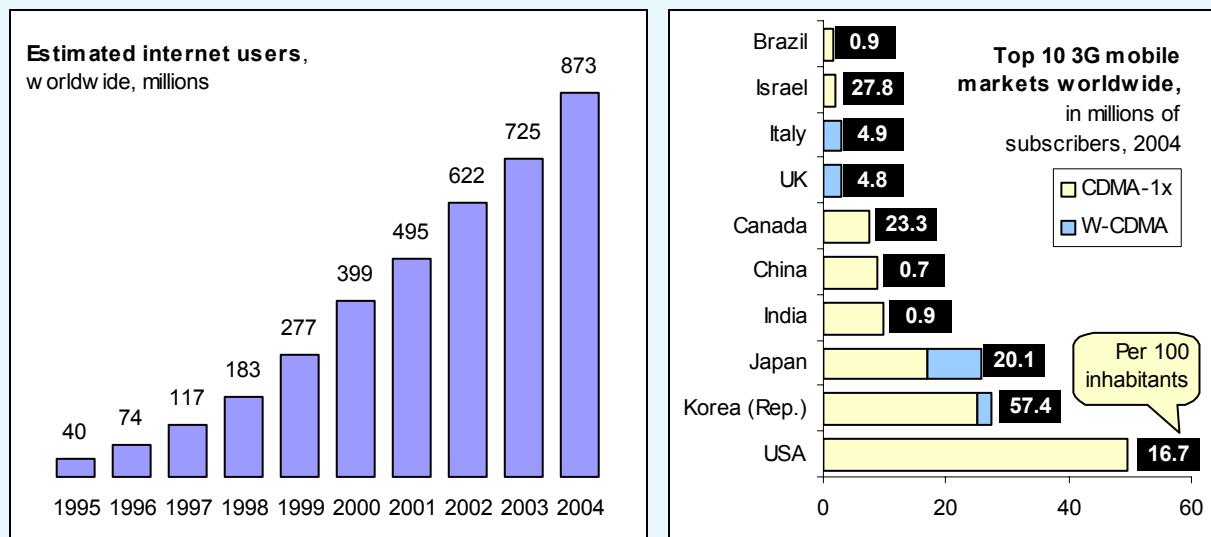
1.2 A question of vision

The promise of a future global Internet of Things is based on solid technical vision and innovation. In this context, it is important to examine the various underlying technical visions for the Internet of Things. The concept of “ubiquitous networks” focuses on the communication aspects of technologies that are available

anytime and everywhere. Similarly, “next-generation networks” (NGN) are integrated core networks that are set to form the underlying platform for the services and applications of the future. On the other hand, ubiquitous computing refers to processing power at the edges of such networks. Let us briefly consider these visions in turn.

Figure 1.1: Access to the internet widens

Internet users and subscribers 1995-2004; Top 10 countries by the number of 3G subscribers, 2004



Source: ITU

1.2.1 Ubiquitous networks

The concept of ubiquitous networks is founded upon the all-inclusive use of networks and networked devices. Literally, a ubiquitous networked environment is one in which networks are available everywhere and anytime (Box 1.1). Early forms of ubiquitous information and communication networks are evident in the widespread use of mobile phones: there were over 1.8 billion mobile phones in circulation by the end of 2004, and the number surpassed 2 billion in mid-2005.³

Box 1.1: Wrapped in ubiquity

“Ubiquitous”: What’s in a word?

The word “ubiquitous” comes from the Latin root of *ubique*, meaning everywhere. However, it is applied to the world of ICTs in at least two slightly different ways.

- In European usage, it tends to be interpreted geographically, meaning available from all parts of the globe, no matter how remote. Although possible, thanks to satellite technology, this may not be economically feasible.
- In Japan and the Republic of Korea, the word is used more often in a social, rather than geographical, context, meaning that a particular communication service may be universally available. “Ubiquitous network society” is defined in Japan, for instance, as “available anywhere, anytime, by anything and anyone”.⁴

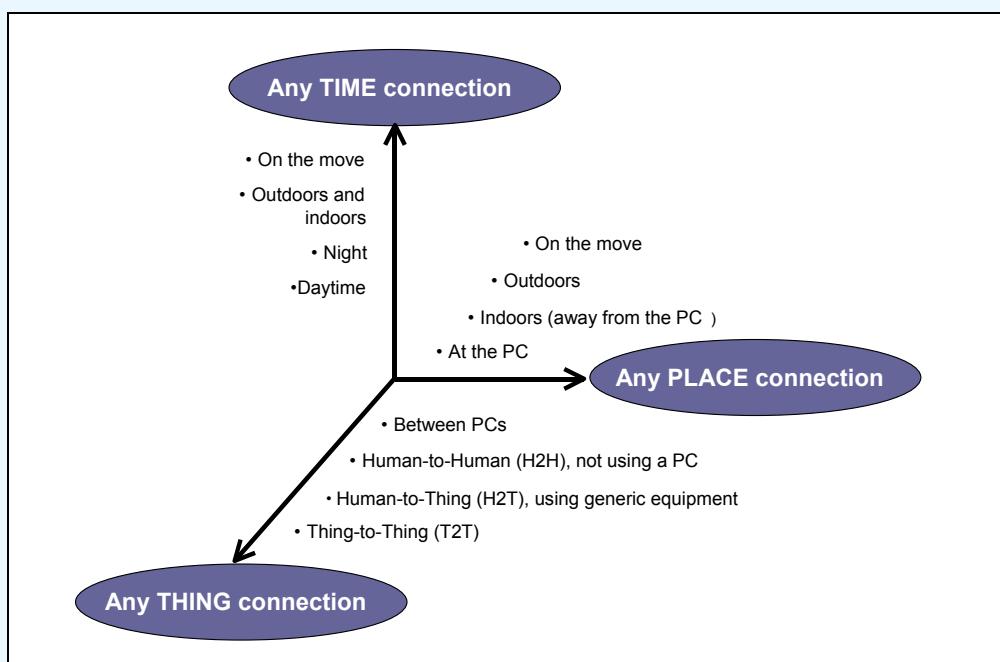
It is this latter definition of ubiquitous – with an emphasis on “anywhere” rather than “everywhere” – that is applied in this report. The term “Ubiquitous Computing” was coined in 1991 by the computer scientist, Marc Weiser. He described a new era in which computer devices will be embedded in everyday objects, invisibly at work in the environment around us; in which intelligent, intuitive interfaces will make computer devices simple to use and unobtrusive; and in which communication networks will connect these devices together to facilitate anywhere, anytime, always-on communications. Ubiquitous computing refers to how individual devices and everyday objects might communicate and process information, creating a world in which things can interact dynamically. A number of similar terms (e.g. “disappearing computing”, “ambient intelligence” or “ubiquitous network societies”) are often used as synonyms. The term “Ubiquitous Network Societies” captures the convergence between a number of technological fields, as well as their implications for the economic, political and social aspects of society.⁵

Source: ITU

Ubiquitous networks take mobile networks one step further, embedding short-range mobile transceivers into a wide array of additional gadgets and everyday items, enabling new forms of collaboration and communication between people and things, and between things themselves.

As the internet first spread, users were amazed at the possibility of contacting people and sending information across oceans and time zones, through e-mail and instant messaging, with just a few clicks of a mouse. In order to do so, however, they typically had to sit in front of a computing device (usually a PC) and dial-up to the internet over their telephone connection. Today, with mobile internet services and the deployment of higher-speed mobile networks such as 3G (IMT-2000), users can connect from almost *any location*. They can also access networks at *any time*, through *always-on* connectivity (wired and wireless broadband). The next step in this technological revolution is to connect inanimate objects and things to communication networks. This is the vision of a truly ubiquitous network—“*anytime, anywhere, by anyone and anything*”. In this context, consumer products might be tracked using tiny radio transmitters or tagged with embedded hyperlinks and sensors. As illustrated in Figure 1.2, connectivity will take on an entirely new dimension. Today, users can connect at any time and at any location. Tomorrow’s global network will not only consist of humans and electronic devices, but all sorts of inanimate things as well. These things will be able to communicate with other things, e.g. fridges with grocery stores, laundry machines with clothing, implanted tags with medical equipment, and vehicles with stationary and moving objects. It would seem that science fiction is slowly turning to science fact in an Internet of Things based on ubiquitous network connectivity.

Figure 1.2: Introducing a new dimension to the telecommunication environment
Connecting Things



Source: ITU, adapted from the Nomura Research Institute, “Ubiquitous Networking: Business Opportunities and Strategic Issues”, August 2004

1.2.3 Ubiquitous computing

As noted in Box 1.1, the term “ubiquitous computing” is said to have been coined in 1991 by Mark Weiser, then the chief scientist at the XEROX Palo Alto Research Centre. Weiser explored enhanced computer use through the increasing “availability” and decreasing “visibility” of processing power. In other words, in his

view, the computer as a dedicated device will eventually disappear, while its information processing capabilities will be increasingly available throughout our surroundings⁶: “the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”⁷

With the benefit of integrated information processing capacity, industrial products will take on smart characteristics and capabilities. They may also take on electronic identities that can be queried remotely, or be equipped with sensors for detecting physical changes around them. Eventually, even particles and “dust” might be tagged and networked. Such developments will make the merely static objects of today into newly dynamic things, embedding intelligence in our environment, and stimulating the creation of innovative products and entirely new services.

In this way, the “virtual world” would “map” the “real world”, given that everything in our physical environment would have its own identity (a passport of sorts) in virtual cyberspace. This will enable communication and interaction between people and things, and between things, on a staggering scale (Figure 1.2). The mass deployment of RFID tags will spur the development of such mesh networks, particularly in urban centres. As a core network to support these developments, NGN may provide an integrated core platform for communications in a world of ubiquitous computing.

1.2.4 Next-generation Networks (NGN)

At present, the underlying mobility of services remains limited: end-user services other than voice are hardly portable across networks. This functionality is central to exploiting thing-to-thing communications. In this respect, next-generation networks hope to offer mobility much more broadly. “Generalized mobility” is a term closely associated with NGN. It denotes the possibility of seamless and ubiquitous access to services, irrespective of location and the technology used.

NGN is a broad concept, and there are several definitions of NGN at this time. ITU formally defines NGN as a “packet-based network able to provide telecommunication services and make use of multiple broadband [...] transport technologies in which service-related functions are independent from underlying transport-related technologies”.⁸ In general, most analysts describe NGN as a multi-service network based on Internet Protocol (IP) technology.⁹ The fundamental difference between the networks of today and NGN will be the full transition they imply from current circuit-switched networks to packet-based systems such as those using IP (Table 1.1). A number of network operators have completed their testing phase, and have already begun replacing their Public Switched Telephone Network (PSTN) equipment with next-generation equipment (e.g. NTT, Verizon, China Telecom, and Bell Canada).

Table 1.1: What’s new in next-generation networks?
Contrasts between today’s PSTN network and tomorrow’s NGN

Today’s PSTN network	Next-generation Networks
• Circuit-switched.	• Packet-based, based on Internet Protocol (IP).
• Limited mobility of end-user services.	• Broad-based ‘generalized mobility’.
• Vertical integration of application and call control layers, with dedicated networks.	• Horizontally-integrated control layers, with simultaneous delivery of applications. Service-related functions independent of transport-related technologies.

Source: ITU

Future services enabled by NGN are expected to adapt to the needs of individual users (people and things), through real-time knowledge of their status and context: for instance, their availability and communication status (e.g. online, offline, busy). Multiple devices, telecommunication technologies, positioning and sensing systems, location-aware or context-aware applications, and so on, form the integral elements of a richer

NGN communication environment.¹⁰ NGN will address both network and service elements, providing new opportunities for service providers, operators, content developers, manufacturers and users.

NGN is being touted as the natural evolution of today's PSTN network, and the logical extension of current broadband and mobile services. NGN is a broad vision that has many aspects in common with fixed-mobile convergence, ubiquitous networks and computing. All of these visions will most likely work in unison to create the ubiquitous communication environment of the future. Far from science fiction, the dawn of a ubiquitous Internet of Things is within reach.

1.3 Why the Internet of Things is important

The creation of the Internet of Things will entail the connection of everyday objects and devices to all kinds of networks, e.g. company intranets, peer-to-peer networks and even the global internet. For this reason, its development is of great significance to the telecommunication industry. It will challenge existing structures within established companies, and form the basis for entirely new opportunities and business models.

The Internet of Things builds upon the revolutionary success of mobile and internet networks by expanding the world's network of networks even further. It does so through the application of key technological enablers. In this report, these enablers have been identified as radio-frequency identification (RFID), wireless sensor technologies, smart technologies and nanotechnology. The 'expanded' internet will be able to detect and monitor changes in the physical status of connected things (through sensors and RFID) in real-time. Developments in miniaturization will further enable technological ubiquity. Networks and the objects they connect are also becoming increasingly intelligent, through developments in "smart technologies".

Although the Internet of Things is a relatively new vision, its enabling technologies have been around for some time, developed in relative isolation from each other. RFID was invented in the middle of the last century and materials using nanotechnology have been on the market for over a decade. The impact of a combination of such technologies cannot be underestimated. In this respect, it is worth looking at the current telecommunication landscape to gauge the future potential relevance of the Internet of Things to the industry as a whole.

1.3.1 Growth of the industry

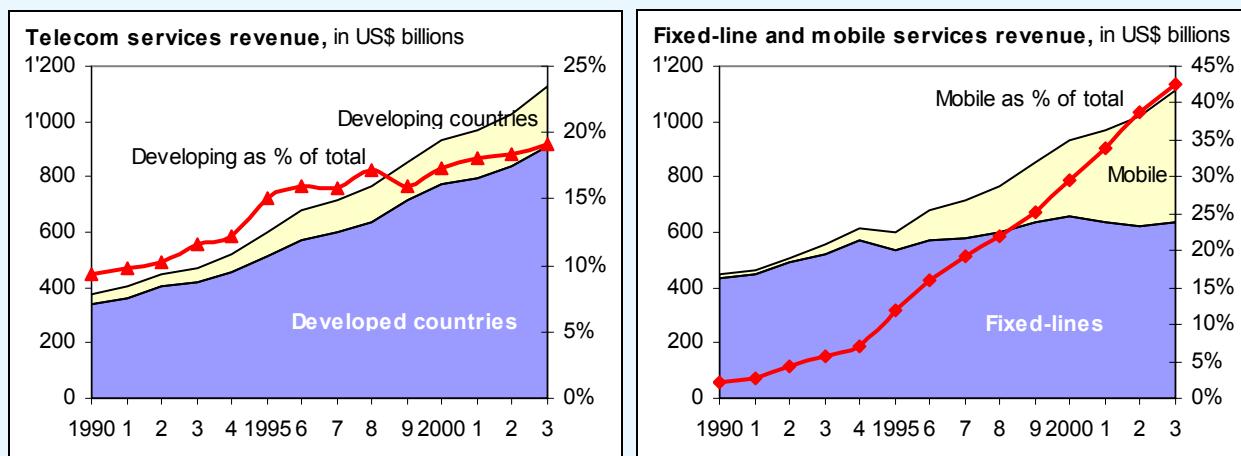
The global telecommunication market has been showing healthy growth thus far. The overall market has almost tripled in value from USD 374 billion in 1990 to USD 1'124 billion in 2003, a growth rate of 8.8 per cent (Figure 1.3). Developing countries, although starting from a much smaller base, have been growing at almost twice the rate of their developed counterparts. In fact, by 2003, the developing world accounted for one fifth of the global market for telecommunication revenue. The most remarkable growth has taken place in mobile communications, which has increased from just 2 per cent of the market, by value, in 1990 to 43 per cent in 2003. It seems likely that in 2005, for the first time ever, revenues from mobile services will now be greater than those from fixed-line operations. This is a remarkable transformation in such a long-established industry.

In comparison, in the more traditional fixed-line market, revenues declined, in US dollar terms, from 2000 to 2002 following the bursting of the internet bubble, before picking up slightly in 2003, thanks mainly to revenue from broadband services. But the long-term revenue growth, 1990-2003, in the fixed-line sector has been only 3 per cent per year, compared with a compound annual growth rate of 35 per cent for mobile services. The main reason for the slower growth in the fixed-line sector is that those developed countries that built out their telecommunication networks in the 1970s and 1980s have long since reached near-universal service, i.e. most households that need a telephone line already having one. Although in the late 1980s and 1990s, it briefly looked as if there would be potential for installing additional lines, e.g. for fax and dial-up internet, the arrival of copper-based broadband internet connections (e.g. xDSL) effectively put an end to this.

Broadband access has also made it possible to use the internet as a platform for voice (i.e. VoIP), thereby transforming the nature of the internet. In this way, the internet is cannibalising existing revenue streams for switched voice.¹¹ Might it go further? If the trend continues, and the internet transforms into a platform for the transmission of data between things (not only humans), then its value will become even more significant.

Figure 1.3: Fast-growing telecoms

Trends in telecommunication service revenues, 1990-2003, in USD billion, broken down by developed/developing and fixed-line/mobile



Note: Figures for 2003 include estimates

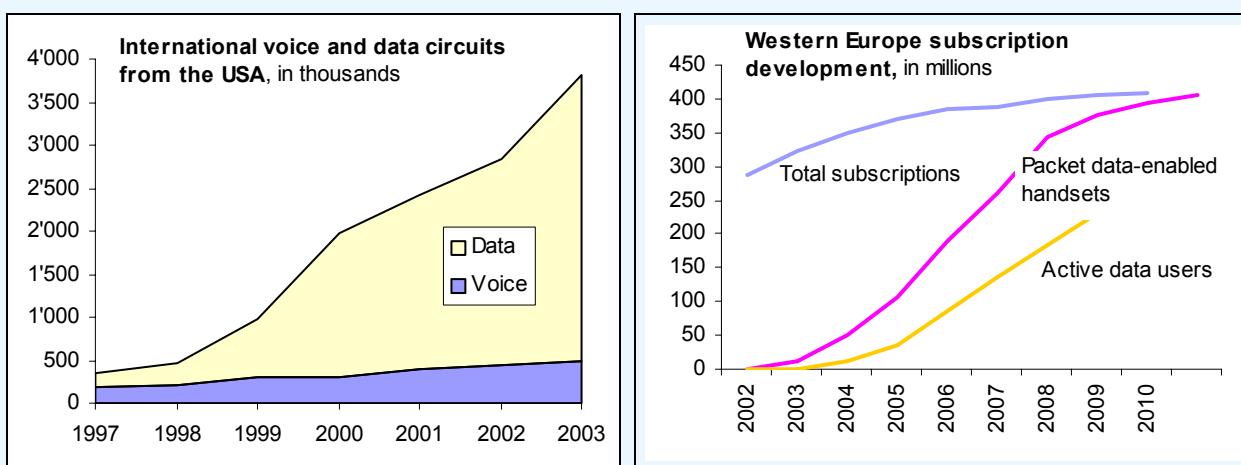
Source: ITU World Telecommunication Indicators Database

Not only can the telecommunication industry profit from the enabling technologies for the Internet of Things by exploiting their benefits internally (e.g. by optimising internal processes), but it can also foster active players in the field through the provision of communication infrastructure and the development of new hardware and services. With millions of smart objects communicating with each other, the income generated by data traffic might continue to grow at a faster rate than spending for voice traffic. As Figure 1.4 illustrates, global revenues for data are already growing at a much faster rate than for voice. In Western Europe in particular, as mobile markets reach saturation, there is both increased data use among users as well as a much keener interest on the part of suppliers to provide data-enabled devices.

Figure 1.4: Data outstrips voice

International data and voice circuits to/from USA, 1997-2003,

Western Europe subscription development in millions of mobile subscribers (2002-2010)



Source: ITU adapted from FCC (left chart); Forrester Research (right chart)

1.3.2 New transitions

The hope, therefore, is that thing-to-thing communications will provide an important new growth market, and that the home of the future – or the car of the future – will have a number of computing/communicating devices embedded within it.

The significance of the Internet of Things is that it stands at the middle of two convergent processes of technological push and commercial push:

- On the technology side, a number of new technologies – such as radio-frequency identification (RFID) in combination with advanced wireless services (e.g. 3G mobile and wireless broadband technologies) – have now enhanced the "ubiquity" of the internet, i.e. it is accessible from almost any point, as well as its "mobility", i.e. it is accessible from small, portable hand-held devices.¹² Thing-to-thing communications also means that “last mile” access might eventually give way to access down to the “last inch”. This coincides with the availability of much higher speeds for internet access.¹³
- On the commercial side, as described above, operators and equipment vendors are “running out” of consumers to whom they can sell current telecommunication services and equipment, that don’t already have it, at least in the developed economies. Thus, the prospects of a new emerging market for thing-to-thing communications are both exciting and essential to sustain future growth prospects.

The missing element from the convergence of these two forces of technology push and commercial push is demand-pull. Do consumers really want fridges that can order the groceries or vacuum cleaners that can communicate with their makers to report faults? More importantly, what are the types of applications for which consumers are and might be willing to pay? To these questions, only the future holds the answers, but it will be fun to find out.

1.4 Structure of the report

This new report, the seventh in the series of ITU Internet Reports, looks at the technologies enabling the Internet of Things, the benefits and opportunities they offer, as well as some emerging challenges:

- Chapter two, *Enabling Technologies*, examines the technologies that will drive the future Internet of Things, including radio-frequency identification (RFID), sensor technologies, smart things, nanotechnology and miniaturization;
- Chapter three, *Shaping the Market*, explores the market potential of these technologies, as well as factors inhibiting market growth. It looks at new business models in selected industries to illustrate how the Internet of Things is changing the way firms do business;
- Chapter four, *Emerging Challenges*, contemplates the hurdles towards standardization and the wider implications of the Internet of Things for society, such as growing concerns over privacy;
- Chapter five, *Opportunities for the Developing World*, sets out some of the benefits these technologies offer to developing countries that may themselves become lead users and drivers of the market;
- Chapter six, *The Big Picture*, draws these threads together and concludes on how our lifestyles may be transformed over the next decade.

The statistical annex to the report presents the latest available data¹⁴ for more than 200 economies worldwide in terms of their usage of ICT services.

Endnotes

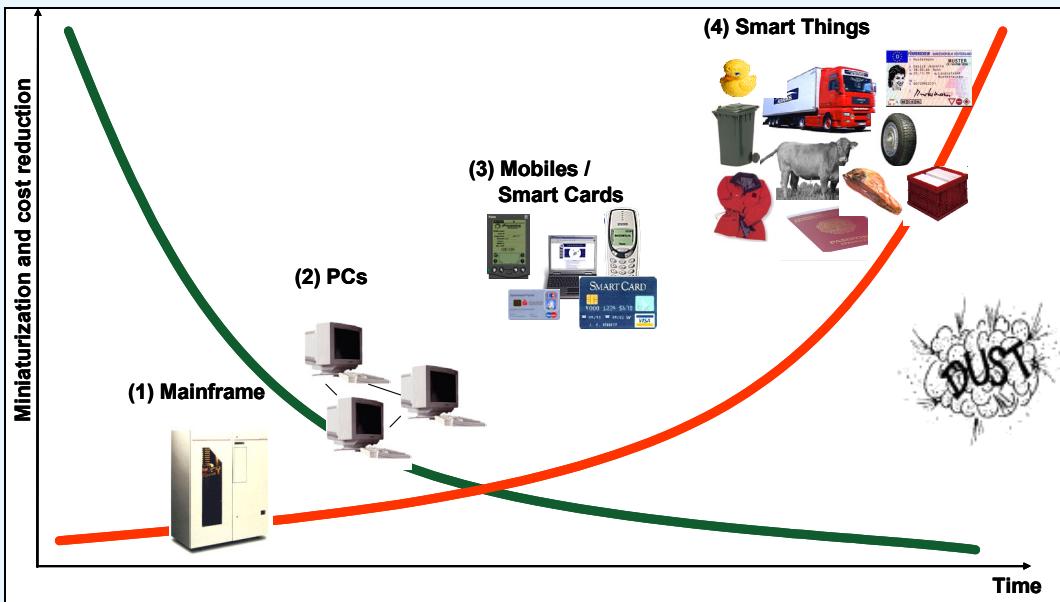
- ¹ This refers to Internet Protocol Version 4. Work is under way to deploy IP version 6 (IPv6) which expands the number of host interface addresses.
- ² The work of the Universal ID centre is described at www.uidcenter.org while a description of ucodes, together with pictures and applications can be found in Sakamura, Ken (2005) “Computers everywhere: The future of ubiquitous computing and networks”, presented at the MIC Japan/ITU/UNU WSIS Thematic Meeting “Towards the realization of the ubiquitous network society”, Tokyo, Japan, 16-17 May 2005, available at: http://www.wsis-japan.jp/doc_pdf/D-7prof_sakamura.pdf.
- ³ ITU World Telecommunication Indicators Database and ITU estimates.
- ⁴ See, for instance, Japan’s contribution to the text of the Final Documents of the WSIS Tunis Phase which proposes the addition of the text: “building ICT networks and developing services that are available anytime, anywhere, by anything and anyone.” (See: <http://www.itu.int/wsis/gfc/docs/5/contributions/Japan.doc>.) The text of the WSIS Plan of Action refers to the availability of ICT services as being, ideally “universal, sustainable, ubiquitous and affordable” (see Para 9 at: http://www.itu.int/wsis/documents/doc_multi.asp?lang=en&id=1161|1160).
- ⁵ See ITU, “Ubiquitous Network Societies and their Impact on the Telecommunication Industry”, available at: <http://www.itu.int/osg/spu/ni/ubiquitous/Papers/UNSImpactPaper.pdf>. All materials and presentations are available for download from the workshop home page at <http://www.itu.int/ubiquitous>.
- ⁶ See ITU, “Ubiquitous Network Societies and the Case of RFID”, available at: http://www.itu.int/osg/spu/ni/ubiquitous/Papers/RFID_background_paper.pdf, and prepared for the ITU New Initiatives Workshop on “Ubiquitous Network Societies” held in April 2005. All materials and presentations are available for download from the workshop home page at <http://www.itu.int/ubiquitous>.
- ⁷ “The Computer for the 21st Century”, Mark Weiser, *Scientific American*, Vol. 265., No 3, pages 94-104, September 1991.
- ⁸ See ITU-T Recommendation Y. 2001 “General overview of NGN”, approved in December 2004 and available at: <http://www.itu.int/rec/recommendation.asp?type=folders&lang=e&parent=T-REC-Y.2001>.
- ⁹ OECD, Working Party on Telecommunication and Information Services Policies, Next-generation Network Development in OECD Countries, 18 January 2005.
- ¹⁰ Radu Popescu-Zeletin et al. (2003), “Service architectures for the wireless world”, Computer Communications, issue 26, pp. 19-25.
- ¹¹ In the United States, TeleGeography Inc. estimates that some 2.7 million homes had already given up their separate telephone subscriptions by mid-2005 and moved to voice over broadband, and that this number is likely to exceed 4 million by the end of the year. See TeleGeography Inc. “US VoIP report”, 2005, available at www.telegeography.com/products/us_voip/index.
- ¹² ITU’s “The Portable Internet” was the topic of the sixth report in this series of ITU Internet Reports, issued in September 2004, and available online at www.itu.int/portableinternet.
- ¹³ ITU’s “Birth of Broadband” was the topic of the fifth report in this series of ITU Internet Reports, issued in October 2003, and available online at www.itu.int/birthofbroadband.
- ¹⁴ For tariff data, “latest available” usually means August 2005. For other data, it is year-end 2004 where possible, or end of 2003-04 financial year for revenue data.

2.1 Introduction

The creation of the Internet of Things depends on dynamic technical innovation in a number of important fields. First, in order to connect everyday objects and devices to large databases and networks – and indeed to the network of networks (the internet) – a simple, unobtrusive and cost-effective system of item identification is indispensable. Only then can data about things be collected and processed. Radio-frequency identification (RFID) offers just such a possibility. Second, data collection can of course benefit from the ability to detect changes in the physical status of things, i.e. through sensor technologies. Furthermore, embedded intelligence in the things themselves can further enhance the power of the network by devolving information processing capabilities to the edges of the network. Finally, advances in miniaturization and nanotechnology mean that smaller and smaller things will have the ability to interact and connect (Figure 2.1). A combination of all of these developments will give rise to an Internet of Things that connects the world's objects in both a sensory and intelligent manner.

In this context, the present chapter examines four important technological enablers of the Internet of Things: radio-frequency identification (RFID), sensor technologies, smart technologies and nanotechnology.

Figure 2.1: Miniaturization and declining prices
Towards a world of smart things



Source: ITU, "Ubiquitous Network Societies and their impact on the telecommunication industry", April 2005, available at <http://www.itu.int/ubiquitous>

2.2 Tagging things: RFID

For information and communication access to be truly and seamlessly embedded in the environment surrounding us, the exponential growth of networked devices must be accompanied by a paradigm shift in computing. Such a paradigm shift will mean that smart computers will become a common item in many households.

Delivering on the promise of the Internet of Things is, however, currently limited by our inability to collect raw data about things, their location and status. Radio-frequency identification (RFID) provides just such a capability and is a key enabler of a ubiquitous communication environment. RFID refers to those technologies that use radio waves to automatically identify and track individual items. In this respect, it can

be conceptualized as analogous to common short-range wireless technologies such as ZigBee, but with much higher computing and tracking capabilities.¹

RFID is not new, as it is based on radio, which dates back to the early understanding of electromagnetic energy by Michael Faraday from the 1840s and was expanded into popular use in the early 20th century.² Shortly after, the 1920s saw the birth of radar, which detects and locates objects (their position and speed) through the reflection of radio waves. RFID combines radio technology with radar and dates back to the seminal 1948 paper by Harry Stockman “Communication by Means of Reflected Power”.³ Although RFID is not new, mass-market applications have only been developed over the last decade.

2.2.1 Technical overview of RFID

Technically speaking, RFID systems consist of three main components (Figure 2.2):

- A transponder or tag to carry data, which is located on the object to be identified. This normally consists of a coupling element (such as a coil, or microwave antenna) and an electronic microchip, less than 1/3 millimetre in size. Tags can be passive, semi-passive or active, based on their power source and the way they are used⁴, and can be read-only, read/write or read/write/re-write, depending on how their data is encoded.⁵ Tags do not need an in-built power source, as they take the energy they need from the electro-magnetic field emitted by readers.
- An interrogator or reader, which reads the transmitted data (e.g. on a device that is handheld or embedded in a wall). Compared with tags, readers are larger, more expensive and power-hungry.
- Middleware⁶, which forward the data to another system, such as a database, a personal computer or robot control system.⁷

In the most common type of system, the reader transmits a low-power radio signal to power the tag (which, like the reader, has its own antenna). The tag then selectively reflects energy and thus transmits some data back to the reader, communicating its identity, location and any other relevant information. Most tags are passive, and activated only when they are within the coverage area of the interrogator. While outside this area, they remain dormant. Information on the tag can be received and read by readers and then forwarded to a computer database (Figure 2.2). Frequencies currently used for data transmission by RFID typically include 125 kHz (low frequency), 13.56 MHz (high frequency), or 800-960 MHz (ultra high frequency). RFID standards relate both to frequency protocols (for data communication) and data format (for data storage on the tag).

Depending on their construction, RFID tags can be less than a square millimetre in area and thinner than a sheet of paper.⁸ One of the most pivotal aspects of these electronic labels is that they allow for the accurate identification of objects and the forwarding of this information to a database stored on the internet or on a remote server. In this manner, data and information processing capabilities can be associated with any kind of object. This means that not only people, but also things will become connected and contactable. In the most common application of RFID, for supply chain management, it is typically used as a long-term enhancement of the traditional bar code. But RFID tags represent much more than the next generation of bar codes and have many unique advantages (Table 2.1). Traditional bar codes identify only a category of product. For instance, all Gillette Mach 3 razor blades have the same bar code. However, with RFID tags, each pack of blades would have its own unique identifier that can be transmitted to suitably located readers for monitoring. The RFID tag can hold much more data than a bar code, and becomes in some sense a mini-database embedded in the item. Currently, the Electronic Product Code (EPC)⁹ is the dominant standard for data contained in RFID tags for the purpose of item-level tracking.

RFID also allows data capture without the need for a line of sight.¹⁰ Some applications limit the read range of RFID tags to between 0.15 – 0.20 metres, but the majority have a range of around a metre. Newer tags in the UHF frequency bands could even have a range of 6-7.5 metres.¹¹ This means that physical manipulation or access to individual items (often stacked or piled) is not needed for identification and tracking. This is not the case with the bar code, which must be “seen” at close range by scanners in order to be identified. Depending on whether tags are read-only, read/write or read/write/re-write, tags can create a variety of interfaces that can connect computers directly to individual physical items, and even to people, thus promising a truly ubiquitous future.

Table 2.1: RFID has been compared to a hi-tech barcode...but it is much more than that!

Contrasts between traditional bar code technology and RFID

Traditional bar codes	RFID
<ul style="list-style-type: none"> • Typically identify only a category of product. 	<ul style="list-style-type: none"> • Unique identification of individual items, allowing databases of specific item/location information to be generated, giving each item its own identity for real-time identification and tracking.
<ul style="list-style-type: none"> • Requires close-range scanning, typically with physical manipulation. 	<ul style="list-style-type: none"> • Data capture without the need for line of sight or physical manipulation.
<ul style="list-style-type: none"> • Data can be saved only once. 	<ul style="list-style-type: none"> • Tags can be passive or active, and also read-only, read/write or read/write/re-write.
<ul style="list-style-type: none"> • Less potential to intrude on privacy. 	<ul style="list-style-type: none"> • Privacy-Enhancing Technologies can be used to kill or block tags (Chapter 4).

Source: ITU

2.2.2 RFID in action

RFID provides the means for location-specific item identification that is fundamental to thing-to-thing communications. To date, much of the growth for RFID has come from traditional applications such as security/access control, automobile immobilization, animal tracking, and toll collection. Supply chain management applications in the retail sector and in government are likely to continue to drive the growth of RFID technology in the short term (see Chapter 3). Specifically, the United States Department of Defence (DoD) is evolving its supply-chain management system towards RFID integration. It has recently published the “Defence Federal Acquisition Regulations Supplement” with specifications for suppliers of RFID-enabled products. Over 43'000 existing DOD suppliers will be affected by the mandate, as well as many other companies in the industry. This development, together with Wal-Mart's supply chain transition to RFID and item-level tracking, promises to be a key driver behind the future development of RFID.¹²

Even though the commercial applications of RFID to date have tended to build on its barcode-like characteristics, RFID offers much more over the long-term, and promises to be a key technology for the Internet of Things. Over the medium-term, the use of RFID with consumer items will catalyze the widespread adoption of RFID. RFID tags have the potential to record everything, from item location and pricing information to washing instructions, banking details and medical records.¹³ Experiments have started that could see RFID used as a mechanism for tracking bank notes¹⁴ and passports.¹⁵ Already today, people around the world use RFID systems for identification badges, fuel payments at gas stations, timing athletes during long-distance races, animal identity verification, and much more.¹⁶

Over the long-term, RFID will be a key enabler of the Internet of Things. Eventually, it will be feasible to “tag and track” virtually every object on earth. Anything, from a medical instrument to a house key, from a cat to a human being, has the potential to become a node of the internet. Emerging innovative applications of RFID will further facilitate the dawn of ubiquitous networking. This section sets out a number of current RFID applications and explores their future uses.

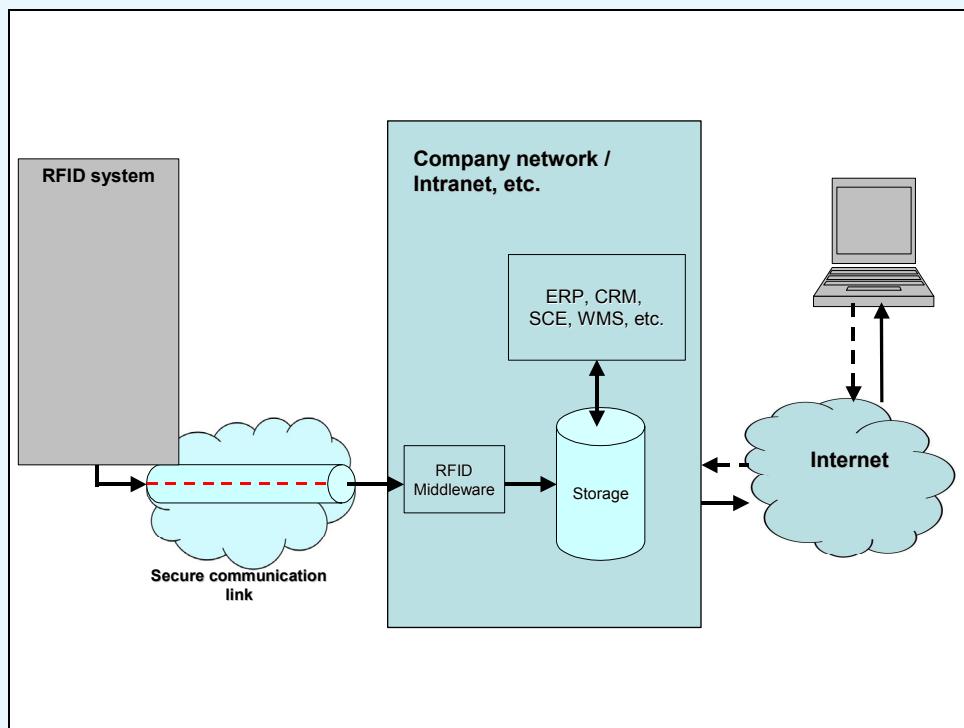
Retail and Transactional RFID

RFID is set to revolutionize the retail sector. By 2008, according to IDTechEx, retailers worldwide are expected to account for over USD 1.3 billion of a global RFID market of USD 7 billion.¹⁷ Not surprisingly, this has tremendous implications for both customers and retailers.

For customers, the main advantage of a retail store using RFID is speedier checkout. This could be achieved using shopping lists generated by smart RFID-enabled devices, such as refrigerators, which can detect the need to restock certain items. These lists could be edited on a mobile phone or a PDA and transmitted to a retail store or downloaded to a data storage device. In the Metro Group Future Store in Rheinberg, Germany, shoppers are guided electronically to find their desired products specified in shopping lists

uploaded by the consumer, through the RFID tags on products. Smart shopping carts equipped with electronic displays communicate with the store's computer system to produce a map identifying the most time-efficient route to obtain the desired items.¹⁸

Figure 2.2: Tagging the internet
An RFID system in a network architecture



Note: ERP – Enterprise Resource Planning; CRM – Customer Relationship Management;
 SCE – Supply Chain Execution; WMS – Warehouse Management System.

Source: ITU

If every item in a consumer's shopping basket is tagged and the necessary reader is installed, there should no longer be any need to lay the items on the belt and manually scan them at checkout to determine the final bill. Eventually, if users are also equipped with contactless payment cards, the long queues at checkout could become a thing of the past. All items in the shopping cart would be automatically debited from consumers' accounts on leaving the store. Early contactless payment solutions using RFID are already being deployed, for instance, in ticketing applications. In the United States, Mobil gas stations and McDonald's are equipped with contactless RFID-enabled payment readers that charge consumers' MasterCard PayPass cards. And in February 2005, Visa introduced a system using RFID to enable consumers to make purchases by simply "waving" their cards near a till.

In the near future, shoppers may be provided with personalized and location-based services while on the move using mobile phones. In particular, based on pre-defined profiles, consumers' mobile devices will receive alerts on current promotions and new offerings when entering designated shopping areas. Retailers, mobile operators and vendors have already begun trials of such services. For example, in 2003, the first trial of mobile RFID shopping was run in Tokyo, opening up an entirely new location-based shopping experience. In June 2005, retail stores and cafes in downtown Seattle began targeting visually and hearing-impaired passers-by with product and navigational information using RFID systems.¹⁹ In March 2004, Nokia introduced the Nokia Mobile RFID Kit for its 5140 and 5140i handsets.²⁰ These handsets combine mobile communication technology with RFID-reader capabilities for supply-chain applications and for mobile data capture on the field.²¹ And in June 2005, in its research centre in Helsinki, Nokia started experimenting with an RFID bracelet phone integrated with location-based services, which could eventually alert users to promotional offers and other pertinent information²² (see also Chapter 3).

For retailers, RFID offers countless advantages. A major benefit for shop-owners (Box 2.1) is a limitless source of empirical data on consumer behaviour and impulse purchases (see Chapter 4). Research by A. T. Kearney found that the introduction of RFID among retailers would generate USD 700'000 in savings per every billion USD in sales, due to the elimination of out-of-stock items.²³ Other savings could be made in the reduction of perishable and date-specific products no longer valid for sale, claims related to inaccuracies in invoices, and the diversion of promotional products shipped to wrong locations.²⁴

The world's largest retailer, Wal-Mart, has pioneered the use of RFID tags along its supply-chain through to the sales floor. Wal-Mart has found the use of RFID technology especially important in improving the visibility of how products move from the stockroom the shelves and, consequently, the availability of the product. The business case became obvious when the retailer's internal research found that, on weekends, only one of every 12 missing stock items is replenished in a timely manner.²⁵ In November 2003, the company issued a mandate requiring its key suppliers to use RFID. By the end of 2005, its top 100 suppliers are required to deploy RFID tags on all pallets and cases, with the rest due to follow suit by the end of 2006.²⁶ The role of Wal-Mart as a lead user of RFID is discussed further in Chapter 3.

Other retailers are also trying on RFID for size. Marks & Spencer, a 400-store British retailer, has been running a series of RFID trials in cooperation with Microsoft²⁷ aiming to ensure product availability in its stores. In particular, the so-called removable "paper intelligent label" with a passive RFID microchip has been added to apparel. The inventory held by individual retailers is typically analysed at the end of the business day. RFID facilitates the collection of inventory data, which is then transmitted to the company's stock-management system so stock is fully replenished by the start of the next day.²⁸

Metro Group, together with IBM, is running a pilot study to examine how RFID affects the whole business process, and especially potential customer benefits. One example is the scanning of tags on apparel in dressing rooms to suggest to customers other colours, sizes and accessories that might suit the garment. The recommendations flash on displays installed in the dressing rooms.²⁹

Tesco, a supermarket chain with USD 64 billion revenue from its operations in Europe and Asia, has begun trials for small item tracking, such as cosmetics and DVDs. The purpose behind the project is better stock-level management and identification of misplaced items.³⁰ To further increase security, a group of German retailers and manufacturers are working on a reusable label that will combine RFID with two anti-theft technologies: acousto-magnetic and radio frequency.³¹

Transactional and retail RFID applications possess huge potential for the market, but only if the proponents of RFID can combat perceptions of RFID as a technology which threatens consumer privacy. There is growing concern among the public that, after purchase, tags embedded in products could continue to transmit information about their location, usage and users. During 2003, consumer boycotts were organized against two large companies planning to deploy RFID, Benetton and Gillette. Benetton subsequently cancelled its plans to deploy RFID technology. The issue of user privacy is addressed in greater depth in Chapter 4.

RFID, infotainment and lifestyle

Although they may not always be aware of it, consumers are already using RFID in many areas of their lives: on toll roads, in offices, in libraries and in public transport. Over the next few years, these tiny tags will be increasingly used to add further convenience to day-to-day living, from sports events to retail shopping (as discussed above). Today, hordes of RFID tags enhance the quality of people's recreational lives in all areas imaginable: sports, art, clubbing, gambling, computer games and other innovative applications.

Casinos quickly realized the potential of RFID for various aspects of their operations. As shown in Box 2.2, they have been enthusiastically embarking upon a form of "ubiquitous tracking" of tokens. Interestingly, the press has touted casinos as technological missionaries in bringing RFID to light.

In the sporting world, entrants in events such as the Boston, New York, Los Angeles, Berlin and Capetown marathons are issued the "ChampionChip", a small token attached to the runner's shoe or attached to a wheelchair. As runners cross stationary mats along the racecourse, these chips enable runners' times to be recorded.³² This information can then be forwarded to the mobile phones of interested spectators through SMS.

Box 2.1: RFID turns traditional marketing theory on its head

From measuring the movement of shopping carts to changing buyers' behaviour

Recent marketing research by the Wharton School at the University of Pennsylvania carried out with the help of RFID technology revealed patterns of consumer behaviour unknown to conventional marketing wisdom. Research called “An Exploratory look at Supermarket Shopping Paths” gleaned evidence from a grocery store where all shopping carts were equipped with active RFID tags. RFID readers were scattered around the store and collected signals from the shopping carts every five seconds, as customers were moving along the aisles.



Traditionally, it has been assumed that customers start with the aisle closest to the entrance, stroll along it, move to the next one and continue like this, until they reach the end of the store. The experiment, however, demonstrated that shoppers only walk by shelves that interest them. Moreover, once they have picked up the desired item, they take the shortest path to the checkout counters. Another finding is that the perimeter of the store, referred to as "the racetrack", is the base from which customers take short trips down the aisles, and not the space visited only incidentally to the aisles, as suggested by the conventional school of thought.

The implications of these findings are immense. Management can now experiment with anything from product placement to shop layout. For example, they could put the most popular items at the back of the store, thereby stimulating impulse purchases when the customer travels towards the desired product. Or they could rearrange items in order to invert shoppers' routine behaviour. It remains to be seen what other conventional assumptions will be overturned with RFID-enabled research.

Image source: Metro Group Future Store Initiative portal

Source: Knowledge@Wharton, "Tag Team: Tracking the Patterns of Supermarket Shoppers", 1 June 2005 at <http://knowledge.wharton.upenn.edu/>

Box 2.2: Chip the chip

Box 2.1. Chip the chip Spotlight on RFID advantages for casinos

As the costs of RFID plummet, casinos across the globe are enjoying the benefits of implementing this technology, including:

- Improved marketing and customer care;
 - More streamlined inventory management;
 - Preventing chip counterfeiting and theft;
 - Prevention of slot-machine keys leaving the facilities;
 - Inventory of uniforms;
 - Monitoring of casino wait staff.



Hard Rock Hotel and Casino in Las Vegas has recently introduced RFID “smart chips” from Progressive Gaming International Corp. to its blackjack tables. With this, the casino can easily define the “worth” of players and direct promotional offers towards the more “precious” customers. Earlier in 2005, the casino Wynn Las Vegas was opened equipped with RFID-enabled tokens and betting tables, mainly for security purposes. The supplier, Gaming Partner International Corporation, GPI Corp., claims that the look and feel of the RFID-enabled chips is virtually indistinguishable from the traditional ones.

The City Casino in Sydney manages a wardrobe inventory of 80'000 uniforms valued at some USD 1.8 million. Tracking through RFID ensures that the right uniforms are ready to wear every time there is a change in shifts.

Image Source: RFID Image Gallery

Sources: InfoWorld, "The case for active RFID", 21 June 2005; *Wall Street Journal*, "Casinos bet on radio-ID gambling chips", 13 May 2005; RFID Update, "Casino supplier doing brisk RFID business", 16 May 2005; ITU, "Ubiquitous Network Societies: The Case of RFID", April 2005, at <http://www.itu.int/ubiquitous>

Other than casinos and sporting events, RFID technology has made an appearance in multiple leisure and entertainment industries. For example, it is increasingly being deployed in libraries to automate the loan and return of library materials. The libraries of Virginia Beach in the United States encourage clients to use RFID-enabled self-service systems for faster checkout. Customers have to wave their library card near a reader and place the stack of books on the pad for scanning.³³ Arts and gaming are other areas ripe for RFID applications (Box 2.3).

Box 2.3: Radio in on arts and gaming

Richer experiences for art lovers and gamers alike with RFID in galleries and arcades



Passive contemplation is no longer the only pastime in galleries. Florida-based technology vendor Sapago recently announced a new version of its Art-FID product. Now visitors to art galleries can access background multimedia information on artworks, such as authors' comments, bio, tools, pictures, their history, price, etc. This is achieved using RFID tags planted next to artworks that transmit bits of data onto handheld computers. For further reflection, visitors can also e-mail this information to their own mailbox. Sapago says that the new product is intended to increase sales for galleries and enhance customer experience.

If artistic contemplation is not your cup of tea, RFID offers more high-tech fun. In the new multi-player arcade role-play game by Sega called Sangokushi, a player's interface is based on "Lord cards" equipped with RFID tags for storing player information. Players move cards on the playing surface and watch their moves on a display, while the general overview of the game is only shown to observers on a large monitor.

Image source: Vcoop

Sources: Sapago, Press release "Sapago Art-FID lets artists speak directly to art collectors", 8 June 2005; RFIDBuzz.com, "RFID arcade games", 20 June 2005

Day after day, RFID is getting closer to home. In fact, it has even penetrated human skin. "Human bar codes", or implantable RFID tags for the tracking and monitoring of individual citizens, are now being used for entertainment purposes. VIP patrons in clubs such as the Baja Beach Club in Barcelona, for instance, receive access to exclusive lounges and instant payment services if they volunteer for the implant (Box 2.4).

Box 2.4: Maintaining a cool lifestyle

RFID implants for humans

The case of Baja Beach Club in Barcelona injecting its VIP visitors' arms with VeriChip for identification and payment has been followed in other nightclubs in Europe. Bar Soba in Glasgow explains the rationale behind the introduction of its implanted "digital wallet" as a way for customers to avoid queues, receive customized service, and not to carry around purses full of cash and credit cards which can be easily lost or stolen on the dance floor.

The VeriChip is the size of a grain of rice, encapsulated in a glass cylinder and does not cause electro-magnetic interference. It is only "awakened" when approached by a reader. The chip is similar to that already implanted in millions of animals, has undergone rigorous examination and is widely considered safe.



Image Source: Membrana

Sources: The Observer, "This chip makes sure you always buy your round", 16 January 2005; ITU, "Ubiquitous Network Societies: The case of RFID", April 2005, at <http://www.itu.int/ubiquitous/>

RFID for security, safety and eco-friendliness

RFID offers significant potential for governments wishing to strengthen their national defence and security. Border crossings are one example. The border between the special administrative region of Hong Kong, China and Shenzhen (China) is highly regulated and is a case in point. Since 2002, China's Schenzen authorities have installed an RFID system to facilitate the flow of low-risk traffic and goods across the

border, and to thwart smuggling. Recently, the United States mandated that all American passports should contain biometric data, such as fingerprints. This requirement has also been extended to nationals from those countries that do not require a visa for travelling to the United States. More recently, the US government has advocated the use of RFID in combination with biometric data on passports. This measure has raised concerns among some technologists and civil libertarians, who fear that information on such chips may be read remotely, thus enabling a person's biographical information and photo to fall into the wrong hands.³⁴

In addition to protecting national security, RFID may be used to safeguard clerical and commercial property, individuals and their belongings. Such applications can now be found at airports, hospitals, educational and day-care institutions, residential communities, leisure parks, churches etc.

RFID has proved indispensable in protecting expensive personal items, such as cars, yachts, watches, musical instruments and so on. In Germany, for example, Philips Semiconductors introduced an RFID labelling system to protect recreational boats (of which there are 660'000 in the country) from theft through secure electronic identification. In the past, boats were simply identified by painting numbers on them, a system prone to fraudulent removal or modification. Since RFID tags allow the identity of a boat to be determined remotely, German authorities can check the status of a boat against their databases of stolen and registered boats, without a search warrant. Musical instruments, too, can be protected from theft through RFID tags. Musical instruments are expensive and some custom-built or vintage guitars, for instance, can cost more than USD 50'000 each. Often, however, they are sold or pawned for a fraction of their worth. They are hard to track down, as many models look alike. The RFID maker Snagg has created chips no bigger than a grain of rice designed for protecting instruments. Snagg's database is available to law enforcement officials, dealers, manufacturers of string instruments, and repair shops.³⁵ Perhaps one of the most unusual applications of RFID is in cemeteries and morgues, where the technology has been used to secure graves and corpses (Box 2.5).

Box 2.5: Haunted by RFID?

RFID combats criminal activities in graveyards and sanctuaries

Multiple cases of teenage vandalism have been reported in Scandinavian graveyards. Up until recently, churches lay unprotected in the face of the intruders. Video surveillance was useless at night, when vandals usually attacked, and churches were generally reluctant to intrude on visitors' privacy.

Graves, as well as valuable artefacts in churches, are now tagged with RFID and when someone breaks in a church or tries to remove a gravestone, a nearby scanner triggers an alarm. This initiative originated with a Danish software developer, Lingsoe Systems. Criminals engaged in the illicit trade of body parts are also threatened by RFID systems. Every year in the United States, thousands of bodies are donated to medical schools for medical research, organ transplants, vehicle security experiments and educational purposes. However, a lucrative black market exists for the trade of corpses and body parts. Californian officials hope that this market can be eradicated with the help of RFID tags inserted in cadavers for automatic tracking.



Image Source: University of Exeter (UK)

Sources: RFIDBuzz.com, "Rest in peace", 6 June 2005; Wired News, "Body ID: Barcodes for cadavers", 5 February 2005

RFID can also be used to safeguard personal safety and security. Public leisure parks, such as Legoland in Denmark, are using RFID technology to attract families concerned with the personal safety of their children and elderly relatives. In Legoland, parents can rent RFID-enabled wristbands from the park's administration to keep a check on their children's whereabouts. Parents and guardians wishing to locate separated or missing children can use their mobile phone to send a text message to an application known as "kidspotter". The application rapidly returns a text message stating the details of the child's last location, including their coordinates, name of the park area, etc.³⁶ In September 2004, the Rikkyo Primary School in Tokyo in Japan carried out an RFID trial to monitor the comings and goings of its students in real-time. The system records the exact time a student enters or leaves the campus, and restricts entry to school grounds. Since tags can be read by scanners from a distance of up to ten metres, students are no longer required to stop at designated checkpoints. In this manner, parents can also check when children arrive and leave school premises. Even newborn babies can be protected from abduction using RFID tags (Box 2.6).

Box 2.6: A babysitter you can trust

An electronic identification system reported to thwart baby abduction



A “Hugs” RFID system has been developed by the Canadian company Instantel (recently acquired by VeryChip Corporation) to prevent the abductions of newborn babies from hospitals. The system includes radio transmitters to be fixed on the wrists or ankles of newborn babies and electronic monitoring systems for installation at various points of healthcare facilities.

VeriChip Corporation (a subsidiary of Applied Digital Solutions, Inc.) has claimed that its new system has helped prevent an alleged kidnapping from a Hospital in North Carolina. The alarm was activated following an unauthorized attempt to remove the infant from the maternity ward.

Happily, the incident was quickly resolved by hospital security officials and no damage was inflicted on the baby.

Coincidentally, the news came only a few days after a press release from an apparel manufacturer in the United States, which has incorporated RFID tags into its baby pyjamas line, for the purpose of preventing abduction. Readers could be placed at the doorways and windows of homes, alerting parents in case the child trespasses over a critical point.

Given that in the United States, it has been claimed that a child disappears from hospital, playground, school or home every 18 seconds, this RFID-enabled protection system comes in the nick of time.

Image Source: Cyberspace community

Sources: Applied Digital Solutions, Press Release, 18 July 2005; CMP TechWeb, “Apparel maker tags RFID for kids’ sleepwear”, 13 July 2005

Environmental protection is an ever-growing concern in the context of public safety: in this context, RFID, in combination with sensors and mobile communications, has much to offer. The example of waste collectors in Sweden (Box 2.7) demonstrates how RFID allows more eco-friendly waste disposal and recycling.

Box 2.7: Tagging the rubbish too?

A Swedish company serves environmental protection



Local authorities in Sweden are encouraging the reduction of waste and recycling by charging for the collection of waste based on weight. This is reinforced through a new tax levied per ton of disposed waste.

Swedish Botek Vägsystem AB, the leading waste collector in Scandinavia, has introduced a truck-mounted electronic system for weighing waste to calculate how much to charge customers. The system also collects, stores and edits useful information on customers and waste.

The system (based on RFID infrastructure supplied by Minec) includes hand-held terminals cradled in the vehicle cab and RFID tags attached to waste bins. The main advantage of RFID transponders over bar codes in this instance is their excellent weather resistance. The RFID microchips can withstand shock, heat, frost and showers and store the data on customers and bin numbers securely, without the risk of tampering. While the truck is on the move, all customer information is transferred to Botek’s central database. Weight statistics and invoices are only a click away. The statistical data obtained from such measurements could help waste creators optimize refuse collection and comply with environmental standards.

Image Source: Minec

Source: AIM Global, “Waste collection data cuts costs and provides environmental information”, 30 June 2004

In food safety, RFID biosensors that can detect whether a perishable item has expired are making their appearance. Such biosensors are tiny and capable of detecting the presence of any biological or chemical agent.³⁷ Consisting of a transducer and a computer chip, the sensor could be embedded in a single RFID tag and placed inside a water bottle or even in the liquid at the bottom of a package of meat. Although the mass adoption of RFID biosensors is some years away, a number of companies, including one of

McDonald's largest beef providers, Golden State Foods, have been testing RFID biosensors since 2002. A system made up of RFID sensors could eventually allow the tracking and monitoring of all food supplies, thereby thwarting contamination and potentially even bio-terrorism. Sensors are discussed further in Section 2.3.

In Europe, as of 1 January 2005, the *General Food Law* (178/2002/EC) requires that the "traceability of food shall be established at all stages of production, processing and distribution to meet the new requirements".³⁸ This regulation has tremendous implications for the further development of RFID, which can provide end-to-end transparency throughout the food supply-chain. For example, in Australia, farmers already have to identify cattle and their origin to comply with National Livestock Identification Scheme (NLIS).³⁹

It should be borne in mind, however, that security is a double-edged sword. Concerns have been voiced around the world that tracking with RFID poses a danger to personal security and privacy. Moreover, chips injected in humans may be just as vulnerable to virus attacks and other network threats as traditional ICT networks.

RFID and healthcare

The healthcare industry has much to benefit from the use of RFID for the prevention of drug counterfeiting, the maintenance of medical equipment and supplies, and the monitoring of patients.

In the pharmaceutical industry, RFID tags can be used to tag bottles of medication destined for pharmacies and drug stores to better detect counterfeit drugs, as these do not often travel through the usual supply chains (Box 2.8). In early 2004, the Food and Drug Administration of the United States issued a report recommending that pharmaceutical companies use RFID on the bottles of the most commonly counterfeited drugs starting in 2006 and on most other drugs by 2007.

Box 2.8: End of fake drugs?

Two American IT giants join forces in a project against counterfeit drugs



Texas Instruments and Verisign are collaborating in the development of an authenticated RFID model using Public Key Infrastructure (PKI) technology to ensure drug safety. Authentication will be carried out through RFID tags on bottles and readers en route from manufacture to sales. The ownership of products can be verified and the elimination of counterfeited drugs becomes possible at all points along the distribution chain. Identification of items at the level of individual products is of utmost importance in the pharmaceutical industry, which is poised to enhance security and chain-of-custody management.

Image source: RFID Image Gallery

Source: Health and Medicine Weekly, "Companies collaborate on radio frequency drug ID model to thwart counterfeiting", 27 June 2005

In July 2004, a group of manufacturers, including Abbott Laboratories, Johnson & Johnson, Pfizer, and Procter & Gamble, began shipping bottles of pills with RFID labels.⁴⁰ In addition to tracking fake drugs, tagged bottles can prevent theft, as well as to recall outdated or damaged medication. As pharmacies receive medication through specific distribution centres, the origin of tagged bottles can be identified. Alarms can be raised when an incomplete or inaccurate set of locations are found on a tag.⁴¹

In the field of medical surgery, several pilot studies are under way to determine how RFID can improve the accuracy of the delivery of the appropriate blood group to patients, compared with current bar-code methods. RFID enables the accurate matching of blood samples/transfusions to the correct patient without line-of-sight data transmission, which can be carried out around the patient, through clothing, bed coverings and non-metallic materials.⁴² For dental prosthetics, the French company Dentalax has incorporated an RFID system into the manufacture of crowns and bridges in the dental industry. An RFID tag is locked into each dental prosthesis, recording every action or procedure conducted on it. The data from the RFID tag can be saved onto a smart card that patients keep for the future reference of their dental practitioner.⁴³

RFID can also help in caring for patients in hospital. As seen above, it can be used to protect newborn infants from abduction (Box 2.6). In Germany, the Klinikum Saarbrucken hospital equips patients of all ages with tagged wristbands to monitor their condition and adjust drug doses correspondingly.⁴⁴ Similarly, in Taiwan, China, the Chang Gung Memorial Hospital provides patients with RFID wristbands loaded with patient data. Plans are under way to extend the use of RFID chips to surgical premises and blood supplies.⁴⁵

In October 2004, the Food and Drug Administration (FDA) of the United States approved the use of the implantable chip Verichip (from Applied Digital Solutions, Inc.) for medical purposes. This chip stores data such as a patient's ID number, blood type and condition. In Mexico, at the beginning of 2005, more than 1'000 patients were carrying Verichips. Coupled with sensor technology, the potential of implantable RFID systems seems limitless.⁴⁶ They have even been used in the context of human reproduction, to match parents with the correct fertilized embryos (Box 2.9).

Box 2.9: RFID for reproduction done right

IVF clinics look into RFID

In 2002, after several rounds of In Vitro Fertilization (IVF) procedures, a white couple from the UK reproduced a pair of dark-skinned twins. The incident happened because the clinic had mistakenly used the biological material from another couple of parents. Similar incidents were reported in Netherlands and the United States. In an effort to eliminate such blunders, the UK's regulatory body, the Human Fertilisation and Embryology Authority (HFEA) has proposed the electronic identification of all embryos, eggs and sperm using RFID tags.

The RFID tags will be placed next to samples, and, when activated, transmit a unique ID code. The alarm will go off each time a suspicious activity on the material is noted. This could happen, for example, when non-matching eggs and sperm are brought too close to one another.

It has yet to be determined whether the radio waves emitted by RFID devices can cause harm to embryos. Scientists are currently engaged in early experiments with mouse embryos to investigate this.

Image Source: University of Exeter (UK)

Source: New Scientist, "Electronic tags for eggs, sperm and embryos", 30 March 2005, available at <http://www.newscientist.com/>



In summary, RFID can be used in patient care to enhance patient safety and optimize hospital workflow. It is equally important in the pharmaceutical industry, where electronic product codes on medication can curtail counterfeiting, streamline revenue distribution, reduce prescription errors, and decrease product returns.

2.2.3 RFID: Shortcut to ubiquity

Based on the above overview of a number of emerging applications, it is clear that RFID will prove a catalyst for the development of the "Internet of Things". Moreover, RFID in combination with sensors and mobile phones can create a "ubiquitous environment" in which the status of users and "smart objects" will be continuously determined, monitored and communicated to users.⁴⁷ Today, a typical RFID tag is about the size of a grain of rice, but rapid advances in this technology herald an age of microscopic, or even "nano-scopic" computing capabilities. Looking beyond the early stages of RFID deployment, a silent revolution is gathering momentum – one that applies the computing power in a tag or chip to smaller and smaller things. In Japan, a series of experiments are under way aiming to create a prototype of just such a ubiquitous environment. One of the central tenets of this work is the creation of the aptly named "ubiquitous communicator" (Box 2.10).

The importance of RFID can hardly be overestimated. National governments are exploring the potential benefits of this technology and, as a consequence, much of RFID growth comes from deployments at the national level, inspired and supported by state administrations. Daeje Chin, the Republic of Korea's Minister for Information and Communication recently declared that the RFID business will be "as important as the mobile phone business".⁴⁸ The Korean government is building several R&D centres to promote faster replacement of bar codes with RFID systems. An estimated USD 800 million will be invested in the

programme, with RFID production due to start in 2006. To date, the Republic of Korea has used RFID for tracking beef imports, managing luggage at several airports and managing inventories.⁴⁸

China will generate a USD 616 million market for RFID by 2009, according to Analysis International, a Beijing-based research firm. Similar to Western nations, the main drivers for RFID development in China are national governments on the one hand, and globalization, on the other. The key areas of application are presently supply-chain management and identification. China procures retail giant Wal-Mart with over USD 100 billion worth of goods⁴⁹, and the retailer is now requiring its largest suppliers to put RFID tags on their cases and pallets. In addition, the government of China plans to issue RFID-enabled national ID cards to every adult in the country, in time for the 2008 Olympics in Beijing. Thus, RFID deployment has become a major focus of technical and policy development in China.⁵⁰

Box 2.10: My pills just called
Large-scale ubiquity experiment in Asia

In September 2004, the Ubiquitous Communicator (UC) was released in Japan by the Ubiquitous ID Center, an R&D foundation with participation from industry, private companies, government institutions and the general public. UC is a portable communication tool that uses information from various tagged objects to provide users with multiple applications while on the move. Holding the UC next to a tagged item, users will receive information about the item by text, voice, photographs or moving pictures. The vision underlying these experiments is that in the future, ultra-tiny computers should be embedded everywhere, in shopping items, clothes, bottles of medicine, electric bulbs, walls, ceilings and floors to make our lives easier and more fun. Unique identifiers, or “Ucodes”, will be assigned to each tag to distinguish between different objects. The proposed Ucodes are Japan’s alternative to EPC or electronic product codes.

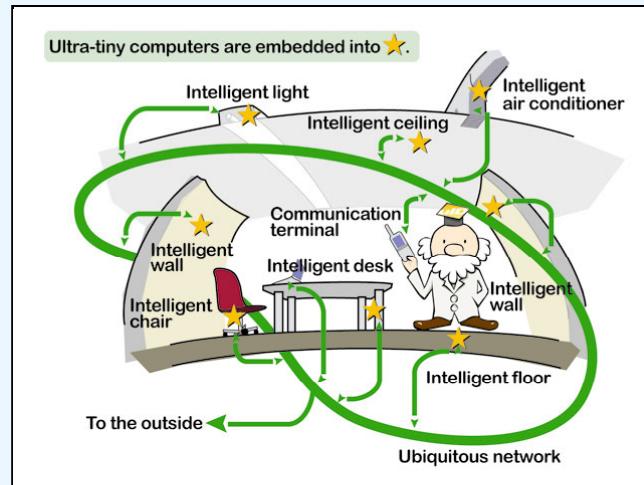
In 2004, several tags were set up within the trial areas and a number of trial services launched:

- Voice guidance to visually-impaired people;
- Transmission of SOS-alarms;
- Receipt of shopping information.

By June 2005, in the Seto Area of Japan, Ucode tags had already been deployed in over 1'000 locations, including on roads and pavements, while in Asakusa, Ucode tags were in use in 80 places.

Image Source: Ubiquitous ID Center

Source: Ubiquitous ID Center at <http://www.uidcenter.org/>



Following the realization of economies of scale and a continuous drop in unit prices, RFID systems are becoming less and less costly to deploy, while remaining easy to operate and maintain. This powerful technology now offers a fast track for developing countries to become more competitive.

Unfortunately, the deployment of RFID-based applications and the widespread realization of their potential have so far been hindered by the lack of established international standards. With the exception of Electronic Product Codes (EPC)⁵¹, there has been a fragmented approach to the setting of standards, in particular for frequency use and protocols. Not every country has agreed on frequencies to be used, and the availability of bandwidth varies across different countries. In this context, the International Telecommunication Union, with its governmental and industry members, may play an important role as facilitator for the harmonizing of fragmented standardization efforts around the globe. This issue will be explored in greater detail in Chapter 4, together with the controversial issue of consumer privacy, which is still the subject of much heated debate.

2.3 Feeling things: Sensor technologies

Sensors are one of the key building blocks of the Internet of Things. As ubiquitous systems, they can be deployed everywhere – from military battlefields to vineyards and redwoods and on the Golden Gate Bridge. They can also be implanted under human skin, in a purse or on a T-shirt. Some can be as small as four millimetres in size, but the data they collect can be received hundreds of miles away. They complement human senses and have become indispensable in a large number of industries, from health care to construction. Sensors have the key advantage that they can anticipate human needs based on information collected about their context.⁵² Their intelligence “multiplied” by numerous networks allows them not only to report about external environment, but also to take action without human intervention. This section introduces sensor technologies, shows how they can be combined with both mobile and RFID technologies, and outlines how wireless sensor networks work.

2.3.1 What is a sensor?

A sensor is an electronic device, which detects, senses or measures physical stimuli – for instance, motion, heat or pressure – and responds in a specific way. It converts signals from stimuli into an analogue or digital form, so that the raw data about detected parameters are readable by machines and humans.⁵³

In general, sensors classified according to the parameter they measure⁵⁴: mechanical (e.g. position, force, pressure, etc.), thermal (e.g. temperature, heat flow), electrostatic or magnetic fields, radiation intensity (e.g. electromagnetic, nuclear), chemical (e.g. humidity, ion, gas concentration), biological (e.g. toxicity, presence of biological organisms), and so on.

Why might one require the use of sensors? One of the first questions people ask over a mobile phone is: “Where are you?” They do this to get information about the location and situation a person is in. This information is needed for more effective decision-making. Much is gained from applying a similar logic to computers: even more so, when computers become ubiquitous. It is extremely important to gather knowledge about the environment, situation or context surrounding an object (computing element) or user, so that decisions taken by the computing element are as relevant to the user’s task or status as possible. However, computers communicate in other ways than people. In a ubiquitous network society, where human-computer interactions should be as simple and effortless as possible, some of the most important sources of information for a computer are its sensors.

Since every unit of the network must be able to receive and send information, distinctive input-output devices are needed. A keyboard is a traditional input device, and printers and screens are traditional output devices. For intelligent or smart things, such as “forget-me-not bags” (Box 2.14), a keyboard or printer are obviously not feasible. Within an intelligent networked system, *sensors* perform the functions of input devices – they serve as “eyes”, collecting information about their environment. In contrast, *actuators* serve as output units – they act as “hands”, implementing decisions.⁵⁵

Sensors collect data from their environment, generating information and ‘awareness’ about their context. Computing systems are context-aware⁵⁶ if they use “context to provide relevant information and/or services to the user, where relevance depends in the user’s task”.⁵⁷ For example, sensors embedded in an electronic jacket can collect information about external temperature and adjust the parameters of the jacket accordingly. There is no exhaustive list of parameters for context awareness. The very definition of “context” is vague. Common parameters include location, identity, time of the day, temperature, humidity, speed, proximity to solids, information about people surrounding the user, and so on.

Sensors play a pivotal role in the building of a ubiquitous Internet of Things. They act as a bridge between the physical and virtual worlds, and are often used in surprising places. Common applications include:

- Military – enemy tracking or battlefield surveillance;
- Environment – monitoring of habitat, the behaviour of Storm Petrel birds⁵⁸, observation of environmental pollution and forecasting of natural disasters;
- Healthcare – monitoring and tracking of patients and doctors and remote monitoring of physiological parameters, such as heart rate, level of substances in blood, care of elderly people;

- Construction – monitoring of structural integrity;
- Commercial applications – remote monitoring of the temperature of products;
- Home applications – smart home, smart things etc.

2.3.2 Wireless sensor networks

It is said that two heads are better than one: the same applies to sensors. The intelligence of a single sensor increases exponentially when used in a network. When a sensor forms part of a sensor network, it is known as a sensor “node”. While it is now easy to deploy single sensors, ensuring connectivity between multiple nodes is a more challenging task. In simple terms, sensor nodes can be connected to each other in two ways: wireline and wireless. Wireline communication protocols provide high levels of security and reliability, and are appropriate “whenever time-critical and mission-critical data and closed-loop control are required”.⁵⁹ However, laying cables and relocating them at a later date can be costly and time-consuming. Taking these factors into consideration, together with advances in miniaturization and low-cost alternatives, wireless links are being increasingly explored for the development of sensor networks. Wireless sensor networks are generally less costly, less visible and more flexible.

A sensor node in a wireless sensor network is a small, low-power device, which normally includes the sensor itself, together with power-supply, data storage, microprocessors, low-power radio, analogue-to-digital converters (ADCs), data transceivers, and controllers that tie all components together.⁶⁰ Wireless sensor networks offer solutions for a number of sectors, such as health care, security, and agriculture (Figure 2.3). Applications include: gun shot detection systems used by police⁶¹; indoor location sensor systems for monitoring elderly people living alone⁶²; indoor and outdoor environmental monitoring; factory and process automation; monitoring wildlife habitats; public safety; and early warning against natural disasters.

One of the most important developments in sensor networks is the possibility for nodes to self-organize themselves into a network. In this way, information gathered and processed by a particular node identifies the nearest available node. This node receives the information and relays it on to a free peer, until the information reaches its ultimate destination.

Many scientific and research groups are working to develop more efficient and feasible sensor networks and overcome the associated technological hurdles.⁶³ The main technical constraints are power, size, memory and storage capacity.⁶⁴ There is a trade-off between increasing power and decreasing size. Today's commercially viable sensors have not yet shrunk to the size of the head of a pin.⁶⁵ They can be as big as a deck of cards or as a small as a stack of United States quarter coins.⁶⁶ The development of the five-millimetre “spec” sensor chip is considered to be a significant breakthrough in this regard.⁶⁷

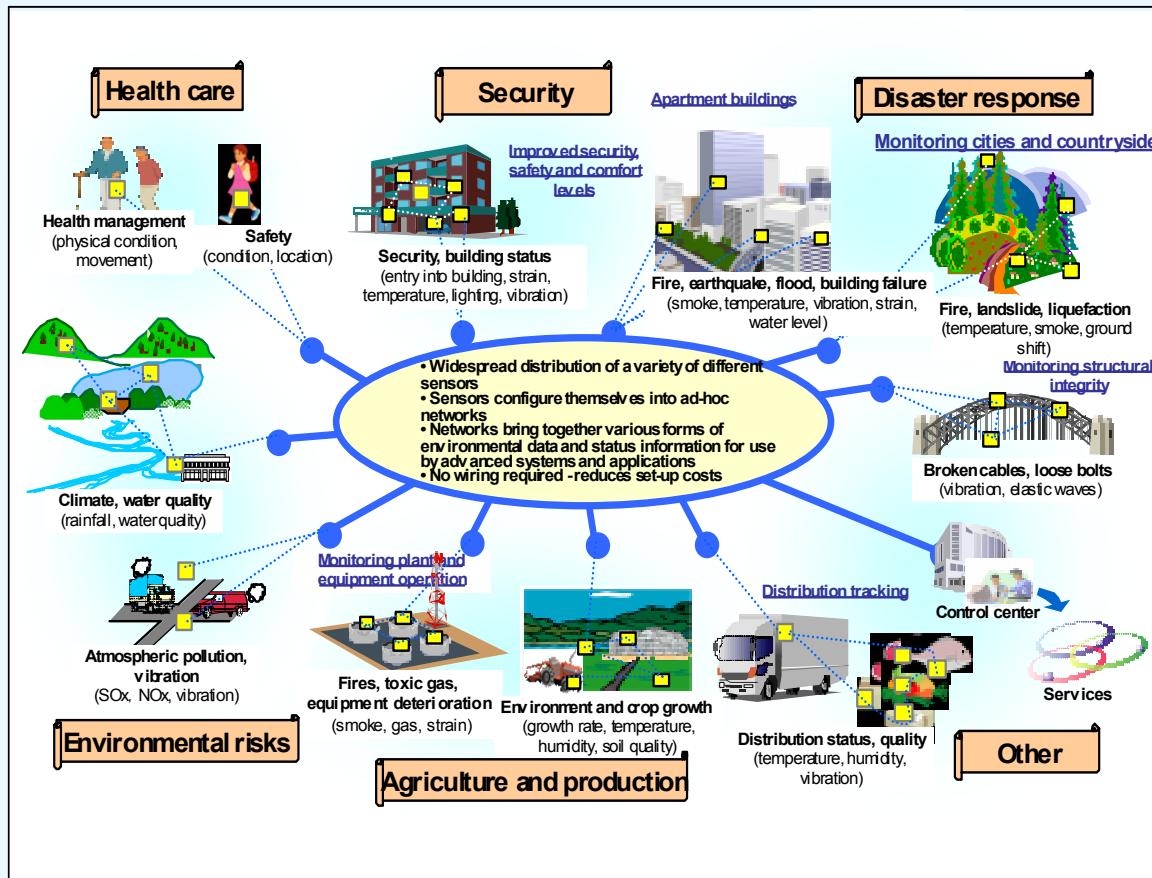
Dust gets smart

Indeed, sensor technologies are beginning to disappear from the scope of “human vision”, while simultaneously acquiring more complex sensory capabilities.⁶⁸ In fact, they may eventually become as tiny as specs of dust. The principles of wireless sensor networks in 1998 were adopted in the “smart dust” concept, developed at the University of California in Berkeley and funded by the United States Defense Advanced Research Projects Agency (DARPA). “Smart dust” implies the miniaturization of traditional sensors to the size of particles of dust (although this task has yet to be achieved) and their interconnection in a wireless sensor network. According to the initial intentions of researchers, smart dust particles can be scattered randomly from a plane or a helicopter onto a battlefield or enemy territory, so that they can gather information about enemy movements or environmental status.

“Motes” (the nickname given to the smaller nodes⁶⁹ of the smart dust network) fulfil sensory, storage, communication and power management functions. Like any computer, a mote has an operating system. Researchers at the University of California in Berkeley (together with Intel) have designed an open source operating system called TinyOS, which is freely available and has become the *de facto* industry standard operational system⁷⁰ for sensor networks. Tasks given to motes can be revised even after they are deployed.⁷¹ In 2003, the University of California at Berkeley developed a chip integrating a sensor and transmitters on a single silicon platform⁷² five millimetres in size, known as a “spec”. The spec, however, still needs “an inductor, an antenna, a 32 kilohertz watch crystal and a power source”.⁷³ However, scientists consider that adding these elements should not dramatically increase the size of a sensor mote. They are also

considering less conventional sources of power, such as solar cells, isotopes⁷⁴ or mechanical sources of energy, including the vibration of windows.⁷⁵

Figure 2.3: The wide reach of sensor networks
A Japanese vision of ubiquitous sensor networks



There are numerous potential non-military applications of smart dust. In 2002, sensor networks were deployed to determine the needs of Leach's Storm-Petrel birds on Great Duck Island, Maine.⁷⁶ Deployments of sensor networks in agriculture also include vineyard monitoring (Box 2.11). Wireless sensor networks have found commercial application in the construction industry. In San Francisco, California, a wireless sensor network (made up of about two hundred motes) is embedded into the Golden Gate Bridge to monitor the bridge's structural integrity. These motes, known as Micro Electro Mechanical Systems (MEMS) sensors⁷⁷, provide real-time information by measuring the stress loads on the bridge e.g. wind or ambient vibrations. The motes measure the sway of the bridge (which in the case of strong wind can be several feet) and relay this information to the central computer for analysis. In case of bad weather, minor earthquakes or other crises, engineers receive alerts and can take necessary action to keep the bridge safe.

Webbing the sensors

Greater artificial intelligence and increased independence from human intervention are the key attributes of the sensor. The development of smart dust implies that sensors are getting smaller, but the creation of a network of sensors means that they are also getting smarter. The next stage for the sensor is the webbed sensor network. A web of sensors can enhance the ability of sensors to act independently, and can lead the way in enhanced web networking to create a sensitive and responsive Internet of Things.

An early prototype of an internet of sensors has been realized by the "Sensor Web" project, developed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) in 1997. Unlike wireless sensor networks (in which numerous sensors collect data from the external environment and

forward it for analysis and decision-making by a human or computer), the Sensor Web shares collected data throughout the network, and uses “embedded intelligence” to act directly on detected changes. A sensor web is a “distributed network, implying that all collected data is shared with other pods (units of the sensor web) across the entire network. Intelligence embedded in the network operating system means that it can be left to operate without the need to communicate with any end user or control system”.⁷⁸

Box 2.11: Better winemaking

Sensor networks for grapes

In Australian winemaking, wireless sensor networks developed by Motorola Australia and the Cooperative Research Centre (CRC) for microelectronics help save water, choose the right location for grapes and fight *botrytis cinerea* fungus, a plant infection which ravages grapes. They fulfill these tasks by measuring moisture, light, humidity, temperature, wind speed and direction. Data about these parameters are collected by 4-millimetre motes distributed over the vineyards and are then relayed through mobile networks to command software, which processes all the information and takes an appropriate decisions, e.g. whether to alert the owner to take action and water the grapes.



Image Source: California Association of Winegrape Growers

Source: The Guardian, “Life: Stop the rot: Could microelectronics save vineyards from a devastating fungus”, 1 July 2001

Although NASA initially intended to apply this technology to monitoring planets other than Earth, the sensor web concept has found more down-to-earth applications. The technology has been tested in the Huntington Botanical Gardens of Southern California, in the deserts of New Mexico, in the river basins of Arizona, and even in Antarctica (Box 2.12). In the Huntington Gardens, sensors were installed to measure light, air temperature, humidity, soil temperature and soil moisture. The Sensor Web ensured that watering (both from sprinklers and rainfall) was uniform in various areas of the garden.

2.3.3 RFID and sensors

The progressive combination of communication technologies and microelectronics gradually removes boundaries between physical objects and the virtual networked world. The main function of an RFID tag is to identify an object and to track the location of a labelled product rapidly and accurately, i.e. to answer questions “what, which and where?” Sensor technology provides information about the external environment and circumstances surrounding an object, thereby answering the question: “how?” Typically, remote sensors are attached to stable ground in a pre-determined position. People receive information about the physical parameters surrounding an object in a specific place. The integration of wireless sensing technologies with RFID tags on moving objects provides a fuller picture about their location and status.

Box 2.12: Sensors even in Antarctica?

Sensor Web deployments in severe environmental conditions

In their quest for life on Mars, scientists from the NASA/JPL Sensor Web project have deployed a sensor web consisting of 14 pods in the MacAlpine Hills in Antarctica. This Sensor Web, distributed over an area of more than 2 square kilometres, collects and relays data on air temperature, humidity and light every five minutes.



The extreme environmental conditions in this cold, dry and windy climate are considered analogous to those on the Martian surface. In such a hostile environment, it is very difficult to detect signs of extant life, as energy and nutrition supply are short and micro-organisms bloom very quickly and hibernate again. In this situation, sensors are a significant aid to scientists in “allowing a continuous virtual presence for instant recognition of favourable conditions” for such brief blooms. The deployment of the Sensor Web in Antarctica has proved the robustness of the system and its ability to monitor rapid changes in the microclimate.

Image Source: United States National Oceanic and Atmospheric Administration

Source: RFID Journal, “NASA Creates Thinking RF Sensors”, 4 October 2004. See also information on “Sensorwebs” available at <http://sensorwebs.jpl.nasa.gov/>

The main distinguishing feature of an RFID sensor tag from a normal RFID tag is that, apart from tracking and monitoring functions, sensor-enabled RFID can function on the basis of data collected by the sensor. As such, it communicates information about momentous events and changes in physical conditions, and can take action (e.g. activate an alert).

These two technologies, in combination with modern wireless networks, create opportunities for a myriad of applications in national security, military field, agriculture, medicine, retail, food industry and many other sectors of the economy. RFID sensing applications⁷⁹ include: monitoring of physical parameters (temperature, pressure, humidity, motion, sounds); non-invasive monitoring (extremely important in medicine); and controlling the integrity of an object (e.g. tamper detection and the detection of harmful agents, such as bacterial contamination). It seems that the spread of RFID sensor technologies in the food industry is inevitable, especially in light of stricter legislation on food quality adopted recently in some countries (e.g. the EU General Food Law mentioned earlier).⁸⁰ The tracking of food using sensors for temperature and meat quality has been widely used from Namibia to the Republic of Korea.

The integration of RFID and wireless sensor technologies can turn science fiction into reality: from monitoring the tyres on your car (Box 2.13), to creating “thinking” spectacles⁸¹ that can remind forgetful elderly or blind people to make a turn on the correct street. Forget-me-not bags, designed by scientists at the Massachusetts Institute of Technology’s Media Lab, remind owners if they have forgotten their keys or their umbrella if it is raining outside (Box 2.14).

Box 2.13: Rolling around on sensors

RFID sensors in tyres

RFID sensors have found new areas of application in automotive industry. RFID sensors are used for measuring the pressure in vehicle tyres and warning drivers if tyre parameters are at dangerous levels. RFID sensor systems transmit regular measurements of temperature and pressure, which are displayed on the dashboard, or through warning lights or digital readouts. Texas Instruments, Crosslink, and Philips Semiconductors have already released RFID sensors for monitoring tyre pressure.



As is the case with food safety, governments are also creating favourable conditions for further development of road safety mechanisms. On 1 November 2000, the United States Congress passed the Transportation Recall Enhancement, Accountability and Documentation Act. One of the requirements of the Act is the need for new vehicles from 2004 onwards to install a system that “warns the operator when a tyre is significantly under inflated”. According to analysts, the global vehicle OEM market for direct tyre pressure monitoring will reach 15 million systems by 2006, growing to over 22 million systems by 2010⁸².

Image Source: West Palm Hyundai

Source: *RFID Journal*, “Chip To Monitor Tire Pressure”, 17 October 2002, available at <http://www.rfidjournal.com/>

The main technical challenges for RFID sensors are their limited processing speed, storage capacity and communication bandwidth. The effective processing and filtering of relevant information also needs to be addressed, as it might be costly to transmit the high volumes of data collected by sensors. In order to overcome these technical challenges, new hardware and software solutions are required, as is cost reduction. At present, there are commercial models which cost from USD 50 to 100 per single mote. According to Intel’s forecasts, as the processing power of chips doubles approximately every 18 months (in line with the well-known Moore’s law), the price of a sensor will drop to USD 5 cents each.⁸³

2.3.4 Sensors and mobile phones

Mobile phones are already an integral part of everyday life for many people. Due to their widespread use, mobile networks play a key role in bringing new “ubiquitous” communication technologies to the masses. Today, mobile phones are not only simple devices for making calls, but they come equipped with data, text

and video streaming functions. The mobile phone is no longer a stranger to sensor technologies. Currently, the combination of sensors with mobile phones offers several possible applications:

- The mobile phone could act as an **intermediary device** for relaying data collected by sensors onwards to the final destination (for example, in the case of telemedicine systems).
- Sensors could **enhance the phone's functions** through biometric- security (for example, fingerprints or face recognition sensors) or touch screen sensors.
- Sensors built into mobile phones can enable **interactive communication**, e.g. with a sense of touch⁸⁴, built-in projectors (Box 2.15), or 3-dimensional movement recognition.⁸⁵
- Mobile phones can **sense the status** of their environment through smoke alarm mobiles⁸⁶ or smell sensors.⁸⁷

Box 2.14: Build your own smart purse!

RFID sensors for the forgetful



MIT Media Lab has designed a build-your-own bag for people who tend to forget keys, mobile phone etc. when leaving home. The bag is made from computerized fabric patches with the radio receiver and antenna, which communicate through signals from RFID tags attached to a mobile phone, a key ring or a wallet.

A sensor built in the bag's handle will detect the moment when it is picked up, indicating that the owner is about to leave and will check the content of the bag and confirm whether the owner has put all the tagged things into the bag or not. If one of the things is missing, the sensor triggers the voice synthesizer, which will announce: "Mobile phone: yes. Wallet: Yes. Keys: No".

Owners can customize the bag adding other functions, for instance, through an option to remind their owners to take an umbrella. The bag downloads weather reports from the internet via Bluetooth. The system will alert the owner to take an umbrella when rain is forecast.

Image Source: MIT Media Lab

Sources: Science Box, @materials, "Smart Fabrics make for enhanced living", 23 October 2004, at <http://science.box.sk/>; MIT Media Lab at <http://science.box.sk/>

Today, with the development of mobile internet and mobile commerce service, users can buy theatre tickets, make hotel reservations, and access bank accounts through their mobile phones. Mobile phones are now a significant source of personal information, such as phone numbers, calendar, photos, messages, passwords and so on. Meanwhile, traditional methods of privacy and data protection, such as Personal Identification Numbers (PINs) and passwords, have become less feasible, convenient and secure. Biometric sensor technologies, including fingerprint or face recognition, offer one possible solution.

In the Republic of Korea, where 75 per cent of the highly tech-savvy population use mobile banking services, security features are indispensable. Recently, LG Electronics released a mobile phone with a fingerprint sensor.⁸⁸ The sensor-enabled phone provides advanced security features to its users. It is located below the display and authenticates the user with a single touch. Japan's NTT DoCoMo released a similar handset (the Fujitsu F505i) with a personal identification system based on fingerprint sensors.

Fingerprints can also be used for age verification to allow access to adult content, gaming applications and chat room access⁸⁹, and grant the right to operate the computer mouse. According to some analysts, the fingerprint sensor market will become the fastest-growing segment of the mobile phone industry.⁹⁰ While Asian companies have already started exploring this market, the release of fingerprint sensor phones in Europe is not expected before the end of 2005.

Fingers are not the only parts of the body that can help prove a user's identity. The "Okay Vision Face Recognition Sensor", developed by the Japanese Omron Corporation, can identify a user by using the phone's camera to take a picture for comparison with the one stored in memory. If there is a match, the handset is unlocked. Compared to fingerprint sensors, facial scanning is less obtrusive, but also less accurate.⁹¹ Eyeglasses and changes in hairstyle influence the accuracy of results. Fingerprint sensing remains accurate over the longer term as well, since the face is bound to change with age⁹².

Box 2.15: Mobile projects

Sensor projector in-built into a mobile phone



At the 2005 CeBIT exhibition held in Hannover, Germany, Siemens demonstrated an experimental model of a mobile phone with a built-in projector. The phone's interior system displays a keypad, presentation or other images on a surface in front of the phone or on a wall. Developers say that the phone can be used for presentations and slideshows for small groups.

Sophisticated sensor technologies combining ultrasound and infrared technologies enable a virtual pen to write using the projected keypad. Signals from the pen are transmitted to the phone through Bluetooth. While a user "types" on the projected keyboard, sensor technology identifies the position of the pen in real time to compose the message. This special pen also has a microphone and speaker, so it also can be used for conversations.

Image Source: Siemens

Source: Siemens, CeBIT 2005, "Siemens Study: Cell Phone with Built-in Projector" at <http://www.siemens.com/>

The capabilities of mobile phone sensors can be extended further still. Mobile phones already have ears, and with the integration of cameras, they now have eyes. Soon, they may also have olfactory capabilities. Researchers from Siemens' laboratory have recently developed a "sniffing" mobile phone.⁹² Tiny sensors inside the mobile phone will give an electronic signal on detecting bad or food-scented breath and other gases. The embedded nanotechnology responds to chemical reactions in the atmosphere. According to its developers, the main target group are beer-drinkers, who may have bad breath, or may not be in a position to drive. Other target groups include asthmatics who can be alerted to an impending attack and cyclists or joggers concerned about the level of ozone. Such a phone could also serve as an always-on smoke detector or fire alarm.

2.4 Thinking things: Smart technologies

Information technologies are getting smarter by the day. In the near future, users may be able to send a message to a friend by typing something on their sleeve, or their purse may remind them not to leave their keys in the house. In fact, keys may soon be a thing of the past, if biometric recognition sensors in smart homes replace them. Current definitions of "smart" are very broad. Any conventional material or thing that can react to external stimuli may be called a "smart thing". In other words, not only are our devices, such as PDAs and mobile phones, getting "smarter", but so too are the clothes we wear, the containers we use and the houses we live in. This section examines some of the most interesting developments in this area.

2.4.1 Smart materials

For some time, human beings have been developing specialized materials that respond to changing conditions. The first prototype of a "smart material" was arguably the electric blanket.⁹³ Although its invention dates back to the 1900s, it gained popularity in the 1920s, as it was prescribed by doctors for tuberculosis patients who needed to breathe fresh air while staying warm. In 1936, high-tech blankets were introduced with features such as automatic activation depending on the ambient temperature. However, at that time, the blankets were still bulky, inconvenient and sometimes even dangerous to use.

The idea of embedding additional computer functionality into everyday things has evolved, and significant progress has been made over the last decade. While light switches in the form of pompoms are exhibited in museums under the banner of extreme textiles⁹⁴, MP3 snowboarding jackets are already on the market (Box 2.17), as are flexible keyboards made of fabric (Box 2.16).

Smart materials incorporate sensors and actuators, as they sense stimuli and respond accordingly. Currently, there are three main kinds of smart materials⁹⁵:

- "Passive" smart materials that respond directly and uniformly to stimuli without processing any of the signal;

- “Active” smart materials that can, with a remote controller, sense a signal and determine how to respond; and
- “Autonomous” smart materials that carry fully integrated controllers, sensors and actuators.

For some, the development of smart fabrics is the aesthetic transformation of technology: from plastic boxes into soft tactile textiles.⁹⁶ Building artificial intelligence features into everyday fabric or ordinary jackets is similar to breathing life into inanimate things – the combination of sensing and actuating “mimics two of the [seven] functions of a living system: awareness of surroundings and a useful response, usually in the form of motion”⁹⁷.

Technologies that are seamlessly embedded in clothing, fabrics or domestic appliances will become less and less visible to the naked eye. For example, scientists at Infineon Technologies have developed smart fabrics with an integrated sensor network that consist of a weave of conductive fibres studded with sensor chips and Light-Emitting Diodes (LEDs). The embedded sensors can measure temperature, vibration, motion and pressure, making even carpets smart.

Such fabrics have many potential applications, ranging from carpets for motion or fire detection to structural health monitoring. If tiny LEDs can be embedded, smart carpets can display directions in a public building (e.g. to an emergency exit). Further potential applications arise in the construction industry. Smart fabric wrapped around columns or laid on the floor can give early warning signals about faults in the concrete, while pressure sensors can detect motion and can be used, for example, to track human footsteps.

Applications for smart textiles are limited only by human imagination. At present, the most developed applications are in aeronautics, national security, automotives, healthcare, design and construction. Different technologies are involved in the creation of intelligent materials, including ceramics, photonics, microsensors, biomimetics⁹⁸, nanotechnology, biotechnology and information processing.⁹⁹ The main technical challenges posed by smart materials are their reliability, performance and life-cycle maintenance cost.

Box 2.16: Softer things for home entertainment

Smart materials in consumer electronics

The company SoftSwitch has developed a touch-sensitive fabric. This electronic material operates on the basis of changes in its electrical state. In its normal condition, SoftSwitch fabric acts as an insulator, but when pressure is applied, it becomes a metal-like conductor. Possible applications include flexible keyboards, fabric remote controls integrated into soft furnishings and clothing with the ability to control audio systems. Softswitch fabrics are washable, durable and capable of operating in extreme environments.



Flexible keypad



Remote control

Image Source: Softswitch

Source: Softswitch at <http://www.softswitch.com>

2.4.2 Smart clothing and wearable computing

The next step forward from smart textiles involves the tailoring of truly smart clothing, with one important implication. Clothing has always been personal, but at the same time passive. It is worn everyday and everywhere, and must typically be washable, durable, comfortable and worn in close proximity to the body. As fashion and technology converge, technology must also acquire all of these characteristics.

There is no clear boundary between smart clothing and wearable computing, although the following distinction may be drawn: in smart clothing, fabric remains the basic element. Optical fibres or fibres than can conduct electricity can be woven between regular threads of fabric. In this way, regular fabric becomes smart, from which smart clothing, such as an MP3 jacket, can be made (Box 2.17).

Box 2.17: Just wear and listen

MP3 Electronic Jackets



The recent collaboration between Burton Snowboards, a company which offers a full range of snowboard equipment and accessories, and Apple, the producer of the iPod, resulted in the limited release of what they claim to be the first electronic jacket with an integrated panel for controlling an iPod. Snowboarders and other active users control their music by touching the flexible control pad (developed by SoftSwitch) on the sleeve of the jacket, while the iPod is held safely in the inner pocket of the jacket.¹⁰⁰ The initial price of the jacket was quoted as USD 499, and the iPod is for course sold separately.

Infineon Technologies AG and German clothing manufacturer Rosner developed a MP3 Bluetooth telephone jacket that, besides controlling an MP3 player, allows the placing of calls through a control pad on your sleeve. The mobile phone and control pad are connected via Bluetooth, and the music system operates as a headset when telephone calls are made.¹⁰¹

Image Source: Softswitch

Source: Apple, Press Release, "Burton and Apple Deliver the Burton Amp Jacket", 7 January 2003, at <http://www.apple.com/pr/library/2003/jan/07burtonipod.html>

By contrast, in the case of wearable computing, computing elements are the basis of the transformation. By miniaturizing size, decreasing weight and adding features such as durability or laundry-compliance, computers can be transformed into wearable computers. Wearable computing can be seen as "the result of a design philosophy that integrates embedded computation and sensing into everyday life to give users continuous access to the capabilities of personal computing".¹⁰² Wearable computers could also make use of smart fabrics, incorporating Global Positioning System (GPS), radio frequency and pressure detectors, temperature and shock sensors (Box 2.18).

Wearable computer hardware typically meets the following criteria¹⁰³:

- The hardware should contain a microprocessor;
- The device should operate using software;
- The device is usually worn or supported on the body to enable hands-free computing; and
- Ideally, the computer should always be accessible and ready to interact with its wearer, through a wireline and/or wireless communication network;

The notion of wearable computing implies situational or context awareness, as discussed above. Based on information about the external environment, the wearable computer is able to respond or take certain decisions such as adjusting to changes in temperature.

Box 2.18: A shirt that makes sense

Wearable computing in healthcare

The Georgia Institute of Technology's School of Textile, together with Fiber Engineering funded by the US Defense Advanced Research Projects Agency (DARPA), have developed smart T-shirts that monitor the heart rate, respiration rate and electrocardiographic pulses of wearers and track their movements. Optical fibres and electrically conductive thread are integrated into the fabric to cover the whole T-shirt with a sensor network. The data collected by sensors are analysed and transmitted to satellites. Wearers can be connected to the internet or to their employer's intranet, so that when a computer chip is plugged into the shirt's network, the employer can track the movements of wearers. This smart sensor application has military uses in fire fighting, where it can be combined with the Global Positioning System (GPS) to help identify the location of fire fighters.¹⁰⁴

Other companies working on smart T-shirts include Sensatex corporation, which has developed a shirt equipped with sensors to measure body parameters such as temperature, respiration rate, pulse and cardiogram and transmit the data through the mobile network to base stations. The information can be forwarded to other devices like a watch, mobile phone or PDA. Application possibilities for this product include the supervision of training squads in serious sport, or in the military, as well as the monitoring of chronically ill patients (e.g. heart attack patients or patients fitted with pacemakers). The intelligent T-shirt can help lessen the constraints on the patient's quality of life. Further benefits include improved mobility for the patient, without affecting emergency response times of ambulance crews, should the patient suffer another attack. The automatic survey of the body's functions also reduces the number of consultations and hospitalizations.

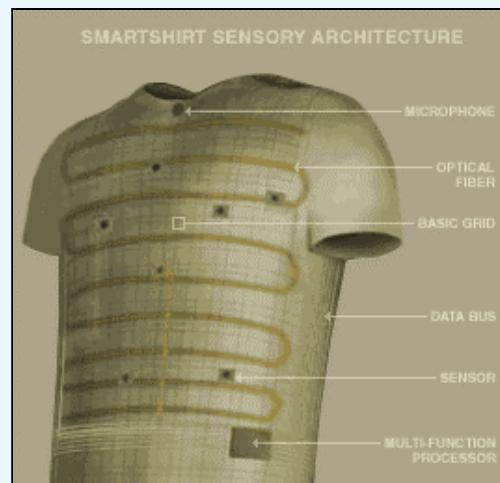


Image Source: Sensatex

Sources: ITU, "Ubiquitous Network Societies: Their Impact on the Telecommunication Industry", April 2005; SmartMobs at <http://www.SmartMobs.com/>;¹⁰⁵ Sensatex at <http://www.sensatex.com>

Some items can combine elements of both wearable computers and smart clothing. Eyeglasses are a good illustration. In late 2005, Orange SA (the wireless subsidiary of France Telecom) plans to launch a mobile video service that will enable subscribers to watch video and access broadband internet content through video eyewear. Users will see large-sized images through a 30-centimetre display (as seen from approximately one metre distance). With two micro-displays, the glasses allow for 5 hours of video and weigh only 70 grams (including three AAA batteries). While wearing the gadget, users can continue walking around easily, as the frame allows them to see around the screen.

The social significance of smart clothing and wearable computers is that they could create intimate, responsive, interactive environments, enabling close human-to-machine interaction. Such closeness goes far beyond the simple proximity of the body to a device. The body itself could be used as a part of networking devices. This idea is at the heart of the concepts of the Personal Area Network (PAN), the Body Area Network (BAN) or the Human Area Network (HAN). However, there are no clearly defined distinctions between these. Some experts consider BAN as a technology for the permanent monitoring of the health status of patients with chronic or heart diseases.¹⁰⁶ Applications in telemedicine such as the smart T-shirt fall into this category (Box 2.18). Others describe a BAN or a HAN as a network that "handles communications between devices using the human body as a medium"¹⁰⁷ (Box 2.19).

2.4.3 Smart homes

In an environment where computing is increasingly ambient, scientists and developers are now turning to the houses in which we live. The smart home of the future might include some of the following features:

- An automated coffee machine, that knows when you have woken up in the morning and motion-sensitive mood lighting;
- Remote voice control that will allow you to switch on and off all home appliances;
- A washing machine that talks to you and updates you about the progress of your laundry;

- A smart toilet that can test urine and send data to your doctor over a wireless network if there is something wrong; and
- Electronic wallpaper that can act as a display.

Box 2.19: The body as a thing in the network

Human Area Networks



In 2005, scientists from the Republic of Korea's Electronics and Telecommunications Research Institute (ETRI) developed a Digital Human Body Communication system. The underlying idea is that if someone wears a watch, has a personal digital assistant and carries a laptop, then potentially, s/he could have as many as three displays, two keyboards, two speakers, two microphones, and one communication device.

If all these separate devices could network through wireless networks, they could share input or output components. This Human Area Network uses the human body as a medium, and allows the transmission of small amounts of data (such as the information on a business card, for example) through simple body contact, such as a handshake. The current data speed is only 2.4 kbit/s, but it is expected to rise to 1 megabyte within a year. Although feasible applications have not yet been developed, possible future applications include: touch-based authentication services, electronic payment, e-business card services and touch-based advertising.

ETRI is not the first to make the transmission of signals through the human body possible. At a Comdex Trade show held in 1996, MIT Media Lab and IBM demonstrated the exchange of business card information through a handshake. Microsoft was awarded a patent for a “method and apparatus for transmitting power and data using the human body” in June 2004.¹⁰⁸ NTT DoCoMo exploits the same principles of human area networking in its product RedTacon.¹⁰⁹

Image Source: Telecoms Korea

Source: Electronics and Telecommunications Research Institute (ETRI)

Recognizing that the kitchen is usually the most frequently used room, scientists are using their imagination to develop new appliances such as:

- An intelligent oven that can be controlled through the internet or phone (Box 2.20);
- An internet refrigerator, that can place orders online, if the user runs out of certain products;
- An air cleaner that can detect impurities and odours, and takes appropriate action to purify the air.

Box 2.20: Hungry? Give your oven a call!

Intelligent cooking

TMIO, a US-based technology company, recently released the Connect Io Intelligent Oven, which can be controlled remotely. You can command the oven via the internet or a mobile phone to cook dinner by the time you get back home. Before leaving home, you place food in the oven and set the oven to the “refrigeration” option. The food stays cool until cooking begins. You can also set a timer, and the oven will cook the food by preset time. If later you find out that you cannot make it home by the set time, you can reset the oven over the internet or make a call either through a land-line or mobile phone, to adjust your instructions accordingly.

Salton Inc. (Beyond™) is another company keen on making everyday life as convenient as possible. The wide range of products that it offers includes a smart microwave oven that can scan barcodes on products, examine cooking instructions and program itself, a smart coffee-brewer and a smart bread making machine.



Image Source: Tony Kubat Photography for Lund Food Holdings

Sources: Salton Inc. and TMIO

Networking and computing intelligence are penetrating into every corner of the home, from lighting, audio and video systems to security and kitchen appliances. The smart home is not just a collection of smart things, sensors and actuators, but an interconnected network of things, enabling voice or data-activated control from anywhere – through voicemail systems, internet, GPRS, SMS, mobile or fixed-line telephones from outside the home. Some of the diverse applications made possible through smart home technologies are illustrated in Figure 2.4. Communication technologies such as ZigBee and Bluetooth create even greater opportunities for a smarter home networking environment (Box 2.21).

Figure 2.4: Smart people, smart home

Technology for intelligent living



Sources: ITU, adapted from Line9

Already, many concrete projects are under way that build on the idea of saturating our surrounding space with all types of computing devices: the “Smart Room” developed by MIT Media Lab, Hewlett Packard’s CoolTown, IBM’s BluesSpace, the University of California’s Smart Kindergarten or Microsoft’s Home of the Future, to name but a few. According to estimates, the global intelligent home industry totalled roughly USD 48 billion in 2003, and is expected to reach USD 102.6 billion in 2007 and USD 162.0 billion by 2012.¹¹⁰ One of the main hurdles to the development of this industry is the lack of interoperable standards in both hardware and software. Security is another important issue, since once smart things are connected, the network vulnerability of the entire system increases.

2.4.4 Smart vehicles

Due to recent technological advances in computing and telecommunications, the perception of the vehicle is also changing. Automobiles today represent not only safe and comfortable means for travelling from one place to another, but also digital platforms for entertainment and access to information far beyond the travelling experience. The concept of the “smart car” is beginning to take off. The key technologies behind the smart vehicle have become known as “telematics”.

Automotive telematics is the blending of computers and telecommunications to enhance motor vehicles and provide convenient online services to road users through always-on connectivity. Current services available in smart cars include the following: emergency and roadside assistance, stolen vehicle tracking, remote door unlocking, driving directions, remote automobile diagnostics, online concierge,

hands-free calling, as well as e-mail and internet browsing. Smart vehicle technologies are a blend of smart materials and structures, innovative sensors, and intelligent flow control strategies, including sonic boom mitigation technologies, revolutionary propulsion ideas, and biology-related concepts.

Box 2.21: Get your house on the phone...

Standards in sensor networking for smart home environments

A number of mobile phone manufacturers are working on integrating ZigBee and Bluetooth together in a single mobile phone. If this is achieved, almost everything in the home could be controlled over a mobile phone.

ZigBee and Bluetooth both operate in 2.4 GHz unlicensed frequency spectrum. ZigBee is a short-range wireless technology (10-60 metres) with relatively low speed (20-250 kbit/s). ZigBee (based on IEEE 802.15.4) was specifically designed for remote control and monitoring in sensor networks. The advantages of the ZigBee standard can be applied in¹¹¹: home and building control, automation, security, consumer electronics, medical monitoring, toys, wireless lightening, HVAC (heat, ventilation and air control) systems. One of the most important benefits of ZigBee is its extremely long battery life (up to 5 years). This is due to the fact that the ZigBee transmitter remains in “sleep” mode, until it needs to pass any traffic. In contrast, Bluetooth needs frequent recharging.



Bluetooth (IEEE 802.15.1) represents a *de facto* standard with higher data transmission rates (of up to 1 Mbit/s) that connects different types of devices wirelessly: mobile phones and headsets, personal digital assistants, computers and printers. Bluetooth emphasizes user mobility and aims to eliminate short-distance cabling, while ZigBee focuses on grand-scale automation and remote control.¹¹²

Image Source: Nokia

Sources: ITU, “ITU Internet Reports 2004: The Portable Internet”, September 2004, at <http://www.itu.int/portableinternet>; Sensors Online, “Standard-based Wireless Networking Alternatives”, December 2003

Redefining the Automobile

The interconnected, responsive and context-aware smart vehicle of tomorrow has much to offer and will play an integral part in the larger network connecting users to their homes, workplaces and places of leisure. Cars that read street signs, communicate with other vehicles, take drivers around traffic jams, conduct remote diagnosis and even provide movies, music and instant communication like e-mail and internet are not as far off as one might think. Through automotive telematics, the car has become more than a simple means of transportation. Rather, it is developing into a “Digital Life Space”¹¹³, a term used by the Republic of Korea to describe its launch of the Jeju Telematic Model City Project in late 2004 (Box 2.22). Within this new digital life space, various activities can take place, including news watching, financial investment, shopping, and entertainment. The car of the future will become a home away from home, and a key enabler of a ubiquitous network society.¹¹⁴

Smart Cars for a Smart Society

Using a myriad of smart materials, sensors, and other information technology solutions, the smart vehicle could avoid accidents, assess its own status (Box 2.13), determine whether action needs to be taken, and if so, take it. It may even know how to escape to a safe haven in case of emergency. The intelligence involved in this sort of decision-making requires self-adaptability, self-sensing and memory.¹¹⁵

Smart cars increasingly need to communicate and connect with the outside world. Telematics solutions of the past have consisted of developing mobile communication and information solutions for the automotive industry based on GSM, GPS and internet technologies. The car of the future will build on these but also draw on expertise from other industries using sensors, RFID and robotics to connect the internal and external environments.

Box 2.22: Driving smarter Korean-style

Telematics transforms cars into digital life spaces



The launch of the Jeju Telematics Model City Project places the Republic of Korea among the leading countries in transforming vehicles into digital life spaces. The project was made possible due to a joint investment of 10 billion Korean won (around USD 10 million) by the Korean Ministry of Information and Communication (MIC), Jeju province, and the private sector. MIC is leading the telematics pilot project allowing Jeju visitors to test the new services. Since September 2004, the project has been promoting telematics in the free zone of Jeju, where it has been made available on rental cars.

The terminal installed in each of the rental cars consists of a 6.5-inch screen, 20-gigabyte storage capacity, wireless Local Area Network (LAN), and a cellular communication modem. SK Telecom, which has launched the telematics services, has also released a single type terminal that enables customers to attach folders. This will allow TV broadcasting and future satellite Digital Multimedia Broadcasting (DMB) services. Other ubiquitous services linked to telematics are also planned for Jeju Island.

The six specific telematics services to be implemented jointly by SK Telecom and Jeju Island are as follows:

- Customized travel and traffic information service offered by navigation via terminals;
- “Jeju Cultural Event” service that provides a variety of event schedules and tourism information on Jeju Island;
- “V-Shop” service that allows customers to order and make payments for special products on Jeju Island through a wireless LAN and cellular network;
- “Safe” service that connects customers to Jeju Island’s Fire Control Center in case of an emergency;
- “Leisure Life Information” service; and
- “Entertainment” service.

The goal, set by MIC, is to boost subscriptions for telematic services to 10 million users and to have in-car mobile office services available by 2007.

Image Source: Siemens

Source: Korea IT Times, “IT839 Strategy Judged Successful”, 10 March 2005, at <http://www.ittimes.co.kr/>

A number of RFID developers are beginning their work on a new generation of RFID products aimed at bringing greater safety and new wireless applications to vehicles. Dedicated Short-Range Communications (DSRC) technology systems (which many consider to be a subset of RFID systems as a whole) will deliver higher data rates and communication ranges to vehicles (i.e. 25 Mbit/s and 1 km, respectively). DSRC applications will mostly likely occupy the 5.9 GHz band, which is under discussion in a number of national markets (e.g. United States and Germany). The DSRC system differs from traditional RFID systems (such as those used for toll collection) in that it is a peer-to-peer system in which any link in the chain can initiate a transaction. Many DSRC applications will not involve roadside RFID readers, but vehicle-to-vehicle (tag-to-tag) communications.¹¹⁶

While revolutionary in a technical sense, the impact of telematics technologies on drivers and passengers are potentially even more dramatic. Consumers will soon demand the same computing flexibility in their vehicles as they have in their office and home, and this will require intelligent devices to be very mobile. In the same way that the smart office turns a journey into a productive session, shopping and working while driving can save time. The car’s interior is emerging as the next space for digital devices. From telematics to back-seat entertainment systems, the vehicle is fast becoming a mobile media centre on wheels, capable of managing content and information for entertainment, productivity, and safety. As emerging technologies gain ground in the automotive industry, video decoding for rear seat entertainment may become as important to consumers as audio compression and DVD playback are today. Still, this is only the beginning. More advanced telematics solutions and wearable personal mobility vehicles (Box 2.23) are being developed and tested. Industry stakeholders and policy-makers need to assess urgently how these new types of vehicles will alter market dynamics.

Box 2.23: Wearable personal mobility vehicles

Driving into the future



The Japanese car manufacturer Toyota is redefining the future of the car with its development of a new category of wearable single passenger robotic vehicles. According to a BBC article from December 2004, drivers will be able to steer around in “four-wheeled leaf-like devices or stroll along enwrapped in an egg-shaped cocoon that walks upright on two feet” – models that are called “personal mobility vehicles”.

The “i-unit” vehicle, shown in the photo, is equipped with Intelligent Transport System (ITS) technologies that allow safe autopilot driving and tight on-the-spot turns. They can move upright amidst pedestrians at low speeds and can be switched into a reclining position at higher speeds. The “i-foot” is a two-legged robot-like device that can be controlled with a joystick. In order for “i-vehicles” to communicate with other vehicles and share information with other devices, the car is equipped with a high-tech visual communication system. A travel destination can be programmed into a vehicle’s navigation system using the floating virtual display (which senses the drivers’ finger positions, as well as showing vehicle data, the locations of other cars, etc.). Other drivers can automatically share this information and follow the lead vehicle. The vehicle can also communicate different emotions using colours on its body panels, lights and rear wheels.

A host of potential applications are being found for these new vehicles. However, for Toyota’s prototypes to really take off, the behavioural patterns of drivers and the usability of the built-in technologies will need to evolve. These are the main challenges for the smart vehicle.

Image Source: Toyota

Sources: BBC News, “Robotic pods take on car design”, 10 December 2004, available at <http://news.bbc.co.uk/>; various articles from the Toyota Europe website, June 2005, at http://www.toyota-europe.com/design/concept_cars/pm/

2.4.5 Robotics

Automation is one of the key elements in the creation of a smarter world. Robots will be an integral part of such an environment. Our perception of robotics has been largely shaped by such Hollywood movies as “Bicentennial Man” and “Star Trek”, but also by darker narratives such as “Terminator”. In many examples, robots have symbolized the evil of the industrialized world and a threat to human well-being, thereby overshadowing the positive impact they might have in enhancing the quality of human lives.

It is difficult to give a precise definition of a robot. The term robot was coined by the great Czech author and playwright, Karel Čapek, in his play, “Rossum’s Universal Robots”, in 1920. In 1950, the American science-fiction writer Isaac Asimov introduced the word “robotics” (the science and study of robots or the industry for the production of robots) in his book “I, Robot”, a collection of short stories published in 1950. In general, a robot can be defined as an automated machine or a mechanical device, that “replaces human effort”¹¹⁸, and which may, in some cases, mimic human or animal behaviour or appearance. Despite our common perception of a robot as a mechanical creature that resembles a human being and imitates his/her behaviour (a humanoid version), robots come in a wide variety of shapes and sizes. In general, robots can be classified into three groups¹¹⁹: industrial robots, service robots and personal robots.

The first industrial robot was manufactured in the middle of the last century by Joseph Engelberger and George C. Devol, considered to be the fathers of industrial robotics. Their first robot was bought by General Motors and its main function was to extract hot parts from die casting machines.¹²⁰ Since that time, little has changed in the nature of the tasks that robots undertake. These “steel-collar workers”¹²¹ are mainly used for automated, repetitive and monotonous tasks. It can be said that they represent a class of “factory floor workers”, whose main functions include assembly-line production, spot welding, painting, grinding surfaces, material handling or removal etc. At present, industrial robotics is made up of “immobile, single task robots that have little interaction with humans or the world around them”.¹²²

The natural evolution of industrial robots has led to a growing segment of service robots. Service robots operate in areas, where tasks may be:

- Dangerous or risky, e.g. bomb-retrieval police robots, repairing robots for submarine cables or space stations, robots for mapping mine shafts;¹²³

- Physically challenging for a human being, e.g. materials removal or heavy lifting;
- In need of high precision, e.g. medical robots involved in surgery operations (for instance, operations where instruments have to move at precisely the same rate as the heart beat)¹²³;
- Difficult or impossible for human beings to have access, e.g. Martian rovers or the international space station;
- Repetitive and monotonous, e.g. robots for industrial cleaning and maintenance of equipment.

Recently, the world's smallest controllable robot was invented by research scientists at Dartmouth College in collaboration with colleagues in other universities. Two hundred of these robots can fit on the top of a regular M&Ms candy. The future possible areas of applications include ensuring information security – assisting with network authentication and authorization. Such robots can also explore hazardous environments or be used in biotechnology, e.g. for the manipulation of cells or tissues¹²⁴.

The industrial or manufacturing robotics segment is a well-established market. However, the personal robotics market is expected to experience the highest growth rates (see Chapter 3) in the short term. Personal robots are used in automated home appliances, home security, entertainment and the care of the elderly or people with disabilities (Box 2.24). One of the most popular and feasible applications for personal robots is the cleaning robot "Roomba", which can recharge itself and navigate the house independently.¹²⁵ Household personal robots of today can carry out many tasks, like mowing the lawn or collecting garbage.

Box 2.24: A robotic handshake

Rubbing shoulders with the world's leaders

Many analysts predict that the personal robotics market will experience significant growth. One of the important drivers of this growth will be the fast-evolving field of humanoid robotics, which are set to revolutionize the world we live in.

The humanoid robot ASIMO (Advanced Step in Innovation Mobility), developed by Honda, became the face of humanoid robotics during a 2003 trade mission to the Czech Republic, where he shook hands with leaders. The 120-centimetre robot has flexible arms and knees. It can not only talk and walk, but also runs smoothly at 3 km/h and does some simple dances. ASIMO is the only humanoid robot in the world that can climb stairs – a big breakthrough in humanoid robotics, as it requires a good sense of balance.¹²⁶

ASIMO was part of the Japanese delegation during the official visit of the Japanese Prime Minister Junichiro Koizumi to the Czech Republic and delivered a short speech in Czech stating: "I have arrived in the Czech Republic, where the word 'robot' was born, together with Prime Minister Koizumi as a Japanese envoy of goodwill."

Sources: BBC News, Japan Robotic Association

One of the biggest segments of the entertainment robot market is toys. Sony has already introduced a fully automated puppy robot by the name of "Aibo". In 2006, IZI Robotics will release a puppy robot that will be able to download content from the internet.¹²⁷ Robots developed by Toyota can play musical instruments using artificial hands and lips. It is hoped that integrating educational functions into toys will boost the popularity of personal entertainment robots.

Tea-serving and waiter robots can take care of elderly people or people with disabilities.¹²⁸ The metre-tall robot "Wakamaru"¹²⁹ developed by Mitsubishi looks after elderly people, reminding them to take their medicines, and also allows monitoring of the house over the internet. If it detects a problem, it immediately alerts the emergency services. The robot "PaPeRo", produced by the NEC Corporation, can play and interact with children and acts as a robotic babysitter. It can dance and utter up to 3'000 phrases. It also responds when touched on the head. Equipped with an internet connection, it can send emergency messages to mobile handsets or PCs of a child's parents.¹³⁰

Robots equipped with sensors enabling them to sense and respond to stimuli will increasingly integrate into the networked world. Robotics introduces a greater degree of automation into everyday life, and will play a key role in the dawn of machine-to-machine interaction, in which data collected from the environment are forwarded to central processing points, in order for decisions to be taken with a minimum of human

intervention. The robots of the future will recognize voice commands and be able to fetch a glass of juice or sake (Japanese liquor) from an RFID-enabled fridge full of tagged items.

Development in personal robotics will also change the nature of human-to-machine interaction. Robots will not only be assistants, but also friends and companions. Tamagotchi, a Japanese-invented virtual pet, was the early sign of treating a computer as a living creature. Scientists have already invented a kind of human-like sensitive artificial skin for robots¹³¹, making robots smile more like humans¹³², and teaching them to communicate and learn from each other.¹³³ In the future, robots, like mobile phones, may become commonplace in our daily lives.

2.5 Shrinking things: Nanotechnology

2.5.1 Defining nanotech

Defining nanotechnology is not easy. The concept of technology invisible to the naked eye, and indeed even to an electron microscope, is impossibly broad. For this reason, it is plagued with notions of both apocalyptic invasions and scientific discoveries to cure every human ailment. Eric Drexler articulated one of the original and more radical visions of nanotechnology¹³⁴ in his 1986 *Engines of Creation*. The founder of the Foresight Institute of California painted a picture of multiple molecular machines capable of replicating themselves and controlled by tiny computers (i.e. “nanobots” or “grey goo”).

Both radical visions (as above) and incremental visions of nanotechnology exist. Radical nanotechnology, in Drexler’s vision, involves the use of hard materials, such as diamond, to fabricate complex structures on a nano-scale, by mechanically moving molecular fragments into position.¹³⁵ Incremental nanotechnology, on the other hand, is a near-market development, which, in a general sense, refers to any development allowing the manipulation of matter at the sub-atomic or molecular levels, i.e. 1-100 nanometres (one nanometre is one billionth of a metre).

It is also useful to distinguish between nanoscience and nanotechnology, also known as nanotech. Nanoscience is in the advanced stages of development, whereas it is still early days for nanotechnology.¹³⁶ Nanoscience deals with “the manipulation and characterization of matter on length scales between the molecular and micron size”. Nanotechnology, by contrast, is an “emerging engineering discipline that applies methods from nanoscience to create products”.¹³⁷ In other words, nanotechnology focuses on the design, characterization, production and application of structures, devices through the manipulation and characterization of matter at the nanoscale.¹³⁸

2.5.2 Applying nanotech

Nanotechnology involves the convergence of basic science and applied disciplines, and will consequently affect a wide range of sectors. Science at the nanoscale level has enjoyed a significant boost from developments in microscopy: notably, electron, scan tunnelling and atomic force microscopes, among others. Today, materials of a nanoscale are being exploited in spacecraft design, computer disks, stain-resistant fabrics, surgical products and cosmetics, among others. Scientists are looking to nanotechnology for new applications in the area of pollutant control and healthcare. Investment in nanotechnology is on the rise around the world. In the United States, for instance, the National Nanotechnology Initiative¹³⁹ was established in 2001 to coordinate and finance national innovation in nanotechnology, and received approximately USD 864 million for 2004, up 10 per cent on the previous year.¹⁴⁰ According to the United States’ National Science Federation (NSF), almost all industrialized countries have been active in nanotechnology since 2001.¹⁴¹ Between 1997 and 2002, the leading countries have increased spending on R&D in this area six-fold (Table 2.2). Together with national research funding, Europe will be allocating more than USD 1 billion annually to these technologies – a figure that is eight times higher than in 1997.

Technical areas ripe for nanotechnology include (Figure 2.5):

- Materials with properties such as in-built chemical sensing or optical switching;
- Medical developments, such as improved drug and gene therapy, biocompatible materials for implants and sensors for disease detection;

- Environmental benefits, such as water purification, artificial photosynthesis of clean energy and pollution control systems;
- Information technologies, such as quantum computing and computer chips that store trillions of bits of information on a device as small as the head of a pin.¹⁴²

Table 2.2: Estimated and projected government R&D investment in nanotech, 1997-2005 (USD millions)

Region	1997	1998	1999	2000	2001	2002	2003	2004	2005
EU	126	151	179	200	~225	~400	~650	~950	~1'050
Japan	120	135	157	245	~465	~720	~800	~900	~950
United States	116	190	255	270	~465	~697	~862	~989	~1'081
Others	70	83	96	110	~380	~550	~800	~900	~1'000
Total	432	559	687	825	~1'535	~2'350	~3'100	~3'700	~4'100
Total as % of 1997	100%	129%	159%	191%	355%	547%	720%	866%	945%

Note: ~ represents estimated expenditures

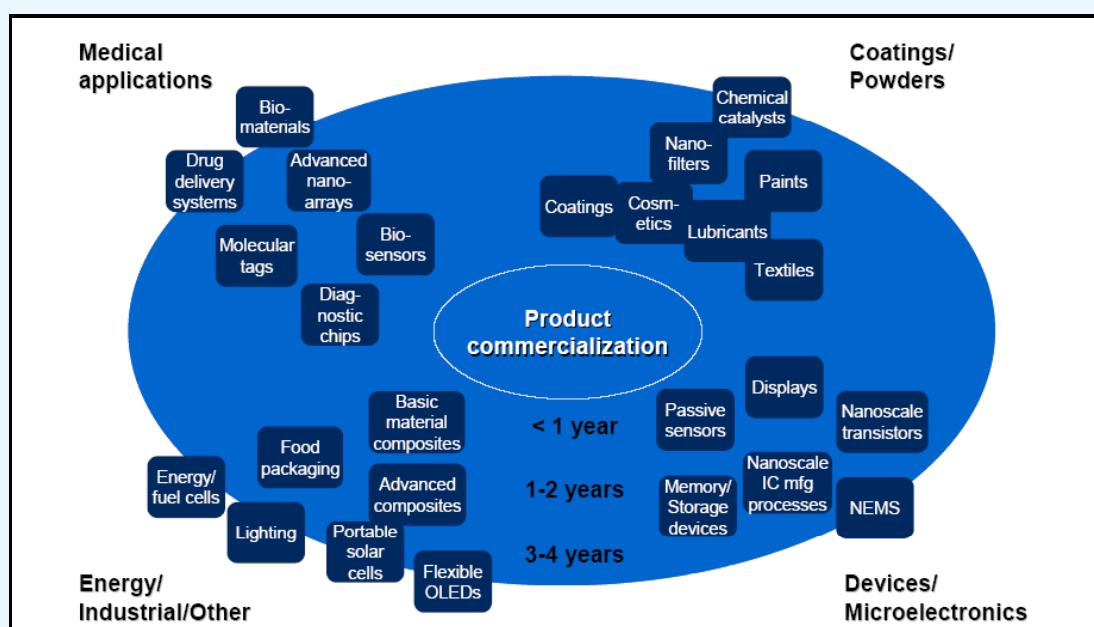
Source: ETC Group, "NanoGeoPolitics: ETC Group Surveys the Political Landscape", adapted from M. Roco, United States National Science Foundation, 2005

2.5.3 Nanotech for ICTs

Not surprisingly, nanotechnology is set to change the ICT industry dramatically, particularly the size of data processing modules and storage devices. Intel, for instance, has developed a microprocessor chip based on Static Random Access Memory (SRAM) cells of 65 nanometres, about half the size of cells currently in use (Box 2.25). The European project NanoCMOS aims to reduce this size and push back the limits of semiconductor performance and density for the development of nano-electronics still further.¹⁴³ Potential benefits include increased speed and memory capacities, and a decrease in energy consumption.

Figure 2.5: Nanotechnology – what and when?

Nanotechnology applications that are quickly approaching commercialization



Source: McKinsey, 2005

Box 2.25: Processing things on a nanoscale

Intel takes information technology on a nano trip

Entering the age of nanotechnology, the IT giant Intel has developed the next generation of chip technology on the nano-scale. A milestone was reached when fully functional 70-megabit Static Random Access Memory (SRAM) chips with more than half a billion transistors were built using 65-nanometre (nm) process technology.

The transistors in the new 65-nm technology have gates (the switches that turn transistors on and off) measuring 35 nm, approximately 30 per cent smaller than the gate lengths on the earlier 90-nm technology. About 100 of these gates could fit inside the diameter of a human red blood cell. The new process technology increases the number of tiny transistors that can be squeezed onto a single chip, providing the basis on which future multicore processors can be delivered. It will also enable Intel to design innovative features into future products, including virtualization and security capabilities.

Image Source: Photodisc

Source: Intel, 2005



Sensors, tiny wires and thin materials for electronic display, will drive innovative product development further in this area. The latest display technology for laptops, mobile phones, and digital cameras is made out of nano-structured polymer films. Nanotechnology will also play an important role in fibre-optics. Nano-crystalline materials will be made with finer and finer resolution for enhanced optic cables, switches, and junctions. Nanotechnology will bring the creation of projection screens and user interfaces for future holographic mobile phones (Holographones) and televisions (HoloTVs) closer to reality. Hewlett-Packard uses imprint, rather than optical, lithography to produce experimental circuits 30 nanometres in width. This manufacturing method is touted by the technology industry as the most promising one.¹⁴⁴ Universities are behind the major advances in the nano-chip research and push the technology to new horizons (Box 2.26).

Box 2.26: Nanotubes hit the big time

Nanotubes to thwart capacity bottlenecks in processors

Nanotubes, one of the central tenets of nanotechnology, have been found capable of boosting wireless network processing speeds to up to 10 Gigahertz. Breakthrough research at the University of California at Irvine revealed that nanotube transistors can not only work at unusually high frequencies, but can also transmit electronic signals very quickly between transistors in a semiconductor chip. The deployment of carbon nanotubes rather than copper or aluminium wires for connecting transistors with each other will eliminate a well-known bottleneck and magnify the processing power of a communications network. It is now possible to combine the technologies for nanotube transistors and nanotube connectivity to produce an ultra-high-speed all-nanotube circuit, faster than known semiconductor chips. The benefits of this discovery can be realized in all communication network devices.

Nanotubes are tiny cylindrical molecules just a few nanometres wide, made of folded sheets of carbon atoms. They are extremely tenacious, and at the same time quite flexible, with excellent conductivity characteristics and can even discharge light. This makes them ideally suited for flat-panel TV displays, fuel cells, building materials and even scaffolds for broken bones.

Sources: Electronic Engineering Times, “Nanotech Breakthrough said to increase wireless speeds”, 13 June 2005; NanoTechwire.com, “Method makes double nanotubes”, 10 March 2005; PhysOrg.com, “Nanotubes in a new light”, 6 July 2005; PhysOrg.com, “Carbon Nanotubes Could Aid Human Bones on the Mend”, 18 July 2005

Not surprisingly, scientists are hard at work on decreasing the size of RFID tags, as developments in nanotechnology are likely to boost the mass penetration of RFID. Hitachi’s “μ-chip”¹⁴⁵ for example, has a 128-bit ROM for storing identification information, but is only 0.4 millimetres square in size. This makes it small enough to be attached to a wide variety of small objects, and even embedded into paper. The principal obstacle to the more widespread use of RFID tags is cost, which is currently around USD 0.50 per tag. Nanotechnology could help bring the cost of RFID tags down to around USD 0.05 by as early as 2006 to enable truly ubiquitous use.¹⁴⁶ Cheaper antennae that can be printed onto paper using nanoparticles are also being developed.¹⁴⁷

For the development of a truly ubiquitous and interactive Internet of Things, the combination of nanotechnology and sensor technology will be significant. A start-up based in the United States, Nanomix Inc., is currently developing innovative new sensor technologies that combine silicon architecture with nanoscale sensing elements, to make smaller, more sensitive and less power-hungry sensors. NanoMarkets LC predicts that the overall nanotechnology sensor market will generate global revenues of USD 2.8 billion in 2008 and USD 17.2 billion by 2012.¹⁴⁸

2.5.4 Nanotech for the future

These are, however, early days for nanoscience and even earlier days for nanotechnology. One of the ongoing problems is the gap between basic and applied research, otherwise known as the “Valley of Death”. Fundraising and human resource development is difficult to secure when developments are long-range, and on the other hand, nanotechnology may be considered too much of an applied science for academics working on basic scientific developments.¹¹⁸

Nanotechnology is not just for the developed world, but also holds great promise for developing countries. Economists believe that developed nations should try to find ways and means to promote nanotechnology development in the poorer countries. Many of these countries are already beginning to harness the potential of nanotechnology. India, for instance, will invest USD 20 million over the next five years (2005–2009) through its Department of Science and Technology into its Nanomaterials Science and Technology Initiative (NSTI). In South Africa, the government’s nanotechnology initiative has brought together a national network of academic researchers involved in areas such as nanoparticle catalysts, nanofiltration, nanowires, nanotubes, and quantum dots. Other developing countries, such as Argentina, Chile, the Philippines and Thailand are already innovating in this area. In Mexico, there are some twenty research groups currently working independently in nanotechnology.

In fields such as healthcare, nanotechnology can provide significant benefits. Although not a panacea for the problems faced by developing countries, experts point to the potential of the technology for sustainable development. This issue was addressed in a 2005 report by the United Nations Task Force on Science, Technology and Innovation¹⁴⁹, which had set up a special working group on genomic and nanotechnology for developing countries. Some of the key applications for developing countries include: energy storage, production, and conversion, agricultural productivity enhancement, water treatment/remediation, disease diagnosis/screening, drug delivery systems, food processing/storage and air pollution control.¹⁵⁰ The benefits of nanotechnology in developing countries, in particular, are discussed in more detail in Chapter 5.

2.6 Conclusion

RFID, sensors, smart technologies (such as robotics and telematics), and nanotechnology will build on the phenomenal success of today’s global internet and mobile communications to shape the future landscape of the Internet of Things. Although the full-scale commercialization of many of the technologies discussed here may require some time yet, early developments have already led to a host of innovative applications likely to become ubiquitous in everyday life: in the home, at work, on the farm, in the hospital, at the shop, on the road, and even inside the body. Item-based tagging and identification will take anytime and anywhere communications to the next revolutionary step in networking: “anything communications”. Empowering things to detect and monitor their environment through sensors will enable the network to sense, react and respond to external stimuli. Embedded intelligence at the edges of the network will further increase the network’s ability to respond. Naturally, the expansion of the Internet of Things has a number of important strategic implications for businesses and governments alike. Shaping a user-friendly and economically viable market will be on the minds of many as they unleash their imagination and creativity on the future.

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3 CHAPTER THREE: SHAPING THE MARKET

3.1 Introduction

The technologies of the Internet of Things offer tremendous potential. It is exciting to observe how fast scientific knowledge, skills and applications are becoming a sizeable chunk of the ICT industry. However, it is important to understand that technologies do not exist in a vacuum. In order for them to materialize into tangible products, services and applications endowed with commercial value, they follow a difficult path. The present chapter will take a closer look at how ground-breaking ideas are taken to market, who is involved in the process of their commercialization, how great their expected potential is, and how market leaders leverage on their strengths.

It all starts, of course, with a new idea. Soon after its inception, this idea must find suitable guardians, i.e. committed parties eager to throw in financial, intellectual and physical resources. The cleverest ideas are those being nurtured and supervised by technological guardians and lead users, until they bear fruit. In this context, an increasing number of players are taking a closer look at the Internet of Things. Analysts are highly optimistic about the prospects of its technologies and predict huge revenues for those that adopt them.

Nonetheless, a number of factors can delay an innovation on its way to becoming a commercial product. Often, industry may not be willing to recognize the need for new approaches. This chapter will look at a number of issues impeding the development of innovative applications and explore some of the ways to address them. It will provide a selection of specific examples from businesses where innovation has become the flesh and blood of corporate strategy. Finally, the chapter will explore how companies can use the Internet of Things to optimize their internal processes, expand traditional markets and diversify into new businesses.

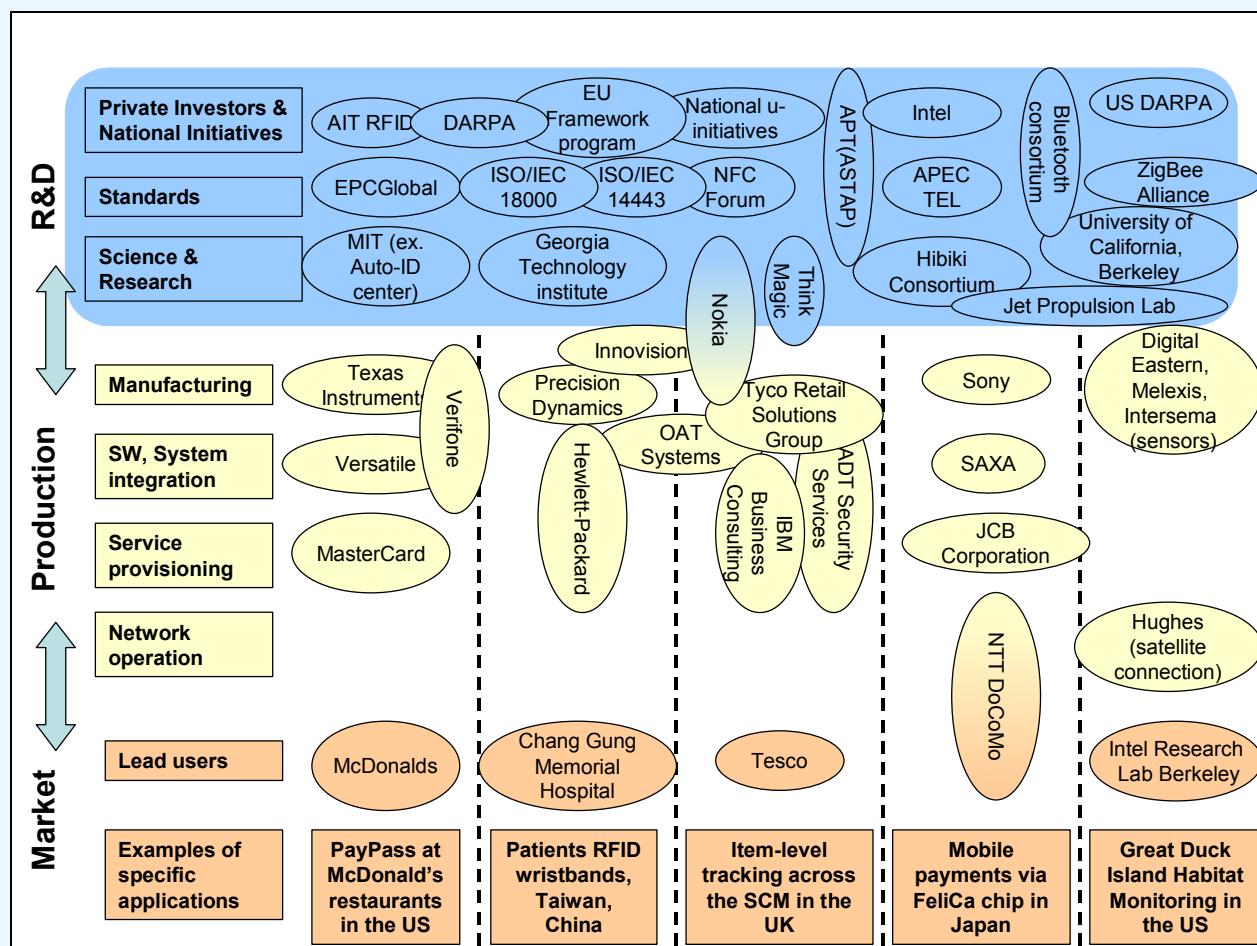
3.2 From idea to market

This section seeks to identify general types of market players and provide examples of companies and organizations, working to develop specific applications. In so doing, it looks at how value is created and by whom. Generally speaking, the process of value creation for the Internet of Things can be broken down into three distinct phases:

- **Research and Development phase:** Many ideas for new technologies are promoted and developed during the Research and Development (R&D) phase. Organizations involved in this phase (such as standard-setting bodies and research institutes), backed by private investors and governments, initiate the development of new products. They then feed their innovations and designs to companies involved in production.
- **Production phase:** Following successful R&D efforts, innovations are taken a step further. The work of a diverse group of companies in the production phase ranges from the creation of sensor nodes to the development of turnkey RFID solutions. Players involved in this phase include chip-makers, system integrators, service providers, mobile operators, etc.
- **Market (commercialization) phase:** Lead users are the main drivers of commercialization and propel the development of the market for the Internet of Things. The concept of lead users of innovative services or products was discussed in a seminal paper by Eric von Hippel¹. In his paper, von Hippel describes lead users as “users whose present strong needs will become general in a marketplace months or years in the future”. He goes on to suggest that all lead users have two characteristics in common: their needs anticipate those of the rest of the market by months or even years, and they benefit substantially from innovative solutions. Lead users in the context of the Internet of Things include the likes of Wal-Mart and NTT DoCoMo who are actively pushing the supply-side of innovations, even when industry lags behind their needs².

These above categories are broad. Given the convergence of technologies and services, there will undoubtedly be some overlap. Interestingly enough, in the emerging but buoyant market of the Internet of Things, some larger companies are playing multiple roles and certain key functions are filled by a wide variety of players. The applications shown in Figure 3.1 represent some prominent examples at the current stage of technological development, focusing mainly on RFID applications.

Figure 3.1: Creating value for the Internet of Things
Specific examples of applications – from idea to market



Note: This diagram covers only a selection of examples of applications and is not intended to be exhaustive. It outlines the complex pattern of interactions between players at various stages from idea to applications. SW refers to software.

Source: ITU

3.2.1 From idea to innovation: Research and development

Research and Development (R&D) is the stage during which ideas become technical innovations. What is the difference between an idea and innovation? The answer is simple, although it might sound a little mundane: innovation has commercial value. R. Smits from the University of Utrecht in the Netherlands provides a good definition: “a successful combination of hardware, software and orgware (“organizational and institutional conditions”) viewed from a societal and/or economic point of view”. A new idea does not necessarily lead to more wealth or social benefits³. This potential is offered by innovation, a complex and interactive process, which “makes a leap in the benefits-to-cost ratio in some area of endeavour”⁴. The Internet of Things implies greater corporate efficiency, cost savings, enhanced quality of life and as such is characterized by strong innovation.

The R&D stage comprises not only research institutions, but also global investors and national initiatives. Its function is to facilitate and fund research and standardization, thereby promoting the broad adoption of technology by industry. Companies may cooperate with each other, based on one-to-many or many-to-many relationships. Often, the functional boundaries between R&D institutions, standardization organizations, investors and government programmes are hardly distinguishable, especially when organizations change roles or status. Such was the case, for example, with the Auto-ID Center which started as a research project in the Massachusetts Institute for Technology (MIT), but later evolved into EPC Global (Figure 3.1), a key standardization body dedicated to RFID.

Science and research institutions are very diverse, including, for example, universities, public scientific institutes and corporate research labs. In fact, they can be generalized as cradles, where the technologies enabling the Internet of Things are nurtured and reared. Importantly, the scope of the research in the most prominent institutions is not confined to basic science. An increasing emphasis is now being placed on applied science. Effective institutional frameworks, such as technology or research parks, can create favourable conditions for the commercialization of scientific findings (for more on technology parks, see Chapter 5).

Usually, funding for research comes from both private (business) and public (government) sectors. For instance, in the case of nanotechnology, about USD 1.7 billion (46 per cent of total nanotechnology research expenditure) was spent in the United States by the private sector; and the remaining 54 per cent came from federal, state and local administrations. In Asia and Europe, the involvement of the private sector was significantly lower, corresponding to 36 and 17 per cent respectively.⁵ In fact, R&D sponsored by the business sector usually takes a different trajectory and pace to the final product, compared to government-sponsored R&D.

Business investment is usually characterized by more applied research and speedier commercialization of technology. In contrast, government support generally has longer-term strategies and a more futuristic focus. However, this difference has been blurring over time and governments are now becoming more interested in applied research. For instance, the Defense Advanced Research Project Agency (DARPA), a specialized agency of the United States Department of Defense, has recently cut its budget for basic research and shifted focus to projects promising a rapid pay-off. It was reported that the budget for computer or IT-related research grew slightly from USD 546 million in 2001 to USD 583 million in 2004, while the budget intended for university research has fallen sharply from USD 214 million to USD 123 million⁶.

Public spending

The nature and scope of government funding in R&D vary from country to country and even within the borders of the same nation. However, generally speaking, public R&D stems from two sources: the military budget or general scientific research programmes.

Military, defence and homeland security departments provide a major source of funding for research motivated by military needs. In the United States, DARPA has been one of the major sources for ICT research funding in recent decades. The internet is one outcome of such research. Development of the smart dust project within the labs of the University of California, Berkeley, was made possible due to funding from DARPA. Recently, the agency allocated around USD 12 million for the development of robotic battlefield surgery systems – so-called “trauma pods”, which can perform full scalpel-and-stitch surgeries. In the field of nanotechnology, the US National Nanotechnology Initiative (NNI), for developing nanotech-based products has been funded by various federal agencies, such as the Departments of Defense, Health and Energy as well as the National Aeronautics and Space Administration (NASA).

In other instances, R&D funding might be underscored by a country’s aspirations to be the leading knowledge- or ICT-based economy and is provided for within the general research budget. This approach can be found in Japan. The country’s “U” initiative, where “U” stands for “Ubiquitous”, is representative of a society where ICT extends deep into people’s lives, industry and economy (e.g. affecting public safety, healthcare and lifestyles). This programme is administered by Japan’s Ministry of Internal Affairs and Communications (MIC) and specifically focuses on RFID and ubiquitous sensor networks⁷. Similar “U”-programmes exist in the Republic of Korea and other Asia-Pacific countries (Box 3.1). In the United States, public R&D funding generally comes from the National Science Foundation (NSF). In 2002, for example, the Center for Embedded Networked Sensing at the University of California in Los Angeles received a 10-year USD 40 million grant for research in the area of wireless sensor networks.

Intergovernmental initiatives at the regional or international level are another powerful means of spurring national research and development through public funds. In the European Union (EU), research is carried out under initiatives termed “Framework Programmes”. The first Framework Programme dates back to 1984, and since that time, the Sixth Framework Programme, with a budget of EUR 17.5 billion (USD 21.97 billion), has been the largest in terms of funds allocated. The EU Framework Programme is in line with the March 2002 Barcelona Council’s decision to increase by 2010 the investment into scientific

research up to 3 per cent of the EU median GDP. It incorporates seven thematic areas for research, which include information society technologies, nanotechnologies, multifunctional materials and new production processes⁸ (Box 3.2). Recognizing the role of small companies in driving technological development, the EU has established the DETECT-it programme, of which the main objective is to fund small and medium-sized enterprises involved in scientific research and innovation. Around EUR 2.2 billion (USD 2.76 billion) will be allocated to this programme⁹. The European Commission has increased financial support for nanotechnology R&D: between 2007 and 2013, the expenditure for nanotechnology-related R&D projects will amount to EUR 4.6 billion (approximately USD 5.7 billion).

Box 3.1: U-Korea and U-Japan

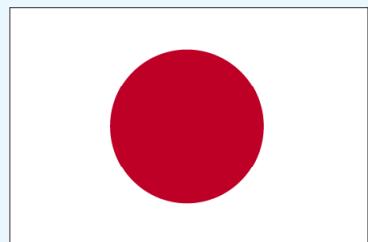
Republic of Korea: ICT paves the way for GDP growth, Japan: shifting from e-Japan to u-Japan

U-Korea: The Republic of Korea has been promoting different schemes to allow Korea to take a leadership role in emerging technologies, notably the “U-Korea” programme, the “Broadband IT Korea Vision 2007” and the “IT 839 Strategy”. In this regard, an important component of Korea’s critical path for achieving a ubiquitous network society, and for sustaining industrial competitiveness is its so-called “IT 839 Strategy”. “839” stands for the rapid growth of eight communication broadcasting services, three state-of-the-art essential networks and nine new sectors. The eight services include: portable internet (WiBro), mobile television (DMB), home networking, vehicle-based information systems (telematics), radio-frequency identification (RFID) technology, W-CDMA mobile telephony, digital television broadcasting, and Voice Over Internet Protocol (VoIP) services.



In order to ensure the provision of these eight services, three advanced networks have to be built: a broadband convergence network (BcN) providing connection speeds at a rate of 50-100 Mbit/s, sensor-based computing networks and the next-generation internet platform based on Internet Protocol version 6 (IPv6). Due to the development of these services and the rollout of world-class networks, the government plans to achieve growth in nine industrial sectors: mobile handsets, digital televisions and broadcast devices, home network equipment, system-on-chip products, next-generation personal computers, embedded software, digital content and solutions, vehicle-based information equipment and intelligent robot products.

U-Japan: The Japanese vision of the further development of the ICT sector has taken the form of the U-Japan strategy, which is aimed at building a ubiquitous network society. This strategy is based on the previous e-Japan strategy and comprises four main policy packages. The first implies infrastructure deployment, i.e. enabling the environment with seamless access to wireless and wireline networks, deployment of broadband infrastructures on a nationwide basis, targeting 100 per cent of the population to have access to high or ultra-high speed broadband. The second pillar addresses advanced ICT usage, including the promotion of content creation, its distribution and use, and the development of local ICT competence. The third component envisages the upgrading of an enabling environment, i.e. the promotion of “21 strategies for ICT’s Safety and Security”, and the formulation of the “Charter for a Ubiquitous Network Society”. The fourth policy package includes the promotion of international and technological strategy. This vision of policy implies that Japan not only seeks to develop an ambitious domestic policy, but also a policy that will promote Japanese interests abroad at international markets. The technology strategy is aimed at the promotion of R&D and standardization in the priority areas, and at strengthening international competitiveness through innovation.



Sources: Ministry of Information and Communications, the Republic of Korea; Ministry of Internal Affairs and Communications, Japan; ITU, “Ubiquitous Network Societies: the Case of the Republic of Korea”, April 2005 at <http://www.itu.int/ubiquitous>

The role of the private sector

As mentioned above, private investors are generally focused on innovations that promise rapid returns. As the development of the Internet of Things progresses, more companies are beginning to collaborate and finance research projects on the technologies making up the Internet of Things.

For example, chip manufacturer Intel is looking to expand its research areas. In 2001, it established four university-based research “labs”: University of California in Berkeley, University of Washington, Carnegie Mellon University and the University of Cambridge. These labs are not expected to create commercial applications, but rather to focus on developing core emerging technologies. As long as their

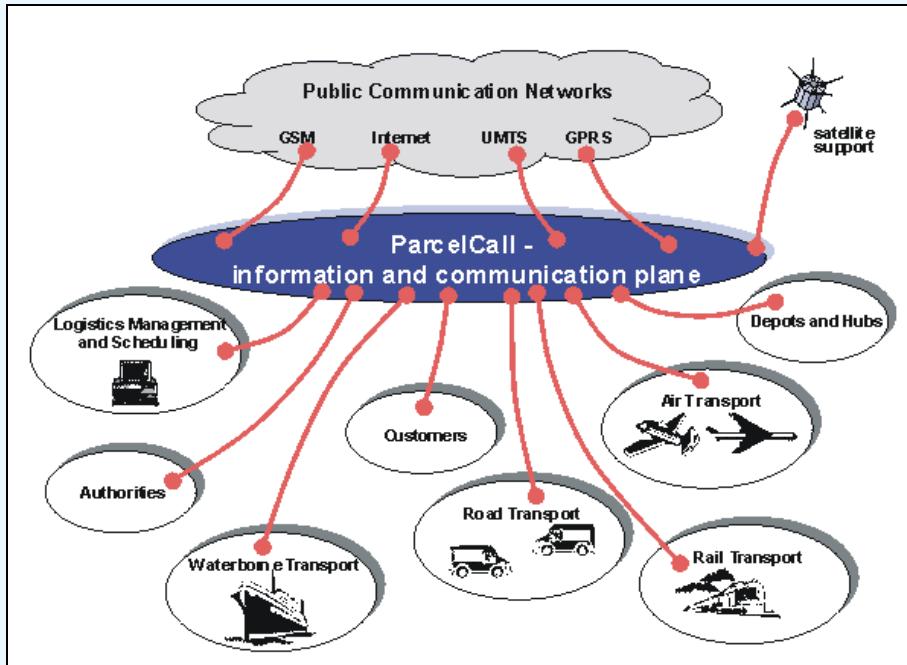
research is related to silicon technology, its specific direction is at the lablet's discretion. Thus, in Cambridge, the research agenda includes optical switches and new programming languages. In Pittsburgh (Carnegie Mellon), scientists are interested in data mining tools for webcam networks. In Seattle (University of Washington), XML-based messaging and wireless personal area networks dominate and in California (Berkeley), it is all about sensor networks¹⁰.

Box 3.2: Europe joins forces for R&D

European Union fosters research towards the efficient tracking system for parcels and ambient intelligence

The European Commission allocated EUR 2.5 million (USD 3.2 million) to ParcelCall, a new research platform for item tracking under its Fifth and Sixth Framework Programmes. The EC is supporting the development of a new system that will provide real-time, intelligent, end-to-end tracking and tracing of items or parcels through network technologies such as RFID, Mobile Logistic Server (MLS), Global Positioning System (GPS) and “thinking tags”. The project ParcelCall builds on previous research programmes, including e.g. CAMELEON, OnTheMove, and AMASE. The next

stage, ParcelCall 2008, will replace passive tags with “thinking tags” with sensory, computing, and memory functionality and active communication capabilities. Given that the prices of RFID tags will decrease over time, the new system is expected to have applications in logistics and beyond. The diagram shows some of the future application possibilities of this system.



The European Commission has contributed EUR 12 million (USD 15 million) to research in ambient intelligence under its Sixth Framework Programme. A partnership of twenty European members under the supervision of the French-Italian chip producer, STMicroelectronics, is conducting a research project, PolyApply, to develop polymer-electronic micro-systems for electronic ambient intelligence. The programme aims to develop wireless communicating micro-systems based on memory-chips and sensors that can be integrated into everyday items.

Image Source: ParcelCall

Source: Parcel Call at <http://www-i4.informatik.rwth-aachen.de/parcelcall/>; PolyApply, at <http://www.polyapply.org/>

In the area of robotics, several traditional IT and automotive multinationals finance in-house research projects. These include ASIMO¹¹ by Honda, QRIO¹² by Sony and “travel robot”¹³ by Hewlett Packard. There are also new commercial companies entirely engaged in R&D and design, such as the US-based pure-play RFID company ThinkMagic, which provides technology specifications to manufacturers of readers. ThinkMagic has deliberately opted to steer away from manufacturing in order to focus fully on design.

Industry members recognize the benefits of cooperation and have begun to join forces through industry associations. As a whole, industry associations are key drivers of standardization and are usually the first to standardize emerging technologies at the international level.¹⁴ In the absence of global specifications, coordinated industry effort may result in a *de facto* standard.

Such was the case with the ZigBee Alliance, responsible for the development of the communication protocol that addresses the needs of wireless sensor networks applications¹⁵. By August 2005, the Alliance included more than 90 members¹⁶. The Near Field Communications (NFC) Forum is an important contributor to the Internet of Things, as it brings together leading mobile handset manufacturers for the elaboration of specifications for integrating RFID systems with mobile devices.

In Japan, the Hibiki Consortium formed in 2003 by a group of over 100 companies (e.g. Hitachi, Dai Nippon Printing, Toppan Printing, NEC etc.) is developing low-cost RFID chips. Similarly, in Korea, the Association of RFID/USN (KARUS) supervises licensing, standardization and development of RFID and sensor network technologies. As of March 2005, it comprised 180 private companies¹⁷. Meanwhile, around 25 national robotics associations are active members of the International Federation of Robotics (IFR) which was formed to “promote research, development and international cooperation in the entire field of robotics”.¹⁸ In the area of nanotechnologies, the Asia-Pacific Nano Forum (APNF)¹⁹ has been established as a unique regional platform for networking among government policy-makers, industry, venture capitalists, and R&D institutions²⁰.

Public and private meet

As noted earlier, public institutions and industry can play an important role in making science and technology work. Successful standardization, one of the key steps in transforming knowledge into marketable products and services, is not possible without the participation of both the private and public sectors. As discussed in Chapter 4, standards can drive or hinder trade. In order for an emerging technology to be successful, it must pass through a standardization process. In Asia, APT (Asia-Pacific Telecommunity) plays a major role in the development of ICT.²¹ Its standardization arm, ASTAP (APT Standardization Program), is responsible for the promotion of regional standardization cooperation. Recently, a new Expert Group has been formed under the aegis of ASTAP dedicated to RFID standardization.

At the international level, the International Telecommunication Union, with its multinational participation and global reach, is well positioned to coordinate standardization efforts of its member countries. For example, RFID is now seen as one of the key priorities of the ITU Telecommunication Standardization Sector, ITU-T. The largest developer of technical standards, the International Organization for Standardization, is also considered a key destination for national, regional and industry standards. According to ISO's website, “ISO occupies a special position between the public and private sectors”²², as its membership is comprised partially of government-mandated institutions and partially of national industry associations. Specifically, the adoption in 2004 of the family of ISO/IEC 18000 standards²³ allocating bandwidth and specifying the radio interface for RFID was a step forward towards the global compatibility of RFID devices.

3.2.2 From innovation to production: Creating value

The production phase offers even more potential for diversification than research and development. To make matters more complex, those very companies that participate in the design of an innovative product may at the same time act as its most important users.

For example, the production of RFID and wireless sensors involves a whole hierarchy of players, including chip makers, sensor makers, system integrators, service and network providers. Robotics involves many enabling technologies starting from microprocessor technology to motion sensors, speech recognition software, etc. There is therefore a wide variety of industry players involved. On the supply side, progress is driven by large consumer electronics and automotive companies, such as Honda, Sony, Hitachi, Epson, developing entertainment and personal robotics, e.g. robot vacuum cleaners or automated lawn mowers. For nanotechnology, a high knowledge intensive area, the production value chain extends from nanomaterials to nanocomponents and even to nano-enabled products.

Manufacturing

The manufacturers of the technologies and products of Internet of Things are one of the core links in the value creation chain. Apart from differences in size, the nature of manufacturing firms varies greatly: they can focus on transponders, readers, middleware and so on. Pure-play RFID players are still rare, but gaining in popularity, e.g. Symbol, Zebra and Intermec. The RFID market is currently dominated by big traditional players from other industries, such as chip-makers Philips Semiconductors and Texas Instruments. Texas instruments is largely known as an integrated circuit (IC) manufacturer for MasterCard PayPass solution (Figure 3.1).

Traditional chip-makers are not only looking to RFID, but also to sensors to extend their commercial reach. Intel, Chipcon, Amtel, Analog Devices, Sony and Samsung are several examples. Motorola's spin-off arm, Freescale, also produces sensors. Pure-play suppliers of wireless sensor networks include Dust Networks and Crossbow Technology.

Other than concentrating entirely on manufacturing, a company may generate more revenue by moving further up the value chain. This has been the case with the company ADT Security Services. In January 2005, it won an exclusive contract for the supply and integration of RFID readers for 1'300 Tesco stores and 35 distribution centres. Meanwhile, its subsidiary, Tyco Retail Solutions Group, manufactures RFID readers based on EPC Global-compliant designs from ThinkMagic (Figure 3.1).

An ever-increasing number of handset manufacturers, too, are entering the scene – one clear leader being Nokia. Recently, the mobile giant announced the launch of an RFID kit aimed at businesses that uses workers' mobile phones for reading RFID tags (Figure 3.1).²⁴ The integration of RFID into mobile phones has implications for their future utility, both for commercial firms and for consumers.

Recognizing the potential of applications based on contactless smart cards for payment, access control, public transportation and last, but not least, national ID cards, some of the largest plastic and microprocessor card manufacturers (e.g. Versatile, Gemplus and Axalto) have now begun equipping their cards with RFID tags (Box 3.4).

Software development and system integration

New challenges and market horizons are arising for software developers and system integrators exploring the technologies enabling the Internet of Things. If we consider hardware as the physical embodiment of an innovative application, then software is both its brain and soul. It makes it tick, but it also allows it to smoothly integrate into and communicate with legacy parts of the user's system. This metaphor shows how fine the line is between the roles of software developer and system integrator. Software developers endow products with features and capabilities; system integrators integrate them into the broader context of the business process. Both are closely inter-related.

The ubiquity of the applications of the Internet of Things makes increased demands on legacy applications and networks. In essence, these will have to operate in real-time, as the networks of RFID tags, readers, sensors, transponders, etc., enable constant and immediate access to a vast amount of information. For example, a shift from case- to pallet- and item-level data tracking will require a complete redesign of companies' data collection systems. According to Kris Pister, founder of Dust company, "for every dollar the big systems integrators and IBM make on sensors and installation, there is 10 dollars to be made on the management of data that comes out"²⁵.

Let us consider the role of RFID middleware (the software component of an RFID system). Forrester Research defines it as "a tool that companies use to manage RFID data by routing it between tag readers and the multitude of systems within their businesses"²⁶. RFID middleware is essentially a tool for the *integration* of tag-emitted data with various enterprise applications. The RFID middleware industry has not yet seen a clear leader emerge. RFID middleware developers come from both software giants and pure-play vendors. Among the most renowned in the field are Microsoft, IBM, Oracle, on the one hand, and OAT Systems, RF Code and Savi Technologies, on the other. OAT Systems, whose CTO Sanjay Sarma founded the Auto-ID Center in MIT, is providing middleware for Tesco, among others (Figure 3.1).

The complexity of the Internet of Things often requires system integration, not only at the application and software level, but also at the level of the company's overall business processes. This is how big players in the area of professional outsourcing services make their market entry. Capgemini, IBM Consulting and Deloitte & Touche are examples of companies recently attracted to the area of RFID. IBM, for example, has provided services for the retailer Metro, supporting the introduction of RFID in its value chain (see Chapter 2). System integration companies able to provide integrated solutions to the users of wireless sensor networks include Invensys, Honeywell, Siemens, Oracle, Dust Networks, Crossbow Technology in San Jose, California, and Millennial Net in Cambridge, Massachusetts²⁷. Chipcon, Freescale, CompXs and Ember Corp provide solutions that comply with ZigBee standards²⁸.

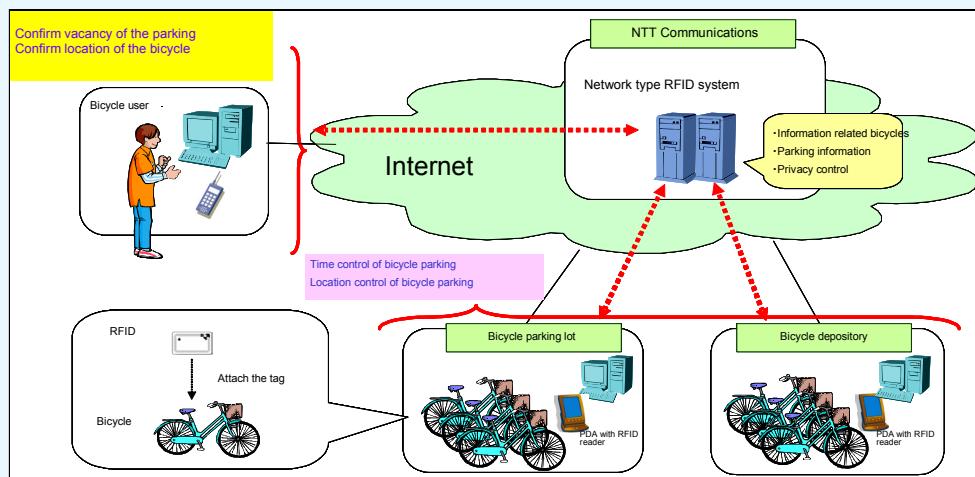
Hewlett-Packard has recently announced a partnership deal with RFID manufacturer Precision Dynamics for the distribution and integration of its products in customer networks. Out of this partnership came,

for example, the implementation of a patient-monitoring system at Chang Gung Memorial Hospital in Taiwan, China, employing RFID wristbands (Figure 3.1). Another interesting application developed in Japan involved the integration of mobile communications, internet and RFID for an end-to-end bicycle parking service (Box 3.3).

Box 3.3: Cycling without hassle

Bicycle parking facilities in Japan to benefit from RFID

Since mid-2004, Japan's Ministry of Internal Affairs and Communications has been running verification tests to investigate the feasibility of RFID and wireless sensor networks in public and private applications requiring automation, such as asset administration, supply-chain management, healthcare, public security, food safety, social services, education and entertainment. One of the experiments involved the use of RFID and mobile communication services during the whole process of bicycle parking, from a vacancy availability check to the management of abandoned bicycles.



In Japan, bicycles are a common form of transportation. They can provide the most convenient, and sometimes the only means of access to a city downtown, a train station, or a leisure park. In the late 1990s, around three million bicycles were parked daily at rail stations, several

times more than the number of commuter cars. Back in 1973, more widespread cycling to train stations resulted in new laws requiring storage facilities near rail stops. An average bicycle parking lot at a Japanese rail station may hold nearly 300 bicycles, so an advanced asset administration system offers considerable benefits.

An experimental RFID system was set up in March 2005 at a number of municipal parking facilities to manage data on availability, bicycle parking time and location. Participating bicycles were equipped with RFID tags, while PDAs with RFID readers were distributed to the facility personnel.

Bicycle users confirmed the availability of parking either using a home PC or a mobile phone for internet access provided by NTT Communications. At the parking facility, staff recorded data from a bicycle, its location and time of storage. The results of the experiment were impressive: convenience for both parking administration and users considerably improved; valuable empirical information was obtained on the practicalities of attaching tags and reliability of readers; privacy protection related to remote access to personal information and access rights management was maintained at the required level. The test is set to expand to verify the collaboration with other municipal services.

Source: Ministry of Internal Affairs and Communications (Japan) "Verification test of RFID utilization", 9 June 2005; Transportation Alternatives, "The electronic bicycle blueprint", January 1999, available at <http://www.transalt.org/>

Service provision

The host of services that can build upon the vision of the Internet of Things are limited only by human imagination. In this respect, many of today's service providers can exploit the potential of the Internet of Things – from fast food restaurants to mobile content providers. They can use the ubiquity it provides as yet another channel for distribution of their traditional services, as a method to improve these services, or as a means to launch entirely new services.

A wide array of industries are already reaping the benefits of the Internet of Things, including the healthcare, services, entertainment, financial and retail sectors. Financial institutions have in fact been pioneers, quickly adopting new technologies to enhance market shares and revenues. MasterCard issued its PayPass card for small RFID-enabled transactions to around 8'000 McDonald's restaurants, as well as for a range of

other institutions in the United States²⁹ (Figure 3.1). The company requires that suppliers of readers go through a compliance test and publishes a list of approved devices for retailers to use. Terminal manufacturers that successfully completed the approval process include, for example, Verifone, Hypercom and ViVOtech. American Express, with its ExpressPay Blue contactless technology, and Visa, with its Contactless Payment programme, are close competitors in RFID. Box 3.4 looks at the increasing number of financial services using RFID. A discussion of business models later in this chapter will provide additional examples of changing business strategies.

Box 3.4: The power of the card

Increasing number of financial services use RFID

According to a global survey of 20'000 consumers conducted by Vodafone in 2004, the majority of people usually carry with them three items, even during the shortest of trips: a mobile phone, a bunch of keys and a wallet. The mobile phone is the most personalized technical device ever known. Keys provide access to cars, homes and offices. The content of one's wallet includes a number of IDs for travel, credit purposes, and some cash. What if these could all be replaced with just one omnipotent card?

RFID could be the ticket. Specifically, RFID-enabled mobile phones, thanks to their highly-secure transaction capabilities, may come to dominate access and payment methods. Car keys enabled with RFID have been used for a long time in central locking and theft protection.



In terms of card payments, Ez-Link, a Singapore-based smart card company founded in 2002, has over six million cards in circulation, with the largest “wallet share” in Singapore. Its Ez-Card was originally designed for use in transport; however it very quickly proved extremely successful in “non-transit”, i.e. retail, leisure, security and government applications. It is, for example, accepted in McDonald’s restaurants in Singapore. Soon, RFID could give access to homes or cars, without the need for traditional keys. Already, RFID is used in contactless card systems in a number of office buildings.

In Hong Kong, China, 10 million Octopus cards in circulation generated eight million daily transactions in 2004. Between one and two per cent of all cash transactions in the city have already been replaced by the Octopus card. A similar multi-application smart-card project is planned for mass deployment in Thailand in 2005. London’s Oyster transit fare payment card might become the next new omnipotent plastic, particularly in advance of the 2012 Olympics. In July 2005, Transport for London (TfL) released a shortlist of seven retailers ready to provide services to over two million users of the card.

Sources: Guy Lawrence, Vice-President Global Marketing Vodafone, presentation at MIDEM Conference, Cannes, 21-25 January 2005; IDTechEx, “Active RFID becomes big business”, 17 August 2005; David Birch, “Identity Cards and Financial Services”, *The Journal of Internet Banking and Commerce*, February, 2005; APEC, “APEC, Policy and Regulatory Update: Thailand”, April 2005; Contactless News, “London’s contactless transit card to be accepted at local merchants”, 27 August 2005

Network operation

Since the Internet of Things is, first and foremost, a networked world, its development will be of particular importance to providers of communication services. As mentioned earlier, technologies comprising the Internet of Things can endow even the smallest things with storage and communication capabilities. In addition, they enable data collection from each item and provide a short-range communication link (“the last inch”) for the forwarding of this data. The development of the Internet of Things would benefit from complementary to longer-range and higher-bandwidth communication networks for data delivery to databases, user terminals, and the internet. Today, this role can be filled by virtually any network operator: mobile, wireline, ISP, Wi-Fi, etc. Still, network operators participating in successful innovative projects of this nature have largely remained unannounced. Perhaps this is because their role is often limited to the provision of communication bandwidth, wireless or wired. In most cases, for handling additional data flows generated by new applications, system integrators attract existing partners that already provide some kind of connectivity to the customer. Under such circumstances, network operators have to unleash their imagination and search for new ways to add value and extract additional revenue. Figure 3.1 sets out a number of examples of applications that have made it to the market due to the involvement of key players, including network operators.

The larger players are already reaping the benefits of the Internet of Things, primarily embodied in the growth of chargeable traffic. Increased volumes of data ready for transmission present enormous opportunities for mobile operators to recover shrinking revenues from voice services. For example, NTT DoCoMo has partnered with the financial institution JCB Corporation and system integrator SAXA to offer its mobile subscribers on-the-go payment services through the Sony FeliCa RF-chips integrated into mobile handsets. The other two mobile network operators in Japan are making similar plans. There are also opportunities for satellite providers, as ubiquitous sensor networks are being deployed to previously impenetrable areas of the earth. In the Leach Storm Petrel habitat monitoring project in Great Duck Island (developed by Intel Research Lab in Berkeley), Hughes provided two-way satellite communication (Figure 3.1). Moreover, Wi-Fi and other wireless broadband networks can provide enhanced capabilities for RFID networking.

3.2.3 From production to market: The role of users

Innovation carried out by a producer on its own may not be fully adequate for the needs of the market. The most prominent applications of the Internet of Things have been developed for use through the active involvement of big entities in the public and private sectors. These entities can be described as "lead users"³⁰, who are expected to lead by example and stimulate further diffusion of technologies.

There is common consensus that the demand side plays a critical role in today's innovation process³¹. Moreover, the role of innovation is not confined to defining special, advanced requirements for producers. It actually represents a shift away from traditional price-dominated and anonymous patterns of user-producer interaction towards closer integration for speedier innovation and technological diffusion. In markets where products are complex and evolve rapidly, such integration is essential at the very early stages of research and development.

The new school of economics recognizes three aspects of user-producer relationships. The first is usually referred to as "feedback loops", involving linkages, interactions and the constant exchange of information between producers and users. Second, the importance of learning from external (suppliers, users, etc.) and internal (testing, errors, etc.) sources is emphasized and finally, innovation and diffusion are seen as closely interconnected.³²

As a result, innovation is said to arise through the close cooperation of producers and users. Lead users play a major role in product design and rollout. In the context of the Internet of Things, Wal-Mart, McDonalds and others are acting as "competent and demanding users of information technology" closely monitoring technological developments, adapting them to their own advantage and mandating suppliers to conform to the technical specifications they develop³³.

An enormous ripple effect was triggered when the giant retailer Wal-Mart issued an RFID mandate in 2003, setting a deadline for its suppliers to put RFID tags on all shipping crates and pallets. Its decision has strategic implications not only for thousands of its direct suppliers, but also for vendors and technology providers in terms of reducing costs, transforming the supply chain and the extending the reach of their applications³⁴.

Lead users in the public sector, represented by governments and government-funded institutions such as the United States National Science Foundation (NSF), also affect the diffusion of technology. The latter, for example, has funded studies of wireless sensor networks within the Intelligent Transportation System (ITS) Program for the prevention of road collisions³⁵. The robotics industry benefits from the interest of the US military, as one of the military's objectives is to ensure that one-third of operational ground combat vehicles are unmanned by 2015³⁶.

The lead users listed in Figure 3.1 are diverse: a retailer, a mobile operator, a restaurant chain, a hospital and a science research lab. They are a unique group and not tied to any particular industry, but homogenous in their demand for new technologies, which outstrips the average demand of any one industry sector. McDonald's Vice-President for Information Technology (Jim Sappington) has been quoted as saying that the company "is always looking for new and innovative ways to use technology to improve customer service in our restaurants"³⁷.

Still, one should not overlook the role of individual consumers, or “lay users”³⁸ in shaping the market. Their readiness to embrace new services offered by lead users will be a crucial factor for enabling technologies to become mature, while their fears and concerns, if not properly addressed, can become a major hindrance for further development (see Chapter 4). According to Lundvall, insufficient involvement of lay users may deprive producers of the valuable experiences they might have otherwise developed and deviate innovations away from user needs. Such deviations are referred to by Lundvall as “unsatisfactory innovations”.³⁹

In summary, lead users and lay users play complementary roles in the innovation and commercialization of emerging technologies. Lead users, being more competent and capable in specific technologies, can suggest improvements during early stages of development, whereas lay users can think “outside the box” and even visualize new uses and applications.⁴⁰

3.3 The potential of the market

The true value of the market for the Internet of Things is very difficult to gauge. Today, we mainly associate the Internet of Things with commercialized RFID technology; however, the underlying notion goes much further and encompasses other enabling technologies, such as sensor networks, nanotechnologies, or robotics, all enablers of the new ubiquitous communication environment.

3.3.1 RFID at the core

RFID has been receiving increasing attention from industry analysts. There is widespread consensus that the impact of RFID on the whole ICT sector will be immediate and that the number of individual RFID-enabled objects will grow rapidly. Analysts’ estimates, however, vary considerably. For example, the total market predictions of the size of the RFID market for 2008 range from USD 2 to 7.26 billion. In order to give a general idea of industry enthusiasm for RFID, a selection of recent market estimates and forecasts are set out below (see also Figure 3.2).

- **Current market:** In 2004, according to the technology-market researcher Venture Development Corp. (VDC), global shipments of RFID systems including hardware, software and integration services reached USD 1.8 billion, representing significant growth from USD 965 million in 2002 and USD 1.4 billion in 2003⁴¹. The analytical firm IDTechEx estimates total shipments of RFID products and services for 2004 at the level of USD 1.49 billion⁴². In-Stat deems that 2004 worldwide revenues from RFID tag sales amounted to USD 300 million⁴³.
- **Over the medium-term:** For 2008, IDTechEx projects USD 7.26 billion for the RFID market. VDC suggests that global RFID revenues are set to reach USD 5.9 billion, in 2008 growing at 38 per cent annually (Frost and Sullivan predict that the annual growth of the total RFID market will be 32 per cent⁴⁴). Yankee Group forecasts the 2008 value of the RFID technology market to be worth USD 4.2 billion⁴⁵. International Data Corporation (IDC) estimates that by 2008, the market for RFID-related services (including consulting, integration, management and deployment) will achieve USD 2 billion⁴⁶.
- **Over the long-term:** In-Stat believes that the market for RFID tags should grow up to USD 2.8 billion in 2009⁴⁷, Datamonitor sees the total market for RFID as a USD 6.1 billion industry by 2010, triple of what it is today⁴⁸. Furthermore, IDTechEx estimates RFID to account for a startling USD 24.5 billion market in 2015⁴⁹.

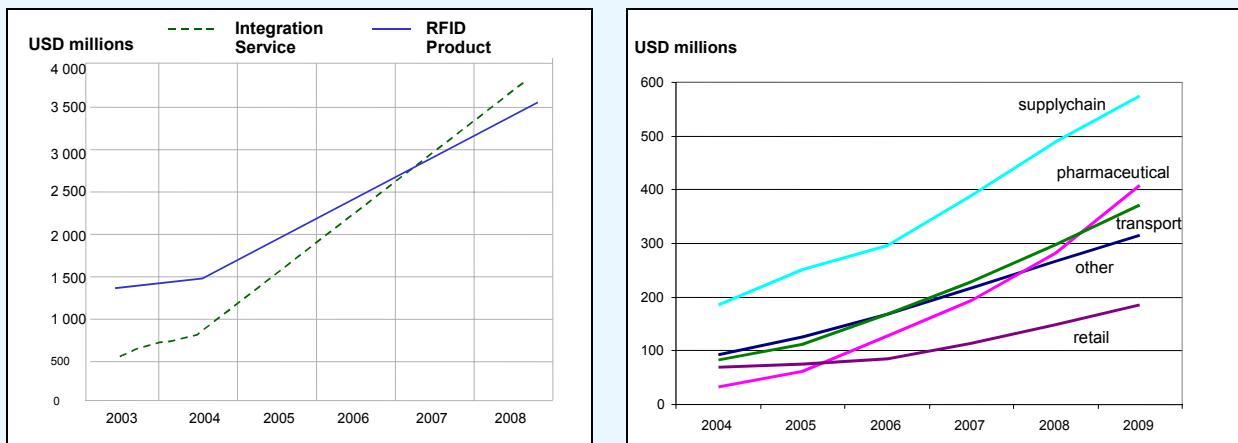
Along with a number of other industry sources, VDC sees the greatest short-term potential of RFID in manufacturing and distribution applications⁵⁰. Adoption is then set to grow across the whole supply-chain, the greatest challenge being for the retail sector. Although it is early days, healthcare is believed to be the fastest-growing sector of RFID.

Contactless smart cards are mostly being used for security/access control, but in future, they will be increasingly utilized for other applications, such as contactless payment, e-passports and ticketing. Frost & Sullivan predict that the number of contactless cards will grow from 121.7 million units shipped in 2004 to 847.3 million in 2009.⁵¹

The emerging trend of integrating RFID in mobile handsets (based on e.g. the Near Field Communications (NFC) standard) deserves special attention. The potential of this shift is immense, starting from applications for mobile workers using the phone for transactional and data transfer purposes, to a variety of lifestyle and home applications, such as short-range downloading of movie trailers or searching for lost belongings. ABI Research predicts that an estimated of 830 million new mobile phones shipped in 2009, 30 per cent will be NFC-compliant⁵².

Figure 3.2: RFID revenue opportunities

Worldwide sales of RFID products and integration services (2003-2008), and total western European RFID revenue by sector (2004-2009)



Sources: ITU, "Ubiquitous Network Societies: The Case of RFID", April 2005, at <http://www.itu.int/ubiquitous> (left chart); Juniper Research, 2005 (right chart)

Naturally, it is the end-user, whose wants and needs are at the core of every value chain, that decides the fate of nascent technologies. A recent survey by Capgemini of over 2'000 European consumers (a follow-up to the US survey referred to in Chapter 4) revealed that despite privacy concerns, the majority of consumers had a favourable attitude towards RFID, and that its most important perceived benefits are improved anti-theft capabilities for cars (70 per cent), faster recovery of stolen items (69 per cent), improved security of prescription drugs (63 per cent) and enhanced food safety and quality. This illustrates the fact that the biggest future prospects of RFID lie in the realm of security⁵³.

The speed of RFID adoption is set to accelerate as soon as Gen 2 RFID systems become available (that is, in early 2006). The compatibility of this long-awaited technology with previous versions of RFID (relating to the air interface protocol) has not yet been widely attained.⁵⁴ Still, UHF Gen 2 specifications, ratified by EPC Global in December 2004 and subsequently submitted to ISO, will improve the accuracy, speed and distance of tag readings⁵⁵. This, along with ongoing tag miniaturization and falling costs, makes RFID the forerunner technology for the Internet of Things.

3.3.2 Prime time for nanotech

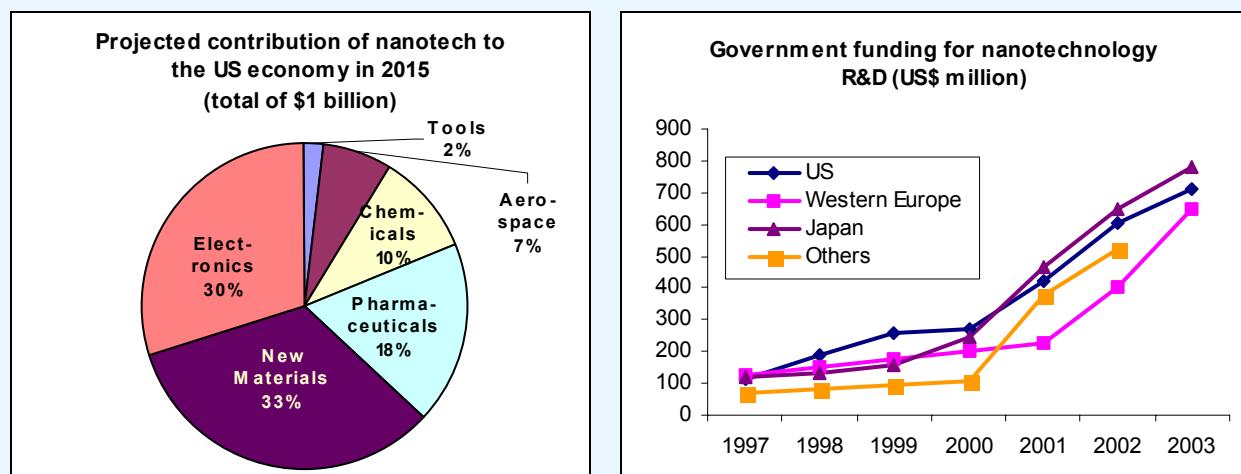
Although current excitement about the market for nanotechnology is limited compared to RFID, investment is on the rise: in 2005, worldwide investments in nanotech reached USD 10 billion⁵⁶. The development of nanotechnologies is being driven by close cooperation between governments, research centres and businesses. These extensive efforts are expected to bring substantial rewards: sales of nanotech products are estimated to rise from less than 0.1 per cent of global manufacturing today to 15 per cent in 2014, reaching a truly impressive USD 2.6 trillion⁵⁷. However, contribution and ensuing growth are not uniform across sectors.

In the United States, the National Science Foundation (NSF) makes the more modest estimate that the worldwide annual industrial production of nanotechnology sectors will reach over USD 1 trillion by 2015, and that most of this increase will stem from the development of new materials, electronics, pharmaceuticals, chemicals, aerospace and tools. A large proportion (two thirds) of this is expected to derive from electronics and new materials (e.g. semiconductors), touted as one of the major drivers for nanoscience and

nanotechnology (Figure 3.3). Already today, the electronics industry includes a substantial number of companies working in the area of nanotechnology. The chemical industry will also benefit from developments in nanotech. Freedonia Group, a US-based research firm, estimates the worldwide market for organic pigments to be USD 10.6 billion by 2008⁵⁸. In the pharmaceutical industry, the consultancy firm NanoMarkets reports that nano-enabled drug discovery solutions will generate revenues of USD 1.3 billion in 2009 and to reach USD 2.5 billion by 2012⁵⁹. The sensor market is another growth area for nanotechnology, in particular for carbon nanotubes. NanoMarkets LC predicts that the overall nanotechnology sensor market will generate global revenues of USD 2.8 billion by 2008, USD 3.6 billion by 2009 and USD 17.2 billion by 2012⁶⁰.

Figure 3.3: The today and tomorrow of nanotechnology

Projected contribution of nanotechnology to the US economy in 2015, and various government funding for nanotechnology R&D (1997-2003)



Sources: National Science Foundation (2003), cited in the OECD Information Technology Outlook 2004 (left chart); Estimates from NanoInvestorNews <http://www.nanoinvestornews.com/>, based on a survey of 741 world companies (right chart)

Like in the case of RFID, there have been a number of efforts to identify desirable consumer applications for nanotechnology. According to a survey recently conducted in the US to determine consumer attitude to nanotechnology, 57 per cent would like to use nanotechnology to treat illnesses, 16 per cent to clean up the environment and 4 per cent to make better products⁶¹.

3.3.3 A feel for sensors

Wireless sensor networks have already been deployed in a number of sectors: automotive, homeland security, medical, aerospace, home automation, remote monitoring, structural monitoring, building automation, environmental monitoring, industrial control, etc.

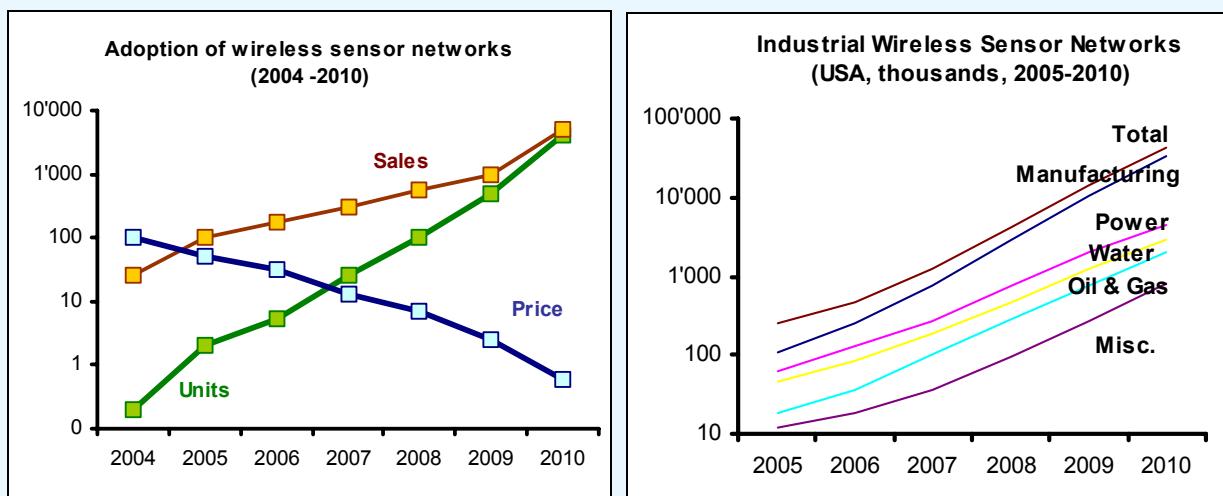
Although different criteria exist for determining the scope of the wireless sensor market, a number of forecasts have been made. According to the research firm ON World, more than a half a billion “nodes” will be supplied in 2010 for a market worth more than USD 7 billion⁶². Currently, the United States and Europe are leading in the research and deployment of wireless sensor networking. Analysts claim that the US market demand for sensors will grow by 7.8 per cent every year to USD 13.6 billion in 2008⁶³. IBM is planning to invest USD 250 million over the next five years and has created a sensors and actuators business unit, which forecasts that the wireless sensor networks market will reach USD 6 billion by 2007. Harbor Research forecasts that compared with the 200'000 nodes that are in use today, there will be 100 million wireless sensors by 2008. According to their estimates, the worldwide market for wireless sensors will reach USD 1 billion by 2009 from USD 100 million in 2005⁶⁴.

Most analysts agree that as prices for sensor nodes fall, the number of units deployed will grow (Figure 3.4). This trend is already observable today. For instance, 500 nodes were used by Eka Systems, and more recently, 3'500 by Nuri Telecom (Republic of Korea) and 25'000 in a network run by Coronis Systems⁶⁵. Standardization is the main barrier to further growth. Currently, the majority of deployments involve

proprietary standards. Major engineering challenges, such as the trade-off between the size of nodes and their consumption of power, have to be resolved before substantially larger networks can be deployed.

Figure 3.4: Sensor networks are growing fast

Adoption of wireless sensor networks (world, 2004-2010), and Industrial wireless sensor networks (USA, thousands, 2005-2010)



Sources: ITU, adapted from Harbor Research, available at <http://news.com.com> (left chart); ITU, adapted from “Coming Soon to Your Neighbourhood”, Wireless Sensors, August 2005 (right chart)

3.3.4 A focus on robotics

One of the starting points for the creation of a world of smart things is the field of robotics, which has experienced steady growth. During the past decade, a range of factors affected the rate of growth of the robotics market, the most important of which is naturally the evolution of technical capabilities. For instance, in the early 1990s, the maximum load of a heavy lifter robot was 275 lbs, whereas it is now up to 1'500 lbs. Enhanced functionality combined with steady progress toward full automation are the key demand drivers.

According to the World Robotics Survey, by the end of 2003, around 600'000 household robots were in use, and almost 700'000 entertainment and leisure robots had been sold. As for industrial robots, around 800'000 units are deployed worldwide, of which 350'000 are in Japan, around 250'000 in the EU, and about 112'000 in North America. In Europe, Germany ranks first according to the number of robots, with 112'700 units, followed by Italy (50'000) and France (26'000). Worldwide annual sales volume is forecast to grow at average 7 per cent per year until 2007, from 81'000 units in 2003 to 106'000 in 2007⁶⁶. The ratio of robots per 10'000 employees in the manufacturing industry worldwide is as follows: 320 in Japan, 148 in Germany, 116 in Italy, and between 50 and 80 in Austria, Benelux, Denmark, Finland, France, Spain, and United States⁶⁷.

Robotics is actively expanding into new markets. Currently, the market size of industrial robotics is greater than the market size of personal and service robotics. However, as shown Figure 3.5 (right chart), the personal robotics segment is likely to lead future market growth. This booming segment includes a wide range of different kinds of robots, from vacuum cleaners and lawnmowers to personal partner-robots. In Japan, one of the main drivers of the personal robotics market is a rapidly aging population – by 2050, more than a third of all the population will be 65 or over, creating a lucrative market potential for the elderly-care robots⁶⁸.

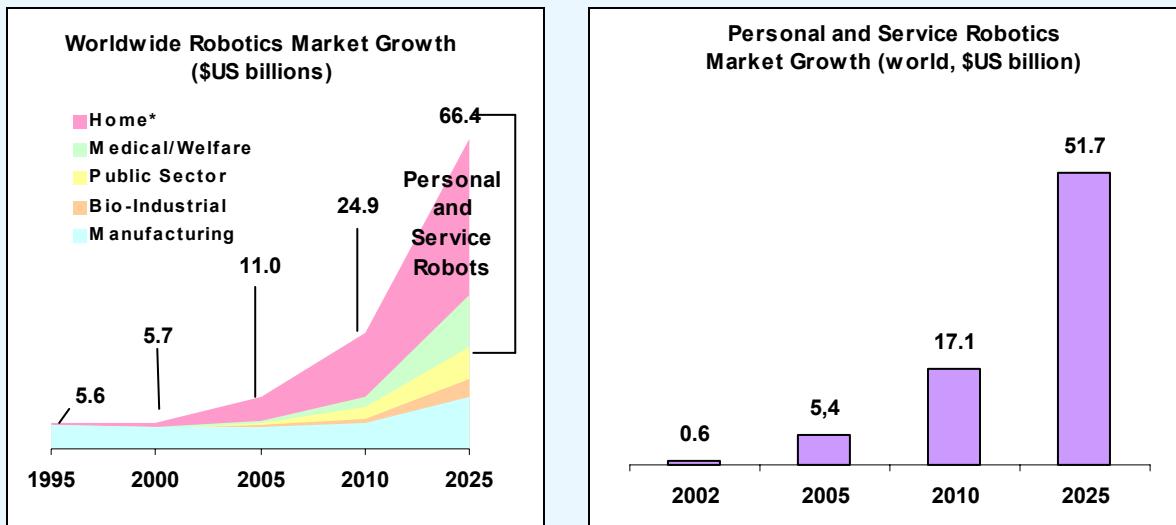
3.4 Growing the market

As is often the case with emerging markets, many demand- and supply-side factors affect the direction of innovation and the adoption of commercialized products and services. This section looks at some of the current and future market constraints and drivers for the Internet of Things. Do these factors have measurable effects only on market potential of applications enabled by the Internet of Things or on their acceptance by users? Clearly, it is both. Given the value creation model for the Internet of Things discussed

in this chapter, it is easy to surmise that such factors are of importance during all stages of development – R&D, production and commercialization.

Figure 3.5: The robotics industry expects significant growth

Worldwide Robotics Market Growth (1995-2025) and Personal and Service Robotics Market Growth (2002-2025)



Note: Left chart excludes simple electronic toys

Source: Japan Robotics Association, "Sizing and Seizing the Robotics Opportunity" at <http://www.robonexus.com/roboticsmarket.htm> (left chart). UN Framework Classification for Energy and Mineral Resources and International Federation of Robotics (right chart).

3.4.1 Barriers to growth

Early stages: Lack of coordination

Early strategic investment in technological development is a prerequisite for the expansion of the Internet of Things⁶⁹. Naturally, expected future growth is important to investors (public or private). The market forecasts provided above demonstrate the potential of the enabling technologies discussed in this report. However, in order to sustain long-term financing in high-tech projects, investor enthusiasm has to be further nourished by the rapid introduction of commercialized products (mainly in the case of private funding) and/or a proven case for competitive advantage (an important element for government funding). It follows, therefore, that projects that lack these features have difficulty in reaching production. This, for example, has been the fate of a number of wearable computer projects discussed in Chapter 2.

Intellectual property rights (IPRs) and, in particular patents, are another important factor affecting the diffusion of emerging technologies. The excessive use of patents by an industry may present a barrier to entry that may be prohibitive to smaller players. In the case of RFID, patent litigation between the largest players, Intermec and Symbol, was ongoing for months⁷⁰, and this has delayed the diffusion of RFID tags in a number of markets. Luckily, in September 2005, the two companies reached a compromise on their intellectual property rights⁷¹.

In addition to the uncertainties surrounding investment in new technologies, the lack of concerted global standardization efforts may have deadly consequences for emerging technologies. Of all the technologies enabling the Internet of Things, perhaps only RFID (and only RFID tag data formats) is on track in terms of standardization and global harmonized adoption. Like RFID frequency protocols, the specification of communication protocols for wireless sensor networks has suffered delays, but is now slowly catching up. With respect to nanotechnology, standardization thus far has been mainly country-specific or vendor-specific. Efforts at creating harmonized products have been fragmented: currently, there is no international agreement, even on terminology⁷². Robotics is an even more complex field, involving a combination of multiple subsystems interacting at different layers from visual sensors to management interfaces. Standardization occurs across a whole range of institutions (Box 3.5), e.g. IEEE, JAUS, OMG,

and SAE⁷³. The relationships between these organizations and the scope of their respective activities remain to be defined.

Box 3.5: Robotics is science, not fiction

Patchwork of standardization for robotics systems

Robotics encompasses electrical, mechanical and computer engineering and may therefore be the most complex discipline under the Internet of Things. This very complexity makes robotics extremely dependant on standardization. International standardization in the field of robotics is distributed across a number of institutions, including:

- The International Organization for Standardization (ISO), where standards related to robots are prepared by the “Robots for industrial environments” subcommittee. Its work covers terminology and definitions in robotics.
- The Society of Automotive Engineers (SAE) robotics group specifies electrical and mechanical interfaces between various subsystems, so that components are standardized for “plug and play” purposes.
- The Joint Architecture for Unmanned Systems (JAUS) group originally provided standards for the military robotics, and is now working on high-level architectures for internal and external communication protocols.
- The Object Management Group (OMG) specifies computer protocols for managing robotics systems and their compatibility with other standard computer and network management systems.
- The Institute of Electrical and Electronics Engineers (IEEE) has dedicated several workgroups to robotics (such as Robotics and Automation Society) in an attempt to develop a common platform for the industry. Strictly speaking, IEEE has not released any robotics standards; however, it seeks to ensure its compliance with existing standards for electronic and communications.



Image Source: Sony, QRIO Robot

Source: Robotics Trends, “Opinion: Robotics and the need for Standards”, 25 May 2005

Given the increasing reliance on wireless networks, and the growth of services in unlicensed spectrum bands, perhaps one of the most difficult regulatory issues to address is spectrum management. Regulation of markets and services will have to adapt and evolve to new technological realities, e.g. burdens on spectrum use, as well as new spectrum-enhancing technologies such as cognitive radio and ultra-wide band. Cognitive radio technology endows wireless devices with machine-learning capabilities to enable them to become intelligent agents for users. It hops between Bluetooth, IEEE 802.11, and cellular standards from 2G to 3G on the same wireless device, depending on the user’s location, electromagnetic interferences, operator tariffs and other criteria⁷⁴. Ultra-wide band (UWB) is a short-range technology designed for personal networks and used to relay data from host devices to other devices in the closest proximity (up to 10 metres), thereby complementing longer-range technologies such as Wi-Fi, WiMAX and GSM. UWB is set to eliminate wires by connecting anything from digital camcorders to PCs, High-Definition TVs (HDTV) and DVD players⁷⁵.

In addition, the current technological landscape has raised a number of concerns relating to privacy, which are only likely to be exacerbated by new developments. Regulation relating to privacy depends on national values and culture and cannot be reduced to a common global denominator. It is difficult to find consensus on privacy issues, even within a single area of jurisdiction (see Chapter 4).

Moreover, inappropriate fiscal policies may create significant barriers for the growth of the global market for the Internet of Things. For instance, high taxation and import tariffs on IT hardware and software directly affect the costs of adoption for producers and users alike. These instruments are often used by governments for the protection of domestic producers. However, they can slow down global technological development, acting as a barrier to international trade. In addition, non-tariff barriers to trade such as product functionality requirements (e.g. equipment certification) also pose some concern.

Production: Cost, interoperability and reliability

There are other unresolved technical issues that block market development even further. Interoperability between different communication platforms, as well as information systems, requires further work. Furthermore, system reliability and the risk of data transmission overload remain problematic. The issue of data overload is expected to grow, as RFID tags and sensors generate ever-increasing amounts of data.

At this stage of development, the costs of the key enabling technologies remain high and may be regarded as one of the biggest barriers to market expansion. Costs of market entry are difficult to overcome for start-up manufacturers, especially in robotics and nanotechnology. It has been estimated that a company looking into the production of carbon nanotubes would have to invest a minimum USD 5 million and a lead time of 9 months just to get going⁷⁶.

Even though prices are gradually dropping, the costs of integrated systems often exceed the economic potential of many entrepreneurs, in particular of small and medium-sized enterprises. A few years ago, many analysts expected the cost of RFID tags to drop to under USD 0.05, a cost point at which mass adoption of RFID can occur. However, the cost decrease has been slower than expected.⁷⁷ Today, prices start from around USD 0.10 to over USD 100, depending on functionality. The high cost means that RFID technology remains prohibitive for many applications. In retail applications, for instance, the price of RFID tags may exceed that of the product itself. Some analysts, however, predict that a cost of USD 0.05 for the most common tags should be attained by the end of 2006.

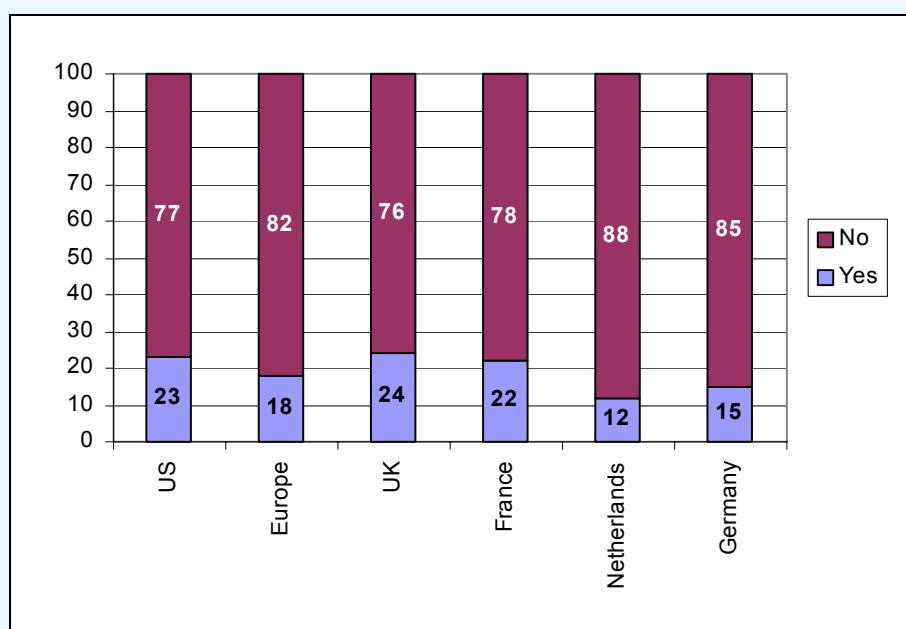
Similar problems have been encountered by nanotech manufacturers. Mass production drives costs down but not enough for them to become economically viable. Five years ago, one gram of low-grade nanotubes cost USD 1'000. The same nanotubes can now be purchased for USD 30, due to greater manufacturing efficiency and processing know-how⁷⁸. A further reduction in costs is essential if nanotubes are to expand their market share further.

Market: User behaviour hard to gauge

Lack of awareness among users is perhaps one of the most important constraints to the development of the Internet of Things. Since the Internet of Things is still in its nascent phase, many users might still have limited knowledge of its potential. RFID is a case in point. Despite the fact that it is currently the most mature industry in the family of the Internet of Things (and tags are used on a regular basis without the knowledge of users), a survey by Capgemini has revealed that only 18 per cent of Europeans and 23 per cent of US consumers have heard about the technology⁷⁹ (Figure 3.6). The general public is even less familiar with the benefits associated with nanotechnologies and wireless sensor networks.

Figure 3.6: Awareness of RFID is low

Responses given to the question “Have you heard of the technology?” (% of consumers)



Source: Capgemini, 2005

Furthermore, the lack of information coupled with unbalanced coverage may lead to misunderstandings about the advantages or disadvantages of emerging technologies, thereby creating an unfavourable consumer attitude. For example, the public perception of robots, machines whose only purpose in life is to “replace

human effort" (see Chapter 2), has been largely shaped by science fiction and Hollywood blockbusters. This has led to a general lack of trust in robotics. Fears of the general public range from job losses to an invasion by tiny robots or "grey goo". Unresolved issues related to privacy and data protection block further diffusion of technologies and even instigate active protests, e.g. in reaction to the adoption of RFID for tracking in-store goods.

3.4.2 Catalysts for growth

Unleashing the imagination

Science is not static - it constantly moves forward. In the context of the underlying technologies of the Internet of Things, there are a number of unexplored markets. Today, robots have entered the home as vacuum cleaners (Box 3.6) and pets (e.g. Sony's Aibo). Tomorrow's elderly-care robots and future robotic functionality are limited only by human imagination. It is difficult to predict the future trajectory of new technologies. In 1949, scientists thought that computers were only suitable for making quick calculations for scientific and data processing. The then president of IBM was made famous by his conviction that computers would not have a large market. When investment is coupled with the power of scientific innovation, new markets for the Internet of Things will surely develop.

Box 3.6: Robovac

Robot vacuum cleaners boost the personal robotics market

The Internet of Things has now entered the home. There will no longer be any need for a maid – the Roomba robovac will help with house cleaning. Roomba – an affordable and practical robot vacuum cleaner with a self-navigation system, manufactured by iRobot, a Massachusetts-based technology start-up – has hit the consumer robotics market. This vacuum cleaner without cables uses sensor technologies and ultrasound to avoid obstacles on its way and to choose the best route. The success of the home robots has encouraged competitors and imitators. The Japanese Matsushita with its version of the robot vacuum cleaner, Electrolux with Trilobite, Samsung with VC-RP30W, LG with Roboking; Australian Lennox with RoboQ and German Karcher with RC3000 robotic floor cleaner joined the battlefield. Some of the latest versions of robovac include extras beyond mere cleaning: they also help with home surveillance and air purification.



The advent of robotic vacuum cleaners on the market is remarkable for several reasons. Sales of robovac have been impressive. It took six years for the market of black-and-white televisions to reach the mark of one million users, and mobile phones were on the market for four years before they reached this mark. In comparison with these figures, robovac have enjoyed a very quick uptake: more than 1.5 million units were sold in less than 2 years. People considered these things to be an integral part of their homes, and the adoption of the robovac at such a quick rate is significant. It is not a question of whether you will have a robot at home: the question is how many? Robovacs may soon be a must-have household appliance, like a fridge, TV or computer.

Image Source: Pangea Tradewinds

Source: CNET News.com, "Robotics Industry Hypes Drive to Market", 10 May 2005; Asia Pulse, "LG Electronic Unveils New Vacuum-Cleaning Robot", 8 January 2005

The question is whether technology itself will create new markets or whether market demand will determine the direction of technological research. The notion of "demand pull" implies identifying market needs before creating products. The notion of "technology push" implies the identification and development of new technology, before looking for suitable markets. Market-driven companies try to develop products to satisfy gaps or needs in the market. Technology-driven companies look beyond current market demand at new technologies that could set trends. There are risks associated with following either one of these approaches. If a firm is strictly market-driven, it may not have technologies available to move into another market, where there is fierce competition. If a company is strictly technology-driven, there is an even greater risk that it will lose its investment if it does not find an audience for its technology.

Multiplying functionalities

As discussed in Chapter two, four key technology areas constitute the backbone of the Internet of Things and possess important functionalities that enhance performance and cut costs: miniaturization, automation,

intelligence and mobility. In a competitive framework, adopting new technologies – given gradually declining costs – will offer improved performance and considerable cost benefits, enabling the development of new applications. Wal-Mart, for instance, stands to save between USD 1.3 and 1.5 billion annually due to the implementation of RFID systems.⁸⁰

Manual labour will be gradually replaced with automated machines offering greater efficiency and accuracy. In the special case of painter robots, for instance, "up to 30 per cent savings in paint usage" can be achieved⁸¹. This can even go further. Sensors have now shrunk to half the size of a grain of sand and this miniaturization has opened new doors for the adoption of wireless sensor networks. Monitoring systems are becoming more convenient and are being integrated into a number of environments (e.g. parks, hospitals etc.). The need for the widespread rollout of many miles of cables has been greatly reduced, due to the mobility and convenience of wireless networks. In HVAC (Heating, Ventilating and Air Conditioning) control systems, the installation of wires represents from 20 to 80 per cent of the cost of a sensor point in an HVAC system⁸². Wireless sensor networks in HVAC control systems not only reduce overall costs by avoiding the installation of cables, but also other mobility and flexibility in relocating thermostats and sensors. In a survey conducted by Sensicast and B&B Electronics, the majority of respondents anticipated savings of between USD 100 to 250 in wiring and labour costs for every wireless sensor deployed⁸³.

The Internet of Things is gradually becoming more affordable. The promise of advanced functionalities married with declining costs will enable the mass proliferation of these emerging technologies. In this regard, personal robotics is a prominent example. Priced at approximately USD 200⁸⁴, the Roomba robot vacuum is breaking the stereotype of the expensive personal robot (Box 3.6). Moreover, when the price of RFID tags falls to USD 0.05, the market is likely to see explosive growth. Even at their current price, RFID chips are already generating savings for a number of businesses (Box 3.7).

Box 3.7: Chips are saving money

Keeping clean at a minimum cost

Although the price of RFID chips is still relatively high, current business practices already demonstrate their efficiency. DataMars has invented a microchip named Laundry Chip, which is heat-and acid-resistant. It is only eleven mm in diameter and suits laundry in residential care homes and homes for the elderly.

Laundries have traditionally used barcode labels to identify items. Chip prices are higher than barcode prices. The unit cost of a barcode including all the materials and printing is 15 eurocents (18 American cents). For a multi-read chip, if produced in amounts higher than 50'500 units, the cost is approximately EUR 1.23 (USD 1.53) plus another 15 eurocents (USD 0.18) for printed labels; in total, the cost of the chip is EUR 1.38 (USD 1.72). Some laundries are nevertheless using more expensive microchips rather than a cheap barcode.



Laundry Chips have a set of unarguable advantages, since the laundry-handling becomes automated and human involvement in scanning barcodes on the items is limited.; correctly stored washing, error-free entry/exit control, automated identification of garments, automation of accounting, savings on labour costs, and savings of both energy and chemicals, thanks to the accurate classification for different washing cycles.

In order to quantify these benefits, the following calculation can be made. Take an average volume of 60'000 clothing items. Given that people change clothing daily, according to statistics, each item goes through a triple wash cycle on a monthly basis. So, 60'000 items are washed three times per month, equivalent to 180'000 processes per month. If the multi-read chip is used, there is a six-cent saving per item. The monthly savings will be equal to EUR 10'800 (USD 13'500), while investments in 60'000 chips will be EUR 82'000 (USD 102'000). This means that the investment will be paid back within eight months. On an investment of EUR 82'800, a laundry can make an immediate saving of Euro 10'800.

Source: LCN, "Small chip, huge laundry benefits", January 2005

Fostering entrepreneurship

In order to transform what might seem like science fiction into science fact, certain risks must be taken in exploring unknown markets. This step, however, has to be nurtured and supported at the governmental level. Government encouragement of innovation within state programmes and additional research funding create

a favourable environment for entrepreneurs. Furthermore, more emphasis on applied research has a positive impact on the market in the short and middle term.

For this reason, fostering R&D and innovation has become an integral part of many national strategies, aimed at improving economic growth, productivity and competitiveness. Governments might, for instance, create tax incentives and/or develop a favourable regulatory framework, ranging from intellectual property rights to venture capital arrangements. Tax incentives are one of the most popular tools for luring companies into R&D and vary in scope from country to country. In general, tax incentives can be divided into two main types: tax relief in proportion to the volume (total amount) of R&D expenditure a company incurs (i.e. volume basis) and tax relief calculated in proportion to the amount by which a company increases its R&D expenditure compared to prior years (i.e. incremental basis)⁸⁵. In addition to tax incentives, there are other parameters that are crucial for firms wishing to start a business, such as education and human capital.

Governments can provide the means to facilitate innovation and reduce the level of risk-taking by innovative firms. In some countries, such as the United Kingdom, the government has created competency centres where stakeholders analyze the implementation of modern solutions. These centres provide the means to test innovations and adjust them to existing business models. The creation of innovation centres and the promotion of business associations also facilitate the exchange of information and knowledge among stakeholders. The diffusion of new exemplary business models can be helpful to those enterprises still afraid of re-engineering their business processes. However, reengineering entails a very high level of risk that, at this stage of development, many entities may tend to avoid.

Partnering for power

As seen above, it is extremely difficult for a company involved in the development of technology to foresee future markets and predict possible applications. Consequently, pursuing either strategy – to be market-driven or technology-oriented – is a risky decision. Therefore, companies have been opting to join forces and explore undiscovered markets in unison. There are many vertical as well as horizontal partnerships between big market players, relevant to the Internet of Things, that have been established over the last few years. For instance, in 2004 SAP and Infineon⁸⁶ – two major global IT players – joined forces in order to provide a true end-to-end RFID solution. This collaboration covers everything from tags to enterprise applications, including hardware, software and related services. In the same year, Oracle and Intel started to work together in order to improve RFID data management.

Partnerships between big players and start-ups are also on the rise, e.g. in 2005, Oracle joined forces with RFID start-up XPaseo, specializing in the production of components and monitoring of RFID-related data.⁸⁷ An increased number of mergers and acquisitions may create concentration in the market over the middle and longer term. Since the technologies underlying the Internet of Things are closely inter-related, alliances and external collaborations can give firms access to new technological breakthroughs and in-depth expertise.

Raising awareness and usability

In order to make the Internet of Things an everyday reality, the core enabling technologies have to be adopted by the general public. This will be possible only if consumers are aware of the benefits and advantages of using or installing new systems and are not faced with complicated user instructions. User-centric design and usability will be particularly important features, especially when taking into account the evolution from simple to complex systems, in which the user might have to become system administrator. In all cases, innovation should occur for the benefit of end-users and not merely for the sake of innovation itself. The importance of usability has been recognized at the international level through the adoption of standards. The ISO 9241-11 defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of user”. According to the ISO 13407 standard, the user-centered design of a product implies “the active involvement of users and a clear understanding of user and task requirements; an appropriate allocation of function between users and technology; the iteration of design solutions; and multi-disciplinary design”⁸⁸.

For many firms, funds allocated for education and awareness-raising campaigns represent a significant share of their marketing budgets. Usability and user-friendly design not only cut these costs, but also increase productivity, sales, revenues and customer satisfaction, while reducing development costs.

Newly emerging technologies have to attract the attention of lead users, but also of so-called trendsetters, including industry associations and the press, who are in a position to change or influence public opinion.

3.5 New business models

The emerging technologies enabling the Internet of Things are increasingly being adopted by companies in different industries, not only as a way of making their current business operations more efficient, but also to enable the creation of new business models. This section looks at how the perception of growth potential and market drivers are affecting the actions companies take and the business models they adopt. Companies are constantly looking for new areas of revenue growth. New technologies can give birth to novel business models, allowing firms to convert innovation into value-adding operations. The internet, for example, has fundamentally changed firms' internal processes, as well as their relationships to competitors.

Competition now extends far beyond established and traditional competitors, and is characterized by new ideas and innovative ways of improving products, services and processes. RFID, sensor technology, nanotechnology and robotics offer opportunities for established companies, as well as start-up enterprises, to create new business models. Even though the market for the Internet of Things is still in an early stage of development, it is growing rapidly. Just as the traditional internet created new opportunities for companies to deliver products, the Internet of Things presents even greater opportunities for business diversification, and may even imply a complete overhaul of established practices.

In order to understand some of the practical implications for firms, this section looks at some examples of what companies in three different industries – the retail, car manufacturing and telecommunication industries – are doing to maintain their competitive edge.

3.5.1 Tomorrow's retailer

In today's challenging business environment, retailers need to build supply chains that are fast, responsive and flexible. RFID and related sensor technologies are already delivering unprecedented value to supply chain management, and the retailers of the future are learning to take advantage of the growing opportunities that technologies can provide, far beyond the traditional supply-chain.

Embracing technology today

Large retailers have been eyeing radio-frequency identification for some time. Those leading the way in Europe (e.g. Marks & Spencer, Metro Group and Tesco) are advancing their initiatives with advanced RFID trials and innovative applications.⁸⁹ As retailers are constantly on the lookout for ways to improve the balance between inventory supply and consumer demand, they want to make sure that there are enough products on the store shelves, while keeping inventory costs down. One of the main benefits of RFID tags compared to conventional barcodes is that they can provide location information about an item, yielding valuable insights into warehouse management, security, logistics, and so on. In fact, RFID is being viewed as the most promising instrument for identifying and tracking products at the item level, improving the visibility of the inventory, and allowing retailers to retain control of the entire supply chain. This flexibility, and the emergence of other related technologies, makes retailers keen to ensure sure that they are first in providing solutions that give them a competitive advantage.

Using RFID technology for enhanced data processing, retailers are changing the ways in which they conduct their business. They are looking for opportunities not only in warehousing, but also along the whole supply chain. Smart retailers believe that implementing RFID early will allow them to deliver benefits to customers ahead of their competitors.

With an RFID future in mind, large retailers like Wal-Mart and Tesco are racing to adopt the systems throughout their operations internal and external. Wal-Mart, one of the world's largest retail chain (with more than 4'700 stores around the globe), has urged its top 100 suppliers to attach RFID chips to all containers of goods shipped to its warehouses.⁹⁰ The company's decision is in line with its operational goals of cost reduction through the intelligent use and application of new technology. Once Wal-Mart's larger suppliers have fully complied with its mandate of RFID implementation, all remaining suppliers will also be forced to adopt RFID. Stocking shelves and managing inventory has, up until now, been

a labour-intensive process. When products come equipped with RFID tags, however, retailers will be able to track them all along the supply chain. This information can then be used to minimize back-office inventory management, while keeping store shelves full. Product security and sales analysis will also be enhanced.

In the longer term

Following gains achieved in the back office, retailers can look into other ways of differentiating themselves from their competitors. However, these are early days, and any application of the Internet of Things by retailers requires trials and further evaluation. Given the improved transparency and availability of information, immediate benefits for retailers include: gains in operational efficiency, shorter delivery times, stocking time reduction, reduced product depletion, and more complete consumption information at hand. These, coupled with greater marketing insight into customers' buying habits, open up new opportunities for retailers, allowing them to venture into new business areas where this information will give them a strategic advantage. This valuable information is also of interest to other parties, including manufacturers. Indeed, retailers could potentially act as suppliers of marketing information to third parties.

The UK-based retailer Tesco is not only embracing low-cost RFID technology in its stores and throughout the supply-chain, but also examining the long-term potential of these technologies for its business.⁹¹ Tesco is expanding a year-long trial tracking the on-shelf availability of DVDs from within two stores to ten, and is further investing in readers, antennae and related equipment to implement other key business strategies.⁹² Item-tracking on shelves in the media department also gives an indication of where customer preferences lie – something that retailers could use to drive new business opportunities (e.g. in the media industry). Moreover, Tesco has already launched its own mobile phone service, competing with UK giants BT and Vodafone.

Meanwhile, manufacturers like Sony and Philips Semiconductors are testing RFID security and payment systems that can merge their online and offline sales businesses. These systems are designed to enable people to download electronic funds and opera tickets to an RFID smart card, thereby allowing companies to expand their businesses into areas where they previously had no obvious scope.

Making it work

The question is no longer if emerging technologies like RFID will be adopted by key players, but rather when and how fast. As a result, retailers and suppliers are taking the necessary steps to comply with their mandates, while others have a wider vision and have fully embraced solutions to improve overall business performance. Firms have been cutting costs from their business operations and supply chains for a number of years, while searching for areas in which to improve efficiency, and have invested in tools and systems to optimize their processes. Significant progress in areas which companies can measure has already been observed, but often parties are overwhelmed by the radical changes needed to their current business processes and IT applications to create a smarter supply chain. Even though technologies such as RFID are being adapted to meet major retailer mandates, a number of producers have limited their activities to tagging products, and have not incorporated this technology along the whole supply and manufacturing process, for maximum benefit. This push for change might, for instance, force the retailer to switch suppliers, integrate backwards or look into other business areas. To achieve the desired benefits, the redesign of all the processes in the supply chain, from supplier to regional distribution centre, from delivery to in-store activities, is necessary. In order to do this effectively, firms must integrate existing technologies as well as make room for emerging ones.

In the future, there will be additional market opportunities for other players closely connected to the retailer – for example the manufacturer of storefronts or smart shelves might act as the main data supplier for retailers and product manufacturers. Moreover, retailers and producers could potentially add value to their products by creating interactive RFID labels that are used not only to track products, but also to display information about them for consumers, such as ingredients, origin, recipes, and so on. This would create interesting opportunities for cross marketing. Still, companies will need to do more than merely come up with clever business models. In this context, partnerships are very likely to arise, as players in the retailing

industry try to understand where their own competencies lie and how to prioritize the areas in which they may need new technical expertise.

3.5.2 The innovative car maker

New applications for sensor and RFID technologies are emerging in the automotive industry and slowly becoming mainstream. Car manufacturers, such as General Motors, Toyota, and Ford, are applying RFID tags to every frame in their assembly lines because of the immediate gains that can be achieved.⁹³ Finding more users implies a reduction in costs and greater savings for companies implementing the technologies, which in turn drives more applications within the automotive industry and outside of it. Car manufacturers are now looking at new manufacturing processes as well as telematics services, including traffic information, navigation assistance and other data services.

Smooth business processes

The implementation of RFID and sensor-based technologies by car manufacturers can deliver the following advantages within the plant: error reduction, greater labour efficiency, better security, enhanced management of staff location, improved demand-forecasting accuracy, and the reduction of critical order cycle times. This has vast implications within the car manufacturing plant and without.

Toyota, for example, employs an active RFID-powered vehicle tracking and management system (VTMS) to locate new vehicles at its processing centres. When new vehicles arrive at the centre, they are each equipped with an active RFID WhereTagTM containing the vehicle identification number. The WhereTagTM remains on the vehicle until it has been customized according to the buyer's specifications and is ready to ship to the dealership.⁹⁴ This allows Toyota to automate their business processes and speed up delivery of vehicles to dealerships, monitoring the exact time of delivery and initiating invoicing only after off-loading has taken place. This in turn reduces processing and labour costs, while achieving better customer service. Many years back, when Toyota's main focus was manufacturing, it used its famous Toyota Production System (TPS) to speed up car manufacturing processes ahead of its competitors. Emerging technologies like RFID in combination with processes like TPS can lead to further efficiency and better response to consumer demand. Such developments might also enable car makers to diversify their business portfolios.

Re-designing business models

Telematics, as described in Chapter 2, refers to the convergence of computers and telecommunications to enhance motor vehicles and provide convenient online services to road users through network connections. Telematics solutions can, among other things, allow companies to achieve their strategic objectives by creating stronger and longer-lasting relationships with customers. With the exception of phone and credit card companies, who have instant access to a wide range of data about their customers, most companies know very little about how their customers use their products. Telematics is revolutionizing the car industry as it expands business areas and opens up the possibility of understanding customers' real needs, desires and habits. Tracking information related to the length of the car journey, driving styles, time spent in cars, locations visited, number of journeys and so on, can be used to design cars and services to meet market requirements. Access to this kind of proprietary information not only provides the potential for a more direct marketing channel for manufacturers, with the possibility of bypassing the car dealer, but can also lead to new product development and business models. Being able to better assess market demand can put innovative car manufacturers ahead of their less tech-savvy competitors.

Business models using telematics presently focus mainly on customers subscribing to car-related services such as traffic information, navigation assistance or additional entertainment content. However, car companies have begun providing complementary services to customers, e.g. by extracting information from the vehicles to offer preventive maintenance. The car maintenance model can lead to significant cost-reduction opportunities through early problem detection, fewer recalls and lower product liability costs. When fitted with the right sensors, car parts can detect faults, and automatically order replacement parts or schedule car maintenance. Another important business model that is slowly making its appearance relates to the collection and sale of such data to third parties.⁹⁵ Access to this new information can provide car makers

with tools to venture into new service areas. With detailed information on the state of the car, how and where it has been used, they may even be able to offer vehicle insurance or road-side assistance to customers.

The success of telematics solutions is dependent on deployment cost, consumer awareness and demand. Given the opportunities that telematics and the convergence of computing and telecommunications can bring, top carmakers are prototyping telematics and online services for a new generation of vehicles. Consumers are beginning to look for the same ICT environment in cars that they have in their offices or homes. In anticipation of this trend, car manufacturers are rapidly putting automotive information and entertainment equipment on the market.

DaimlerChrysler, for example, has introduced a Bluetooth-based system (UConnect) that allows specially equipped mobile phones to synchronize with in-car telematics hardware. This move might be an indication of an area in which car makers will play a greater role in the future. UConnect allows an ordinary mobile phone, placed on the car seat, to work with the telematic systems in the car.⁹⁶ The driver dials the phone using voice commands and can engage in conversation by talking into a receiver installed in the car. His or her interlocutor can be heard through the car's built-in speaker system.⁹⁷ Similarly, General Motors has chosen to include its telematics system "OnStar" on all of cars manufactured after 2007 (Box 3.8), which is likely to affect the industry as a whole.

Box 3.8: Connecting strategies for the automotive industry

Telematic solutions enhance what the car can do for you

General Motors (GM) will routinely install its OnStar equipment on all of its consumer passenger cars, SUVs and light trucks sold in North America starting with 2007 models for providing the full experience of integrating the car into the smarter world. The reason behind this decision is that wide-scale installation onto all GM vehicles will lower the costs; interfaces, harnesses and modules can be consolidated, hopefully lowering the marginal cost of adding new subscribers as some infrastructure and operating expenses are already in place; and a services platform for future business and service portfolios can be provided. Putting OnStar on all vehicles sold will also increase the awareness of telematic solutions, which in turn will allow GM to leverage off the increased awareness of the OnStar brand, to help in the overall promotion of telematics solutions to the general public. Installing OnStar in all vehicles also puts further pressure on GM competitors that currently do not offer telematic solutions.

However, the GM's OnStar business model has both its supporters and critics. OnStar currently offers its services to more than 2 million GM vehicle owners (as well as Acura, Audi, Isuzu, Lexus and Subaru owners) at monthly fees ranging from USD 17 to USD 70 – depending on the level of service provided. Some analysts claim that only two thirds of OnStar-equipped vehicles are ever activated by the car owner, despite the fact that the service is free for one year. OnStar re-subscription rates are also said to be below fifty per cent, which is significantly less than the seventy-eighty per cent renewal rate that is needed to reach profitability. But for car manufacturers, it is all about harnessing the power of new breakthrough technologies, in order to gain competitive advantage and increase their share of the market. Customer acceptance is key in this process, and as public awareness increases, the potential to expand the market beyond high-end vehicles by all car manufacturers is also growing.

Sources: General Motors Press Release, "OnStar and StabiliTrak To Become Standard Equipment On GM Vehicles", 30 January 2005, at <http://www.gm.com>; The Detroit News Auto Insider, "GM to use OnStar to notify owners of recalls", 17 August 2005, at <http://www.detnews.com>

A new balancing act

For the car manufacturer of the past, the balancing act has depended to a large extent upon production equipment uptime and precise synchronization between various departments in the process, from stamping, plastics, and engine operations, to assembly, body and paint shops. The focus on telematic solutions, enabling the smart car to communicate with its surrounding environment, poses new challenges that the players of today might not be ready to face. Developing the appropriate partnerships could fill capability gaps and address the apparent challenges in the industry. A car manufacturer could, for instance, quite easily collaborate with a mobile operator to provide communication services to its vehicles. The manufacturer might be interested in exploiting other aspects of the relationship, such as servicing vehicles, providing information to insurance companies, working with breakdown as well as scrap metal companies, and taking a proportion of mobile subscription and traffic revenues. Future developments depend on how strong the partnerships with the operator and vehicle customers are and how willing they are to share information for the benefit of all parties. The mobile operator could take this a step further by, for instance, working with other partners to deliver additional services to the very same vehicle owners. The success of any business

model will be determined in the end by the customer, and who they might trust for providing a particular service. As the Internet of Things is built on the seamless interaction between objects, new revenue streams by car manufacturers, as well as other parties, can only be generated through close linkages.

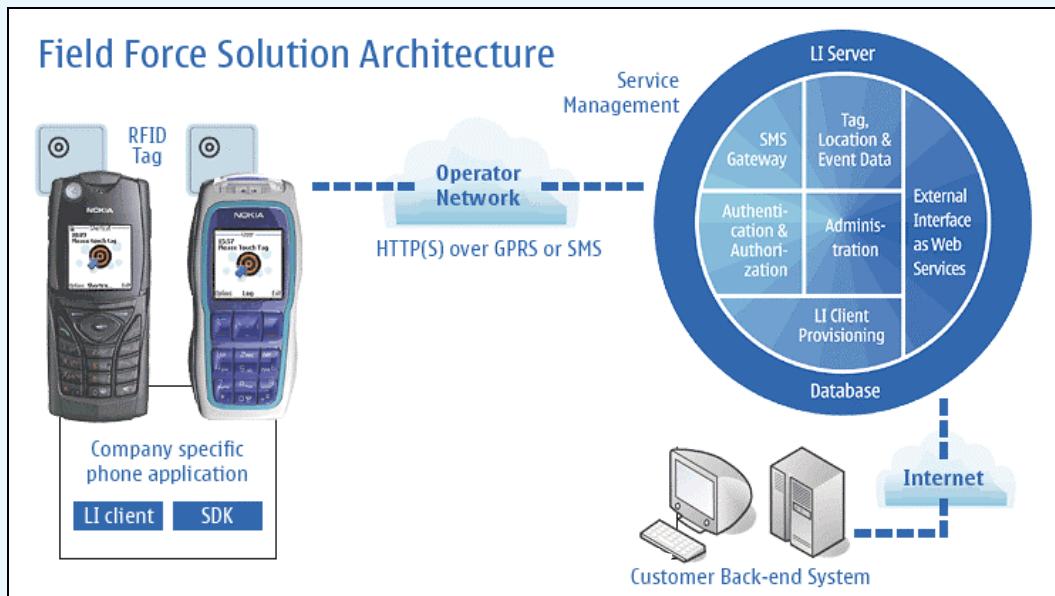
3.5.3 The telecom player of the future

Even though early business cases for RFID focused on logistics and supply-chain management, future development will be more diverse and affect a large number of companies, especially in the telecommunication industry. Network operators and service providers can take on increasingly challenging roles for delivering and operating back-end infrastructure and services related to the Internet of Things. When items everywhere, large and small, carry RFID tags, a multitude of different applications will become possible in the home and in business. The mobile phone, in particular, will provide an important portal to new enhanced services.

Box 3.9: Telecom device producers exploring RFID-related opportunities

RFID makes its way into the mobile phone

The Nokia Mobile RFID Kit (part of the Nokia Field Force Solution) released in 2005 includes two Xpress-on RFID reader shells, along with application software and a number of RFID tags. The RFID-enabled mobile phone can read RFID tags to initiate an action, such as calling, messaging, browsing or recording data. With this new direction, Nokia is targeting field-force personnel, who might use the phones to read RFID tags and translate their content into action.



The creation of the NFC (Near Field Communications) standard will give a further boost to the convergence of mobile phones and RFID technology. NFC is a short-range wireless technology that enables easy and convenient interaction between devices. Operating in 13.56 MHz frequency range, the technology allows for transmission over a distance of a few centimetres and is optimized for service discovery and initiation.⁹⁸ NFC technology enables RFID reader-only, tag-only, and smart-card-only solutions.

Since the mobile handset need only be held near tagged items to access information, some expect NFC to be key to areas such as mobile electronic business cards and payments. However, NFC is still in a testing phase. At this time, the main target is the Asian market, where contactless smart card systems are already widely used. With NFC, mobile users will be presented with the opportunity to buy public transportation tickets, download entertainment and other new services using their handsets. Based on the ISO 18092 standard, NFC will expand the traditional reach of the telecom network. Handset manufacturers, such as Samsung and Motorola, have already revealed plans to integrate NFC-related technologies in their handsets.

Source: Nokia

While traditional network operators focused on voice, tomorrow's telecommunication players will shift more and more to data services. Better storage capacity and higher data transmission volumes will increase overall revenues stemming from the Internet of Things. Mobile operators (2G and 3G) can extend the reach of their current networks by linking them to RFID systems or incorporating sensor technology in handsets.

The adoption of RFID systems by businesses and consumers is likely to generate additional data traffic, a boon for network operators. Similarly, handset manufacturers will team up with RFID technology providers to develop joint products.

As mentioned above, Nokia released its first RFID-enabled mobile phones in mid-2005. The market for RFID-enabled mobile phones overall is predicted to grow substantially in the coming ten years: the number of RFID handsets is expected to grow from 50 million units in 2005 to 300 million in 2010 and 600 million in 2015⁹⁹.

Near Field Communications (NFC) is a new standard enabling the convergence of mobile phone technologies and RFID. By touching RFID-tagged objects, users will be able to read information about the object, send data to other objects, access databases and record new data entries. The RFID reader in the phone can scan the content of the tagged object and respond. For instance, the location, task status, or working time can be sent as an SMS message or over the phone's internet connection (Box 3.9 above).

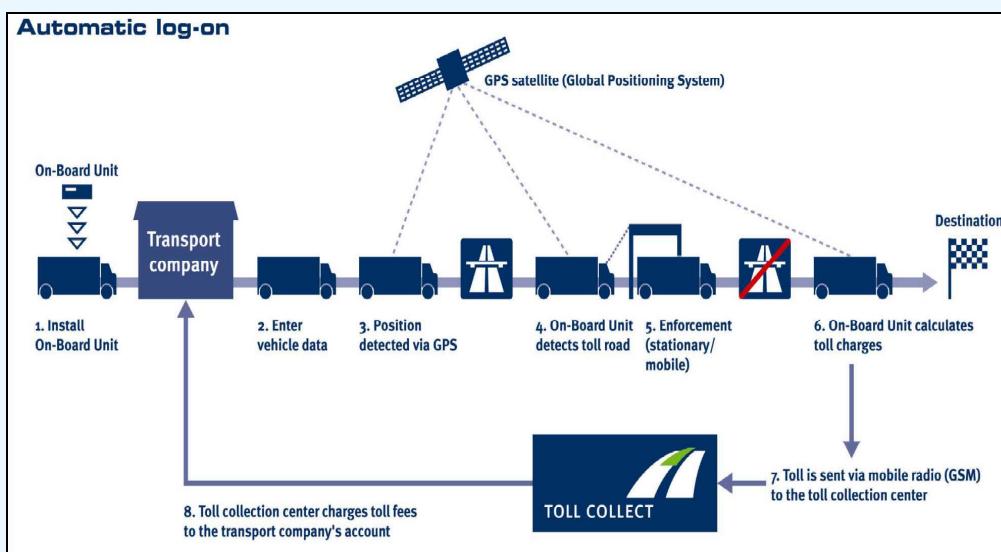
Box 3.10: DSRC-enabled business model for expanding the telecom network

Benefits for telecom operators through the expansion of basic infrastructure

A new generation of RFID for vehicles, Dedicated Short-Range Communications (DSRC) technology may prove an important component, opening up the potential for new revenue streams. DSRC can offer much higher data transmission speeds than traditional RFID, which is crucial for fast-moving vehicles. Its main advantage is the longer read-range. DSRC can also operate under multiple overlapping communication zones, a condition that most RFID systems today cannot meet.

DSRC systems offer the potential for partnerships between different players – car manufacturers, traffic authorities, toll collectors, and telecom operators. Toll collection uses not only DSRC and RFID, but also Global Positioning System (GPS) and GSM networks to provide connectivity between all parties. Payment systems being tested for frequent road users in a number of different countries are based heavily on a GPS (satellite) tracking transponder, but also include elements of RFID as used for regular tolling, electronic odometers, and other technologies.¹⁰⁰ The aim of the integrated systems is to generate a record of distance travelled on different roads, so that the charging can be differentiated by time and place. The systems also use a mobile wireless communication system to link the in-vehicle equipment with the accounting and payment centre.

In January 2005, Germany implemented an automatic toll collection system which charges the car and truck drivers according to the number of kilometres driven on the highway. Through a satellite system, users can drive on highways continuously without having to stop or to pay road tolls. The charging system is fully automated and there is no need for the direct involvement of people. The system is based on the combination of GPS, GSM and sensors, thereby generating additional traffic for wireless network operators. As illustrated below, the system works as follows: a vehicle registered under the toll collection system is identified by GPS as it enters onto the highway. The on-board unit (OBU) detects the nearest toll station and calculates the charges. This information is sent automatically over the mobile network to the toll collect booking centre, which charges the transport company.



Sources: German Ministry of Transport, Building and Housing; *RFID Journal*, "Automotive RFID Gets Rolling", 14 April 2004; *Tollroadsnews.com*, "Brits to toll trucks in 2006", 10 June 2003

Many large telecom operators, in particular mobile operators, are exploring new areas of growth. Object-to-object communications is one such area. Based on estimates by the FocalPoint Group, the market value worldwide of object-to-object communications in 2004 was close to USD 34 billion. Their forecast shows that, when including hardware, software and services, this figure might reach USD 180 billion by 2008. Alexander Research presents even more optimistic expectations, predicting that the value of the market for this form of communication will reach USD 270 billion in 2010 compared to the USD 24 billion estimate of 2004. This has far-reaching implications for the telecommunication sector. Mobile players like Orange, Vodafone and NTT DoCoMo are already intensifying their efforts to address the needs in the market for this new type of communication service. Mobile operators have a competitive advantage given their existing relationships with end users, which they could leverage to offer more diverse value-added services. Clearly, network operators have much to gain from these emerging technologies as many will generate additional traffic (Box 3.10 above).¹⁰¹ Still, the collaboration of different parties – mobile operators, manufacturers, suppliers, retailers and banks – remains important challenge for companies that have been used to playing solo.¹⁰²

3.5.4 Competing in a changing marketplace

The wide variety of possible applications of technologies like RFID, nanotechnology, sensors and robotics can increase a firm's ability to innovate as well as compete. Their implementation can improve data collection and in turn allow for transparency, detailed analysis, and better decision-making in business processes. Some of the more specific benefits include: real-time product tracking, enhanced accuracy in distribution-related processes, and lower human resources costs. The advantages stemming from the technologies enabling Internet of Things go far beyond the supply chain, and affect entities ranging from government agencies and hospitals to insurance companies and customer service departments.

The Internet of Things represents a departure from traditional telecommunications and it is therefore not a simple task to map the direction and impact of its enabling technologies. The integration of these new technologies is a challenge, but should be viewed in terms of the new opportunity it offers rather than any threat posed to existing business models. The business models discussed above are innovative but still need to be replicated more widely. As industry and government agencies reach agreement on standards and as infrastructure is upgraded, prices for technologies will drop further. However, it is the change in the business processes within firms that will be fundamental to their success in a transformed marketplace.

3.6 Conclusion

The Internet of Things promises increased revenues, diversified services and smarter products. However, the lack of awareness about its potential is hindering market development and preventing firms from exploiting the underlying technologies fully. Although it is difficult to quantify with precision the future size of the market, the forecasts cited above suggest significant growth over the short to medium-term.

In developing and re-designing business models, firms must apprise themselves of the different barriers and drivers of this growth. Lead users, in particular, play an important role in enticing other players to adopt new technologies, by exploring new ways of doing business, e.g. through miniaturization, real-time identification, and further automation. Raising awareness among end-users is equally crucial. Only then can technologies reach markets with the adequate demand in place.

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4 CHAPTER FOUR: EMERGING CHALLENGES

4.1 Introduction

For businesses and consumers alike to fully exploit the potential of the new technologies discussed in this report, a number of public policy challenges must be overcome. In the first instance, standardization and interoperability are pre-requisites for the widespread diffusion of any technological development. Governments must also create effective mechanisms for fostering national innovation and managing their progress. One of most important challenges, particularly for technologies such as RFID and sensor networks, is the protection of consumer privacy. This chapter examines some of these challenges, before exploring the broader socio-ethical implications of a truly pervasive Internet of Things.

4.2 Standardization and harmonization

Standards are ubiquitous – hardly a day passes during which we do not encounter standards in one form or another. The metric system, for instance, is one of the oldest standards around. Frequent travellers are familiar with the benefits of standardization, but also with the inconveniences brought about by a lack of standards, e.g. in trying to recharge mobile phones using different types of electrical sockets. With computers, it was problematic for some time to open a Microsoft Word file using an Apple computer. Standardization benefits not only consumers, but businesses too. Firms can enter foreign markets more easily when they comply with the standards prevailing in the host country. Nearly all commercially successful technologies have undergone some process of standardization in order to achieve mass market penetration. The ubiquitous internet and mobile phones of today would not have thrived without key underlying standards, e.g. GSM, IMT-2000 and TCP/IP.

4.2.1 Setting the standard

Standards have a number of different dimensions. Generally, a standard can be defined as a model or action to be compared with,¹ or a format to be followed.² In common terms, a “standard” means something that is recognizable and familiar to many people. For instance, when two people from different geographical and cultural backgrounds look at a computer, they both know that it is a computer, and that it has standard features that are commonly and widely used (Figure 4.1). Standards eliminate relativity and imply a minimum level of quality. Technical standards are “document[s] established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines, or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.”³

Within field of ICTs, standards are often crucial for the development and diffusion of hardware components, software and services. The presence or absence of standards encourages or hinders market development and technological diffusion. One example often cited is that of mobile communications in Europe and the United States. In Europe, the GSM standard was mandated at the European level early on, which boosted the rapid development of the European mobile communication market. In contrast, regulators in the United States allowed the market to decide which standard was better, resulting in a highly fragmented market structure, where users experience problems with roaming and handset interoperability.

According to some economists, standardization can account for as much as one-third of economic growth.⁴ Similarly, a lack of standards may hinder economic growth and prevent the development, export and spread of new technologies. Excessive or inappropriate use of standards beyond the remit of consumer safety means standards can act as technical barriers to trade and may be used as a severe protectionist measure, alongside quotas and tariffs.⁵ Lack of compatibility with national standards may prevent foreign suppliers from entering specific markets (e.g. the second-generation mobile phone market in Japan is dominated by the PDC standard, in use only in that country). Harmonized standards, on the other hand, can open up more markets to smaller companies. For large monopolists, standardization poses the risk of losing a dominant market position. Standardization can also promote technological development and help avoid the duplication of research efforts. When industry players agree on a basic standard, researchers from different laboratories do not have to start research from scratch, but can use the standard and improve upon it. As Craig Barrett, President of Intel, once said, standards allow the industry to “evolve around [those] common characteristics and innovate on top of them.”⁶

Figure 4.1: What is a standard?

The importance of standards in different contexts



Source: Swiss-Japan Association for Engineers and Scientists at <http://www.swiss-japan.org/>

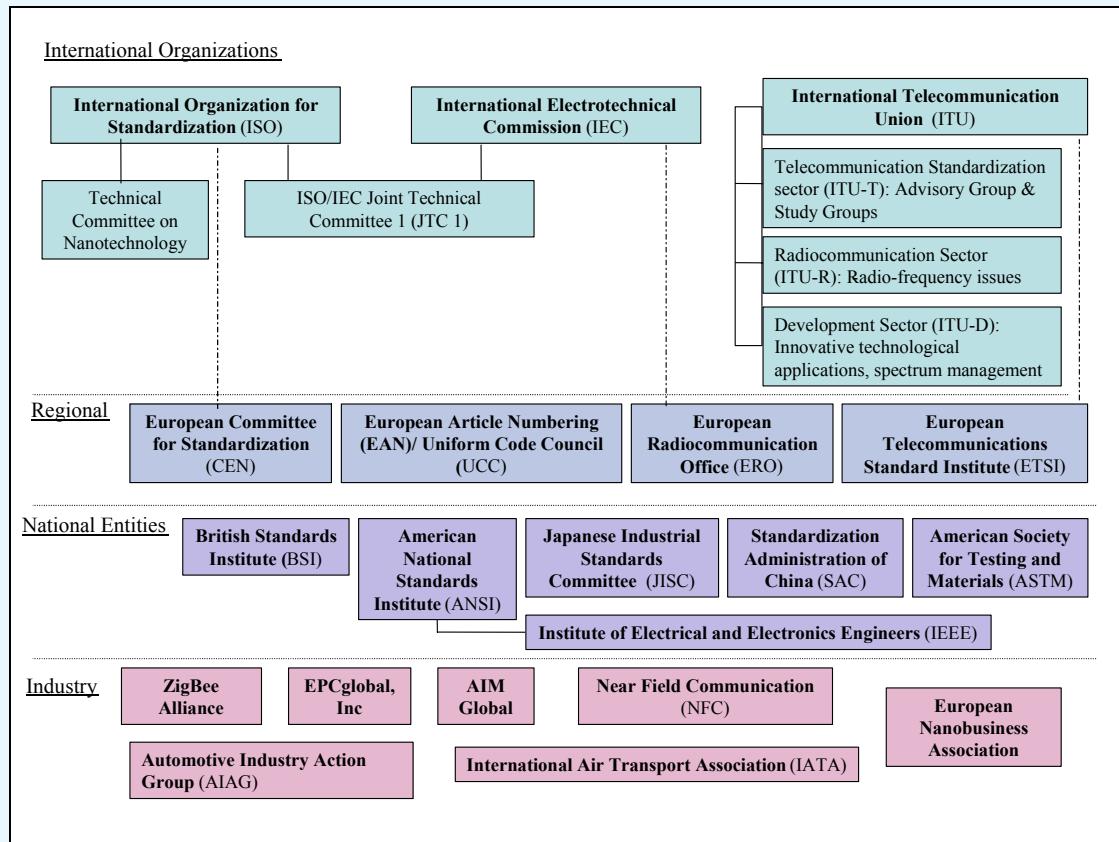
From the users' perspective, the importance of standards lies in the ability of consumers to use products from different manufacturers, whilst preserving interoperability and standard features. Moreover, setting standards promotes economies of scale. A large number of manufacturers or suppliers using the same standard means greater choice and lower prices for consumers.

4.2.2 Working together

The creation of standards enables the use of interoperable technologies across different suppliers, industries and countries. Multiple organizations are participating in the establishment of standards for specific applications underlying the Internet of Things - in specific sectors (e.g. aviation or the automotive industry) or for cross-sector uses. An important function of standardization institutions is that they facilitate the coordination of standardization efforts in a certain area and promote more widespread acceptance of standards.⁷ These organizations can include entities from industry and the private sector, as well as national, regional and international standard-setting entities. Given the ongoing convergence of different computing and communication platforms, it is increasingly difficult to distinguish between different "standardization jurisdictions". While international organizations such as the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO)⁸ have committees for most or all of the technologies covered in this report,⁹ mapping the complete institutional framework underlying the creation of the Internet of Things is a complex task beyond the scope of the present report. There is a host of organizations at the regional, national and industry level that focus on a particular technology (RFID, nanotechnologies), process (data collection, transmission and frequency allocation, security) or application. A simplified outline of the institutional structure in standardization for the Internet of Things is set out in Figure 4.2.

Figure 4.2: The world of standards

Map of international standardization institutions for the Internet of Things



Source: ITU, adapted from FMI-ADC1 TAG, “SC 31/FMI-ADC1 TAG: The Roadmap to International Auto-ID Standards”, January 2003

4.2.3 Harmonizing the Internet of Things

As the Internet of Things becomes a reality, networking will become even more complex, with virtually every computing element or household object becoming part of a larger interconnected system. In the future digital home, refrigerators could order food directly from the supermarket, scanning items using RFID and sending an order to the supermarket over a mobile messaging platform. In this example, the fridge, the RFID tags and readers, together with the mobile networks, must all support the same communication protocols, and be able to communicate with each other. Indeed, all the computing elements in the digital home must interact in harmony, just like musical instruments in an orchestra.

The evolution of a standard typically follows one of three scenarios:¹⁰

- **Market-defined standards:** In this case, the standard is usually proprietary, i.e. a user can be locked into one vendor, due to the incompatibility of products from different vendors. The Microsoft operating system “Windows” is one of the most familiar examples. But even when a proprietary standard dominates the market, alternatives may emerge, such as, for instance, open source software.¹¹ The Linux operating system is the forerunner of the open source movement. Other successful products include Apache, software that runs web servers.¹² In the internet browser market, though Microsoft Internet Explorer has the lion’s share, users can now choose from alternatives such as Firefox and Opera.¹³
- **Industry agreement:** Industry players sometimes reach an agreement to establish a group to work on a standard. In 1998, for instance, Ericsson, IBM, Nokia, Toshiba and Intel created the Bluetooth special interest group (Bluetooth SIG).¹⁴ Usually, such standards are open and non-proprietary, so developers of the standard agree to reveal intellectual property regarding the standard “on a non-discriminatory, royalty-free or reasonable royalty basis to all interested parties.”¹⁵

- ***De-jure* national or international standards:** *De jure* standards can also be set at the national or international level, when governmental bodies mandate or adopt the standard. The IMT-2000 family of standards for 3G mobile networks was developed under the auspices of the International Telecommunication Union (ITU). The rationale behind this decision was to create a harmonized approach to third-generation mobile networks, and to prevent further fragmentation of the mobile market.

For the enabling technologies that are the key building blocks of the Internet of Things, standardization has so far evolved through a mixture of *ad-hoc* industry agreement and the use of national and international standards. An example of the latter is the allocation of radio spectrum frequencies for the deployment of applications related to the Internet of Things. The allocation of frequencies for different services and technologies is regulated at the national level by ministries of communication, post or regulatory commissions, such as the Federal Communications Commission in the United States. At the regional and international levels, organizations such as the European Telecommunications Standards Institute (ETSI) and ITU respectively have promoted harmonization to facilitate harmonized spectrum allocation across countries. RFID technologies, for instance, operate in different frequency bands depending on the type of application, and this area is currently in need of further standardization (Table 4.1).

Table 4.1: RFID rides different waves

RFID frequency bands and applications

Frequency Band	Applications	Comments
Low-Frequency (LF): 125-134 kHz	Animal tracking, car immobilizers.	This frequency band works well in environments where liquids or metal are present and when fast read rates are not needed.
High-Frequency (HF): 13.56 MHz	Smart cards, SIM cards, labels, passive tags.	Most commonly used band.
Ultra-High Frequency (UHF): 433 MHz 860-870 MHz 902-928 MHz 950-956 MHz	Low-power active tags; item-level tracking.	This band offers a longer reach (less than a few metres) and provides the ability to read multiple tags at higher speeds.
Microwave (μ Wave): 2.45 GHz	Industrial uses; electronic toll collection.	This band is also used for Wi-Fi systems and Bluetooth.

Sources: ITU, adapted from J. Falck, “European Regulatory Standards for RFID”, 20 April 2004; D. Heyman, “Standards”, 20 April 2004, at http://www.cordis.lu/ist/directorate_d/ebusiness/workshop.htm; V. Stanford, “Pervasive Computing Goes the Last Hundred Feet with RFID Systems”, *Pervasive Computing*, Vol. 2, Issue 2, April-June 2003

The need for standards in the coming era of ubiquitous computing is heightened by the convergence of different communication and computing platforms. At present, users can access the internet from laptops or mobile communication devices (for example, phones, PDAs or smart phones). Devices can also exchange data wirelessly using Bluetooth or infrared – due to an alliance between computer and handset manufacturers, who have joined forces in the hope of providing standardized platforms. However, it is hardly possible to expect that scientists can define standards for all devices or services *a priori*. According to some expectations, mass penetration or true ubiquity will most likely be based on open standards, rather than proprietary technologies.¹⁶ In this vision of the Internet of Things, ICTs will transform from being revolutionary or disruptive technologies into an integral part of modern infrastructure – exactly as it happened with electricity or the steam engine.

For the technologies underlying the Internet of Things, some success in standardization has been achieved, for instance, in standards relating to data formats for RFID tags (Box 4.1). The Auto-ID Center was established in the late 1990s for standardization efforts in RFID. The Center is an industry alliance between RFID manufacturers and suppliers closely involved in the development of new applications and products. The Auto-ID Center had some notable success in achieving the interoperability between different RFID systems. It has since been incorporated into the non-profit organization, EPC Global, which continues to represent the interests of different stakeholders and to coordinate efforts in RFID standardization.

Box 4.1: Agreeing on radio-frequency identification*Standardization process for RFID*

The RFID standardization process started in the late 1990s with the establishment of an Auto-ID Center. The purpose of this Center was to “facilitate full-scale interoperability between multi-vendor RFID systems and to propel RFID technology into a broad array of markets.”¹⁷ In 2003, Auto-ID research activity developed into the creation of EPC Global.

There are two main types of RFID standards under development. The first relates to RFID frequency and protocols for the communication of readers with tags and labels, which is being dealt with by international standard-setting bodies, such as the European Telecommunications Standards Institute. The second concerns the standardization of data formats placed on these tags and labels (e.g. the Electronic Product Codes).¹⁸

The RFID standardization process is taking place in different forums. EPC Global in its Version 1.0 defined the overall system and specific requirements. Due to this specification, tags and readers can communicate with each other in line with the principle of interoperability. ISO has developed a series of standards that cover the structure of radio-frequency identification codes for animals, certain parameters of vicinity cards, requirements for automatic identification of freight containers and data capture techniques for item management.¹⁹ ANSI developed a standard ANSI 256, which is applied to a family of compatible RFID devices. The Standardization Administration of China announced in 2004 that it has set up an RFID Tag Standards Working Group to develop China's national standards.

Despite these efforts, there is still a lack of harmonized and globally accepted interoperable standards on RFID infrastructure and protocols.²⁰ In this situation, there have been calls for increased involvement of ITU in the standardization and harmonization of RFID.²¹

Sources: ITU; B. Manish, *RFID Field Guide: Deploying Radio Frequency Identification Systems*, Prentice Hall PTR, 2005

Other key segments however, suffer from limited standardization preventing their widespread adoption, for instance in the case of sensor technologies and smart appliances. A lack of standards and interoperability has posed a challenge to the widespread adoption of these technologies. Headway in standards for nanotechnology is being made in a number of countries, but mostly at the national level (Box 4.2). Different countries are establishing bodies to oversee the development of nanotechnology and standards in nanotechnology.

At the same time, since standards can act as technical barriers for trade, the role of international collaboration is important. In this context, international organizations such as ITU can contribute to the management and harmonization of standardization processes at the global level. Given its membership of governments, private sector entities and civil society, ITU provides a particularly effective forum for international standard-setting. Standard-setting is now an integral part of strategies for technological development for both public and private players, and will become even more important given rapid innovation, growing technological pervasiveness and the importance of technology for economic growth. The mantra in the race for standards seems to be: “if you lose in international standardization, you will lose markets.”²²

4.3 Privacy implications

This section looks at the growing importance of the protection of privacy in the environment of the Internet of Things. Defining privacy is no easy task, as the concept is an elusive one. It incorporates multiple perspectives (legal, technical, sociological) and is culturally, politically and historically “bounded”. An increasingly pervasive internet also raises important socio-ethical concerns that are worth considering.

4.3.1 Privacy: An evolving concept?

In contemporary terms, the notion of privacy revolves around the distinction between the private and public spheres of human existence – the word “privacy” itself originates from the Latin word “privatus” which means “apart from the public life”. However, new technologies are rapidly erasing these boundaries. The overwhelming use of the mobile phone, as an early example of ubiquitous ICTs, is merging the public and private spheres, as public places are increasingly privy to the private lives and conversations of mobile

users.²³ Information and communication technologies have in some sense expanded traditional physical space, through the creation of “virtual communication” spaces. The deliberate linkage of the physical world with the virtual world through RFID tags and sensors has led to a further “permeability”²⁴ between the public and private contexts. The debate surrounding privacy in a ubiquitous Internet of Things hinges upon an individual’s ability to control the blurring boundary between the public and private spheres, and to determine who can access his/her private sphere and under what conditions.²⁵ Privacy has been defined by scholars as “the power to control what others can come to know about you”²⁶ and “the right to determine how, when and to what extent data about oneself are released to others.”²⁷

Box 4.2: Standardizing on a nano-scale

Developing standards for nanotechnology

According to some estimates, the global market for nanotechnology will reach USD 1 trillion by 2011. But one of the fundamental challenges in the further development of the nanotechnology market is the lack of standards, ranging from basic definitions to calibration and measurement. The absence of these basic definitions demonstrates how significant the standardization gap in nanotechnologies actually is. For instance, there is still no documented or commonly agreed answer as to how nanofibres differ from nanowires. Adopting common definitions in nano-terminology will enable scientists all over the world to speak one common language. Currently, a number of institutions at both the international and national levels are involved in the standardization of nanotechnology.

At the international level, the ISO Technical Committee on Nanotechnology will deal with standards regarding classification, terminology, metrology and environmental issues. The IEEE Standards Association launched a Nanotechnology Standards Initiative in 2003 to develop nanoelectronics standards. This project will focus on the development of standard methods for the electrical characterization of nanotubes, nanoscale devices, components and other materials.

With regard to national initiatives, it is vitally important for countries to keep up with the standardization race, because once a country’s national standards are adopted internationally, this country can gain huge advantage in global markets. Thus, in the United States, the ANSI Nanotechnology Standards Panel, together with the National Institute for Standards and Technology, published recommendations identifying the most urgent areas for standardization, including metrology, terminology material properties, testing methods for toxicity and environmental factors.²⁸

In Europe, the European Committee for Standardization created a special task force to deal with nanostandards. Other European organizations include EUROMET (the European Collaboration on Measurement Standards), EUROLAB (the European Federation of National Associations of Measurement, Testing and Analytical Laboratories) and EUSPEN (the European Society for Precision Engineering and Nanotechnology).

The Chinese experience is also worth highlighting. China was the first country in the world to set nanostandards. On 1 April 2005, seven standards (out of the fifteen that are currently under study) entered into force. Further, a National Nanotechnology Standardization Committee has recently been established.

Sources: Nanoparticle News, “Held to High Standards?”, December 2004; Nanotechwire, “IEST Joins ISO Committee for Nanotechnology Standards”, 12 July 2005, at <http://nanotechwire.com/>; M2 Presswire, “Large scale gains for small scale work”, 6 June 2005

The concept of privacy often leads to discussions about anonymity. Although they are related, privacy and anonymity have some important differences. In communications, privacy implies possession of and control over personal information and the terms and conditions under which it is used, stored, or disclosed to others. Anonymity, on the other hand, implies the absence of information about the identity of a person, and relates to the terms and conditions under which such information might be collected – e.g. a person can be “anonymous” on the internet by using programs that disable cookies or hide the geographic location of the user.

It has generally been recognized that the notion of privacy is not uniform across cultures. Some cultures view privacy as a fundamental human right and have enacted specific regulatory instruments to safeguard the protection of privacy. In other cultures, privacy is less of a concern for both governments and citizens. Some experts argue that in many developing countries, policy-makers have paid limited attention to privacy concerns, whereas in the industrialized world, privacy has been largely codified.²⁹

Despite the cultural relativity³⁰ of the notion of privacy, the value it holds in most modern societies is likely to remain for some time to come. But it is also a historically bounded and dynamic concept. In other words, notions of privacy have evolved and shifted over time. Most citizens of today's global economy must own some sort of identification document (identity card, passport), but this is relatively recent in human history. In the information age, internet cookies, which caused uproar several years ago, seem now to be accepted as standard practice. Surveillance cameras, which at first seemed an invasive tool, have become commonplace. According to one estimate, the average person in the United Kingdom is recorded by CCTV (closed circuit television) cameras over 300 times a day.³¹ These cameras are increasingly sophisticated, and can even be connected to the World Wide Web, enabling owners to operate them remotely from their personal desktops.³² Although the initial purposes of such data collection may have been limited in scope, national security concerns, coupled with public acquiescence over time, may lead to the inadvertent surrender of a growing amount of personal information by citizens.

In the political context, privacy has often been cited as critical and indispensable to democratic societies. According to the legal scholar Lawrence Lessig, there are a number of compelling reasons that favour the protection of privacy within society:

- *Privacy as Empowerment*: Privacy empowers people to control information about themselves;
- *Privacy as Utility*: Privacy is a utility that protects people against unwanted nuisances. It includes the right to be left alone;
- *Privacy as Dignity*: Privacy is related to dignity in the reciprocal obligations between parties to disclose information;
- *Privacy as a Regulating Agent*: Privacy is also a regulating agent in the sense that it can be used to balance and check the power of those capable of collecting data.³³

As such, the right to privacy has two important facets: a) the freedom to control personal information and b) the freedom from interference or disruption. The first facet is under threat from the ability of emerging technologies to collect data on people's everyday activities. The second is under threat by developments such as commercial messaging (e.g. spam).

Users of today's internet already fill in forms for many information services using false names and addresses, as they are increasingly afraid of revealing personal information when online. A future in which all kinds of applications and objects prompt users for personal identification might exacerbate this climate of distrust. When tiny devices, the size of a grain of sand, give the wind a pair of eyes or doorknobs carry fingerprint sensors, no deliberate prompting will be required.³⁴ As communications between people, clothes, pens, furniture and appliances increase, human beings will have fewer and fewer tedious routine tasks,³⁵ with computing and processing occurring unnoticed in the background.³⁶ Invisible and constant data exchange between things and people, and between things themselves, will occur unbeknown to those affected. The old cliché "if these walls had ears..." may no longer begin with a conditional "if". This begs the question as to who will ultimately retain control over the data collected by the ears and eyes embedded in the surrounding environment.

The more complex and pervasive technological systems become, the more vulnerable they will be to abuse. Thus, in order to convince users to participate in the Internet of Things, effective mechanisms for privacy and data protection must be put into place. Users need to be given assurance that their privacy will be protected at all times. In this context, the establishment of trust in the management of identity is fundamental. A suitable balance between the release of a user's identity (and also the identity of things associated with users, such as remotely controlled webcams) and the withholding of data needs to be achieved early on in the development of commercial services. This balance must be struck across several domains of privacy protection: technical, regulatory, industrial, and sociological (Figure 4.3).

Technical solutions are already an important element in the design of systems underlying the Internet of Things (e.g. fingerprint sensors). Yet, technical solutions alone are insufficient for addressing privacy requirements. Regulatory and legal actions in the form of enabling statutes and regulation are also key mechanisms. Equally important is the socio-ethical domain, which views privacy as a social issue related to cultural practices, ethics and institutions. Solutions and design proposals for the future of

the Internet of Things should contain elements addressing each of the facets of privacy to ensure the fullest possible protection of privacy.

4.3.2 Challenges and possible privacy abuses

As with any other technology, the enabling technologies of the Internet of Things provide benefits but also challenges for different stakeholders. In particular, these technologies require balancing the benefits of personal convenience and security against potential abuses of privacy, in order to retain control over personal information and ensure freedom from interference.

RFID and sensor technologies have an increased capacity to collect and disseminate personal information. The provision of personalized services, such as those offered for smart homes and phones, requires these technologies to collect increasingly sophisticated personal data, from an individual's preferences to voice patterns, fingerprints and other biometrics, such as retina scans. This data collection facilitates personal identification but at the same time, makes it difficult for individuals to maintain control over their personal information and to remain anonymous, when so desired, in the world of the Internet of Things.

By the same token, the combination of RFID tags and mobile communications may challenge the ability of individuals to be free from interference, particularly from unsolicited advertising and other commercial messaging. The current experience of spam in mobile communications allows us to foresee a future where an increased number of unsolicited messages may be generated not only by other persons or businesses, but also by the objects around us. Ubiquitous communications, along with the collection of information about personal preferences, transactions and activities by sensors and RFID tags will provide greater opportunities for organizations to bombard consumers with targeted marketing information.

An overload of unsolicited messages and personalized marketing could discourage consumers from using new technologies, unless they perceive some usefulness in the information provided. In fact, research has shown that the level of acceptance for unsolicited messaging might be as socio-culturally bounded as the concept of privacy itself. A recent study of consumer perception of mobile unsolicited messaging conducted by ITU, in collaboration with the University of St. Gallen and bmd wireless, found differences in tolerance to spam among different regions of the world.³⁷ While 80 per cent of mobile users surveyed in South East Asia (SEA) – the region with the highest use of short message services (SMS) in the survey – considered it acceptable to receive one to five unsolicited messages from their mobile network operator per month, only 59 and 64 per cent of those surveyed in North America (NA) and Central Europe (CE) thought so respectively.

The content and target audience for such messages also affect the tolerance of unsolicited messages. Commercial short messages targeted to children had a lower level of tolerance in all regions (32 per cent for SEA, 12 per cent for NA and 4 per cent for CE) due to concerns about the appropriateness of their content. The ITU and University of St. Gallen survey also highlighted the potential economic impact of increased unsolicited messages. The majority of professionals surveyed in this study expected an increase in commercial messaging over the next two years, which they consider could rebound adversely on their organizations, especially in countries where incoming messages are billable to the recipient.

Providing control to individuals over the quantity, quality and longevity of the data stored about them, as well as freedom from interference, are central aspects of the privacy dilemma that need to be solved before these technologies become part of our daily lives in a more pervasive fashion. How much control and freedom are given to an individual in a particular society will depend on many factors, including the level of awareness about potential abuses, the cultural value given to privacy, current laws, as well as the availability and affordability of technical protection. As such, the boundaries between convenience, security and invasion of privacy can become quite flexible.

Sacrificing privacy for the sake of convenience

The Internet of Things will provide added conveniences for households, for shopping, and for the work environments. However, this might come at a premium, i.e. requiring the disclosure of more and more private information. In an ideal world, individuals would be able to make rational decisions on the trade-offs between privacy rights and the value of increased convenience, based on informed consent. Yet, implementing this perfect vision in the world of the Internet of Things might be more difficult than expected.

First, there is the issue of obtaining individual consent for personal data collection. Enabling technologies related to the Internet of Things are being embedded in other objects and individuals may be unaware of their presence in the environment, making surveillance seamless. As the enabling technologies become more widespread and pervasive, the principle of requesting individual consent every time a person enters into contact with a new data-collecting device becomes outdated. To avoid being bothered with consent requests, individuals may accept the collection of data as a default, disregard the requests or turn off this capability if integrated into the device. Disabling or ignoring safety devices is a common occurrence when browsing the internet, for instance. Messages warning of the possibility of someone having access to the data being transmitted when logging in on certain websites appear so often that they tend to be ignored or simply disabled by users.

Furthermore, there are also the issue of incomplete and asymmetric information between data subjects and data collectors. A study conducted by Intel Research in the United States on people living in a smart environment using RFID and sensor technologies discovered limitations in individuals' understanding of the uses and abuses of data collected by these technologies, especially where data can be shared with third parties.³⁸ According to researcher Richard Beckwith, when people are unaware or badly informed of the surveillance capabilities of technologies, they tend to trust these to be benign.³⁹ Surveys conducted last year in the United States by the National Consumer Council and Cap Gemini Ernst & Young (CGEY) underscore the lack of consumer awareness and understanding of RFID's implications for privacy. For example, CGEY's survey of 1'000 people in the United States indicated that less than 25 per cent of those interviewed knew about RFID.⁴⁰

Other recent studies have examined people's ability to evaluate the costs and benefits of privacy-related decisions.⁴¹ Even when they have complete information about personal data collection, the complexity of data collection issues may exceed people's capacity to deal with the information. Acquisti and Grossklags found that, to cope with complexity, individuals draw upon their previous experiences with technology, which may result in inappropriate privacy attitudes for the new technological context.⁴² For instance, even when information on technological protection and restrictions against access to data are readily available, people still do not protect themselves against threats, such as identity theft, because they under-estimate the possibility of such risks actually occurring.

These types of deviations from rational behaviour towards privacy protection also occur when individuals are promised instant rewards in exchange for personal information. In this instance, individuals often choose short-term benefits, at the expense of longer-term privacy concerns. One example of this is the use of loyalty cards, which trace the purchases and preferences of members that have provided personal information (e.g. name, address and telephone numbers) in exchange for discounts. Beckwith points out that "people are more likely to accept potentially invasive technology if they think its benefits will outweigh its potential risks."⁴³ The risk of over-releasing personal information may be further exacerbated as the number of companies using RFID tracking devices and loyalty programmes increases (Box 4.6).

By now, several potential threats to individual privacy have been identified with emerging technologies like RFID. Some of them are more technical, while others are more ethical. Technical issues mainly deal with the possibility of tracking RFID tags on purchased items (such as apparel, consumer packaged goods or tyres) beyond the cash-counter. For example, eavesdroppers armed with RFID readers in a parking lot could identify newly purchased items left in cars⁴⁴, so they know exactly which cars to break into.

Sensor networks, the foundation of smart spaces, are also subject to vulnerabilities. Potential attacks on sensor technologies include the falsification of sensor data, the extraction of sensed information through eavesdropping technologies and even attacks on network functions, which may result in denial of service. Haowen Chan and Adrian Perrig, researchers at Carnegie Mellon University, observe: "sensor networks aggravate the privacy problem, because they make large volumes of information easily available through remote access. Hence, adversaries need not be physically present to maintain surveillance."⁴⁵ Consequently, risks faced by data thieves and attackers decrease as these technologies allow them to collect information from further away and from multiple locations simultaneously.

The main ethical implications relate to the tracking of humans (children, patients, employees), breaching their rights to privacy and dignity. One of the strongest recent public protests was about monitoring at work. The idea of tracking employees is not a new one. One of the first conscious attempts to monitor labour dates

back to 1880, when it was decided to attach stopwatches to shovellers at Midrade Steel in the United Kingdom. In the early 1900s, monitoring of the labour force found its theoretical underpinning in the “Taylorism” movement. “Fordism” followed, with its view of surveillance as a key success factor in running an efficient assembly line.⁴⁶ Today’s techniques for tagging employees (see the examples described in Chapter 2) are being contested by an increasing number of trade unions (Box 4.3). In July 2005, one of the UK’s largest trade unions, the GMB, demanded an end to RFID for staff tracking in European groceries, claiming an invasion of workers’ privacy.⁴⁷

Box 4.3: RFID threatens privacy

Tagging products, workers and consumers is becoming mainstream



Recent practices introduced by several large firms in Britain suggest that RFID tags are entering mainstream business. Managers see RFID as a means of cutting costs and improving efficiency and accountability in the workplace. Companies including Tesco, Sainsbury’s and Asda have recently deployed technology allowing RFID readers carried by employees to be tracked by managers, effectively introducing the conditions for permanent surveillance. More than 10'000 workers have been asked to wear small computers on their wrists, arms and fingers, or in some cases, to put on a vest containing a computer, which

instructs them as to where to go and what to do. The companies say the RFID system makes work practices more efficient, increases the speed of service and reduces theft. However, the employee is unable to do anything without the computer recording and monitoring the employee’s behaviour. RFID-wearable computer technology and satellite technology used in this way could seriously threaten workers’ right to privacy.

The next step could be to “tag” consumers by tagging products with RFID. The German retail giant Metro AG already uses RFID tags in its Rheinberg store. Loyalty cards and smart shopping trolleys assist customers in finding tagged goods. They can store information about a consumer’s past shopping habits in order to highlight special offers and the location/availability of specific items. Products communicate with smart shelves so that they can be replaced well before supplies are exhausted. At the checkout desk, payment can be similarly expedited. From the supermarket’s perspective, stock checks and payment are much easier and in-store security is improved, as the tags allow tracking of the products. Conversely, this innovation could threaten basic consumer rights, including privacy. Given the ability to link tags with personal data, RFID applications in consumer channels could be poached for tracking and surveillance purposes.

Image Source: Donald Cheke, Textual Creations (Canada)

Sources: News Factor, “RFID Tags Need Privacy Policies”, 9 June 2005 at <http://www.newsfactor.com/>; Boyds Solicitors, “Tracked by Your Clothes”, 30 May 2003 at <http://www.boydslaw.co.uk/>

Still, tagging individual patients in hospitals or in the home could greatly facilitate healthcare delivery (Chapter 2), through streamlined and efficient procedures. They could also help identify victims of natural disasters, accidents or terrorist attacks, typically a lengthy and complex process.⁴⁸ However, controversy following the US Food and Drug Administration’s approval of VeriChip for use in medical purposes (see Chapter 2) has raised doubts as to whether it is in the best interests of patients to give medical personnel instant access to their records.⁴⁹ The collection of biometric data for personal identification is equally contentious.

In telematics, one technology that combines the capability of tracking an individual’s position with access to medical records is already around us: cars equipped with Global Positioning Systems. In-car communication systems with Intelligent Transport Systems give information to the driver about navigation, parking or weather and support him in finding a hotel or restaurant in the area, while recording the services requested by the driver and the car’s performance in a “black box”. In emergencies, the system automatically connects the driver to emergency services, and provides the services with access to the driver’s medical records and those of passengers if needed. Examples of these services include the “OnStar” system implemented in the United States by General Motors (Box 3.4), Fiat’s “Connect” system in Italy and other EU countries and Daimler Chrysler’s “Tegaron” system in Germany.⁵⁰

Although in-car communications are one example of the convenience of emerging technologies, users also have to be vigilant about their possibilities for surveillance. Tracking cars means tracking the position of drivers, and even their activities, while driving: how fast you drive, where you stayed or stopped to eat.

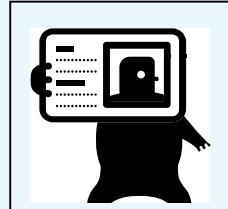
In the United States and Europe, location data are protected, requiring user consent for their release, except in emergencies. The collection and processing of medical records are also regulated to ensure their security. The threats posed to privacy relate to the potential uses of the data collected by a car's black box or the need for processing systems such as OnStar to have access to a database of medical records. Users' control over the information collected, including their location, is fundamental if privacy rights are to be protected. It is necessary to find a compromise in which consumers can obtain the benefits and convenience of personalized services, without too great a loss of privacy.

In the name of national security

Another source of concern is the possible misuse of biometric passports and ID cards, such as travel passes or social security cards. Potential dangers associated with electronic identification include, for example, identity theft and illegitimate tracking. These applications of emerging technologies have fostered debate on the trade-offs between national security and personal privacy. In recent years, the fear of terrorism has made the collection of personal identification, profiling and data mining a matter of national policy, prompting increased interest of government agencies in tracking and tagging technologies (Box 4.4).

Box 4.4: To secure and protect

RFID use in e-initiatives for increased security



The deployment of new technologies as part of e-government programmes is a clear indication of governments' commitment to scientific and technological development. In an effort to strengthen national security, many countries are already implementing projects for the use of RFID tags in national identification cards. The European Union, for instance, is looking into the deployment of electronic ID cards across its 25-nation bloc. Estonia, touted as one of Central Europe's most advanced and tech-savvy nations, is issuing its 1.4 million citizens with an "EstEID", a chip-based ID card that carries the citizen's name, home address, date and place of birth, digital certificates and e-mail. The card will be valid for travelling to most European Union countries and for electronic payments, filing tax documents, banking and access to e-government services. Citizens in Italy, Belgium, and Finland are already using electronic ID cards, while citizens in France, Netherlands, Sweden and Spain are preparing to do so.

Other countries in Asia, the Middle East and America are following this trend. China has initiated a massive project aimed to provide its entire adult population with national ID cards by 2008. In Pakistan, the National Database and Registration Authority first issued machine-readable passports in 2004, before the European initiatives were being implemented. An RFID system, the "Vehicle Identification and Tracking System", is being used by the Pakistani police against car jacking, to reduce the number of stolen or commandeered cars. Meanwhile, in the United States, the Department of Homeland Security will require all federal employees and contractors to use a "DHS Access Card", an identity card containing multiple means of identifications, including an RFID tag, bar code, fingerprint, a magnetic strip and a digitalized photo by October 2005. Similarly, the United States House of Representatives approved in February 2005 a measure for states to make drivers' licenses compliant with federal antiterrorist standards by 2008. The inclusion of RFID tags in drivers' licenses is still under debate at the federal level.

The use of RFID tags in identification cards has also faced opposition elsewhere. In the United Kingdom, the Government's plan to introduce a compulsory biometric national ID card by 2013 and the use of RFID tags in the new biometric passports (expected in 2006) has generated heated debate. Governments tend to emphasize the additional benefits of the ID cards, such as instant access to multiple online services and their convenience. In Malaysia, for example, a single card combines a driving license, health insurance, toll payments and ATM cash withdrawal. Yet one should not forget that a "side-effect" of such initiatives is the centralized collection of information and potentially a database of all citizens, visitors, tourists and immigrants.

Image Source: Microsoft Office Clip Art

Sources: Electronic Privacy Information Center, "Homeland Security ID Card Is Not So Secure", April 2005 at <http://www.epic.org/privacy/surveillance/>; Card Technology, "Going global with national ID", 1 June 2005; ITU, "Ubiquitous Network Societies: The Case of Radio Frequency Identification", April 2005 at <http://www.itu.int/ubiquitous/>

The "Total Information Awareness Program" proposed by the United States Department of Defence after the 2001 attacks exemplifies this trend. The purpose of the program was to use data mining to collect information on individuals from different public databases and commercial data aggregators. It is claimed that its analysis and compilation would allow predictions of potential terrorist behaviour. After some

criticism, the Senate cancelled funding for this program and the Information Awareness Office at the Pentagon was closed. Similar data mining projects were considered by the Transportation Security Administration and the FBI.

Although governments are promoting initiatives to “enhance security, increase efficiency, reduce identity fraud, and protect personal privacy”⁵¹, RFID technology has been proven vulnerable to interference. Research at the Johns Hopkins University and RSA Laboratories showed that the Digital Signature Transponder (DST), an encryption-enabled RFID tag used in vehicle immobilization and electronic payment systems, could be broken into, allowing access to its secret keys.⁵² Exxon Mobil’s SpeedPass, a payment system using DST for buying gasoline and for car passage through the Washington DC Metro area electronic tollbooths,⁵³ could be an extensive source of information on drivers’ location if all transactions were reported live to a central storage.⁵⁴

Skimming (the use of a reader by an intruder to capture electronic information from a passport chip without the passport holder’s knowledge or consent) is a potential threat to the application of RFID in passports and ID cards. Mobile phone users will be exposed to the danger of third parties accessing their personal information, should RFID-based passport data be integrated with phones’ SIM cards. This scenario may arise in Finland (where mobile penetration already reached 100 per cent of population some time ago). Since early 2005, a new identification tool has been adopted in Finland called the “mobile citizen certificate” for use in public and private services, whereby an individual can identify himself using a regular four-digit PIN code.

The sheer capacity of the technologies of the Internet of Things introduces far wider dimensions to data collection and privacy that can only be compensated for by coordinated action. Such action includes the introduction of principles and guidelines for data protection, technological innovation in privacy-enhancing technologies (PETs) and the organized action of informed consumers. The next section discusses some of the efforts and solutions that are being deployed to promote higher levels of privacy protection.

4.3.3 Initiatives to Protect Privacy

The Internet of Things presents new challenges and needs new responses in all the areas it will affect, including policy-making, technological development, markets, society and consumer rights (Figure 4.3). The economic interests of stakeholders must be weighed carefully to develop an environment in which commercial interests can flourish, whilst respecting individual rights. This section examines some of the initiatives that are being undertaken to protect privacy, from market-based measures to legislative and technical solutions.

Privacy protection: Legal and regulatory principles and their application

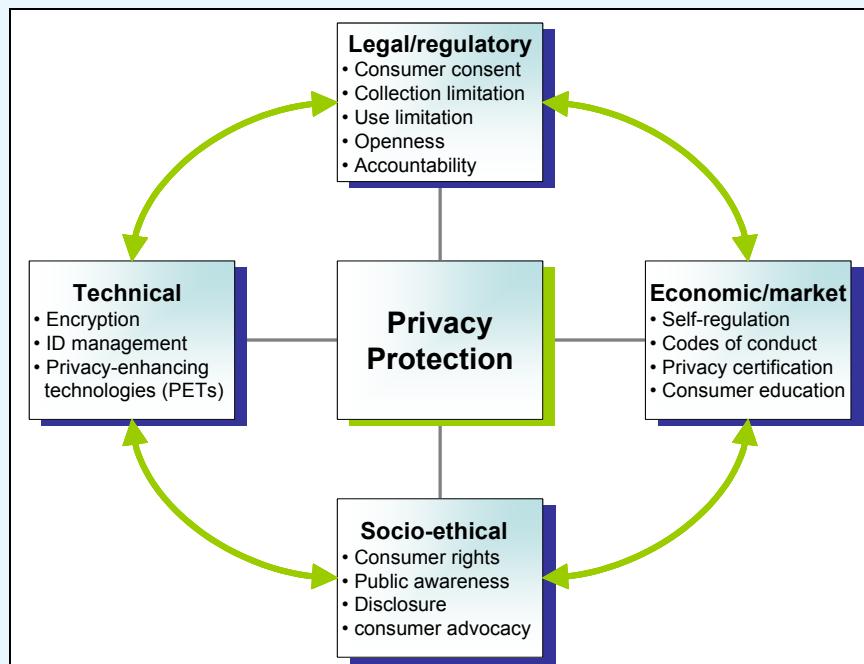
The protection of privacy from abuse has been a concern of many countries across the world, leading to legislative attempts to enshrine these principles in national law and guidelines. At the international level, Article 12 of the “Universal Declaration of Human Rights”, adopted by the United Nations General Assembly in December 1948, marked an initial step toward international recognition of the right to privacy, defined as the protection of the individual against “arbitrary interference with his privacy, family, home or correspondence.”⁵⁵

Following advances in computing and communication technologies in the 1970s, new concerns arose regarding the storage and use of personal data by government and private entities at the national and international levels.⁵⁶ Increase in the flows of information across borders made clear the need for guidelines regarding the type of data collected and disclosed, the fairness of its collection and use, as well as the right of individuals to access the personal data being collected about them. In 1980, the Organisation for Economic Co-operation and Development (OECD) adopted the “Guidelines on the Protection of Privacy and Transborder Flows of Personal Data”. These principles sought to harmonize national laws on data privacy and reduce barriers for trans-border data flows that could affect economic activities, such as international banking and insurance. The Guidelines applied the following seven basic principles at the national level and provided the basis for future legislation on data privacy:

- **Collection limitation:** Confines the collection of data to the collection that is required for a particular business purpose only and demands the request of consent from the data subject;
- **Use limitation:** Data are to be used only in strict correspondence with the declared purpose;

- **Data Quality:** Ensures that the data collected are as complete, current and correct as possible. Data should be kept only as long as is needed to fulfil the original purposes of collection.
- **Individual participation:** Individuals have the right to know which data about them are stored by a third party.
- **Purpose specification:** Data subjects have to be informed of the purpose of data collection at the time of such collection at the latest.
- **Openness:** Data collectors should provide the means by which it is possible to establish the existence and nature of personal data, the main purposes of their use, as well as the identity and usual residence of the data controller.
- **Security safeguards:** All efforts must be made in order to protect the personal data from unauthorized use.
- **Accountability:** Data controllers should be accountable for fulfilling the principles above.⁵⁷

Figure 4.3: Privacy protection
A multi-faceted approach to protecting consumers



Source: ITU

Similar principles have been adopted by other international organizations and are being promoted for adoption by governments. Major pieces of legislation include: the “Convention for the Protection of Individuals with regard to the Automatic Processing of Personal Data”⁵⁸ adopted by the Council of Europe in 1981; the “Guidelines for the Regulation of Computerized Personal Data Files”⁵⁹ of the United Nations (December 1990); and the European Union’s “Directive on the protection of individuals with regard to the processing of personal data and on the free movement of such data” (1995)⁶⁰ (hereinafter referred to as “Data Protection Directive”). The EU Directive is of particular interest. When it was implemented in 1998, it required member states to impose a moratorium on data transfers with countries outside the EU that do not provide a comparable level of data protection and privacy legislation. Consequently, many countries outside this region have begun legislative processes to comply with the Directive’s requirements.

More recently, privacy advocates in the United States have released a proposal for privacy protection that addresses some of the current legislative loopholes, while following OECD principles of notice, access, informed consent and control. Although the “Model Regime for Privacy Protection”, developed by Daniel Solove of George Washington University Law School and Chris Hoofnagle of the Electronic Privacy Center, is based on the specific circumstances of the United States, it could be used as a “wish list”⁶¹ or blueprint for

privacy protection elsewhere. This model proposes specific legislative steps to solve problems that can arise with the unauthorized collection, storage and sale of personal data, including:

- **Anonymity of data brokers:** The model proposes the establishment of a central registry, managed by the federal government, with which all companies involved in the collection, storage or sale of personal data should register. Such registration would be a positive step, as consumers may not be aware of all the companies collecting personal information beyond the credit bureaus, such as commercial data brokers.
- **Asymmetric information:** To promote completeness of information, the activities of registered companies should be made publicly available by government, including the type and purpose of the personal data collected, the type of clients (third party entities) they serve and how these clients are screened to ensure their legitimacy.
- **Cumbersome opting-out processes:** In most cases, services allow the sharing of personal user data by default. However, many companies that share customers' personal data with third parties provide consumers with the option to opt-out of the sharing program by calling a number or sending a letter of request. Thus, if customers are interested in controlling the distribution of their personal information, it is necessary for them to contact each of the companies they deal with to opt-out. In contrast, Solove and Hoofnagle propose a "one-step exercise of rights" embodied in the creation of a centralized do-not-share list, similar to the Do-Not-Call list for deterring telemarketing calls.⁶² With the one-step approach, consumers would be able to contact a single entity, such as the Registrar, to opt out of third-party data-sharing programs for all parties they deal with. Firms seeking access to personal data collected on the centralized mechanism would require a court order and probable cause.
- **Lack of control over who has access to personal information:** Identity theft is a growing concern, as the amount of personal data collected increases. In the United States, individuals do not have control over the release of personal information included in credit reports, and are not notified when a creditor consults their record to authorize credit to an identity thief. Solove and Hoofnagle propose that individuals retain control over this data, so that creditors interested in accessing credit reports would have to request permission from data owners.
- **Lack of accountability:** According to Solove and Hoofnagle, requiring companies to inform their clients when a security or privacy breach has occurred will improve the openness and exchange of information between data providers and data brokers. It will also clarify the responsibility (both financial and social) that data collectors and brokers should have towards the individuals from whom they collect the data. To avoid the use of class-action suits, Solove and Hoofnagle propose the creation of a fund to be financed through fines imposed on negligent companies to compensate the victims of identity theft and other privacy abuses.⁶³

Some countries have taken concrete actions to protect consumers against the threats of specific enabling technologies. The Ministry of Internal Affairs and Communications (MIC) and the Ministry of Economy, Trade and Industry (METI) of the Government of Japan have developed a set of privacy protection guidelines to safeguard personal information stored on RFID tags. These Guidelines also follow the principles established by the OECD in 1980 for the promotion of openness, consumer consent and accuracy among companies collecting, using and sharing personal information recorded in RFID tags (Box 4.5). Importantly, the two Ministries tried to strike a balance between protecting consumers and exploiting the potential social benefits of RFID, especially in areas such as environmental protection and road safety. On the one hand, the Guidelines empower consumers by informing them about the presence of tags in the products they purchase and by giving them the choice of deactivating them. On the other hand, the Guidelines encourage companies using RFID tags to inform consumers of the impact that the removal or deactivation of these tags would have on future consumer and social benefits.

A multilateral approach seems to be the best strategy to protect consumers in the face of the proliferation of unsolicited messages (spam) through different technologies. The International Telecommunication Union (ITU) is promoting cooperation in counteracting spam as part of its leading role in the implementation of the Declaration of Principles and the Plan of Action of the World Summit on the Information Society (WSIS). As part of its measures to counter spam, ITU has created harmonized policy frameworks, promoted

the exchange of information and best practices among countries, especially among developing countries which may lack resources to combat spam, and hosted several symposiums in this area.⁶⁴ These symposiums have highlighted the importance of cooperation among the different stakeholders, particularly industry players, to successfully solve the problems related to unsolicited messaging. International coordination against spam will become even more important as the number of devices producing messages increases with the implementation of the Internet of Things. It is possible that some of the lessons learned from mobile communications can be applied to messages and information sent by RFID tags and other technologies.

Box 4.5: Feeling comfortable with RFID

Japan's guidelines for privacy protection



Promoting consumer acceptance of and trust in ICTs, including RFID technologies, is a key policy goal of the Ubiquitous Japan (U-Japan) strategy, a plan that intends to maintain and reinforce Japan's position as a leading ICT nation by 2010. To make consumers feel more comfortable about the use of RFID tags, Japan established “Guidelines for Privacy Protection with Regard to RFID Tags”. Under these guidelines, companies dealing with RFID tags and personal information are required to:

- Inform consumers of the purpose of data collection and use;
- Obtain consumer consent;
- Prevent leakage, loss and damage to the information collected;
- Disclose information recorded in RFID tags at consumer request;
- Ensure data accuracy; and
- Appoint an information administrator who would be responsible for ensuring adequate implementation of these measures and for handling consumer complaints.

The guidelines build upon Japan's “Law for the Protection of Personal Information” (Law No. 57 of 2003) by adapting it to the specific challenges and capabilities of RFID tags. In particular, they extend the definition of personal information included in the Law to cover the information recorded in RFID tags, even in cases where a specific individual cannot be identified by the information contained in the tags. In addition, the guidelines acknowledge that privacy is an evolving concept, and will thus be periodically updated to accommodate changes in socio-economic conditions.

Image source: Bigfoto

Source: Ministry of Internal Affairs and Communications (MIC), Japan

While legislative guidelines can help protect privacy, they are unlikely to be sufficient. The next section looks at some of the technological design solutions that are being explored to help protect privacy.

Privacy by design: Technological solutions

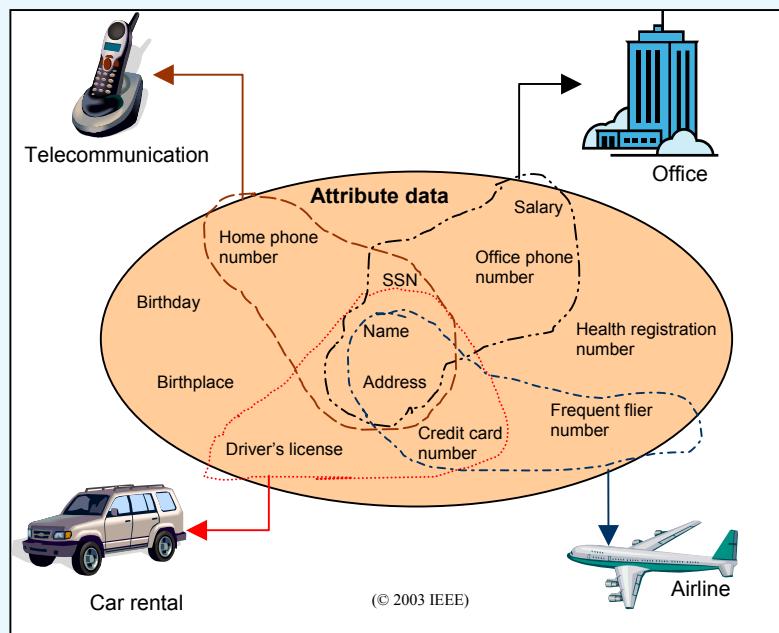
Given that the threat to privacy has grown with the development of new technologies, it is natural that new technological tools are being developed to protect privacy and preserve the benefits of new technological developments, while limiting their drawbacks. Similarly to current online business practices, the basic technological principle is to allow consumers to opt-out of potential interactions with tracking and sensing devices. Identity management technologies allow users to create different pseudo-identities for use in different contexts in their public and private spaces, providing them with more anonymity (Box 4.6). Researchers point out, however, that a more ethical approach would be to make “opt-in” the technical default for these devices, enabling people to decide for themselves and give informed consent to data collectors and brokers for the collection and use of their personal information.⁶⁵

In the case of sensor technologies, such as smart dust, increased privacy protection requires the possibility of detecting the presence of sensors and deactivating them. Similarly, in the use of RFID the biggest challenge is communicating to consumers which of the items they own or use are tagged and therefore “readable”. The associated technical challenge facing technology designers is introducing the ability to de-activate tags whenever required.

Box 4.6: What might service providers know about you?

Management of multiple identities

Controlling anonymity in the Internet of Things is a true challenge. While e-commerce has used peer-to-peer transactions (where user information is managed without intermediaries, making identification of individuals easier) new approaches to multiple and dependable digital identity (MDDI) management give users greater control over the information exchanged about them in different transactions and with diverse providers. Next-generation MDDI standards are based on trust management or a “federated” approach, which involves the use of a trusted third-party to support and manage users’ identities. These standards promote greater anonymity and the use of *pseudo-identities*, in which only a partial profile about the user is given. These *pseudo-* or *digital identities* vary in the amount and type of information they contain, going from *nym*s (giving users different identities for transactions with other parties in different environments, but requiring strong authentication, e.g. smart cards or biometrics) to *partial identities* (including only subsets of data used in interactions with specific parties, as shown in the figure below). Anonymity, on the other hand, needs the information released to be fully unidentifiable, so that no link can be made to users’ identity.



Identity management systems are being implemented by firms such as Microsoft (.Net Passport) and Novell (DigitalMe). These systems provide users with a single identity that can be used in multiple services online, freeing users from having to remember user names and passwords for each of them. Liberty Alliance, a multinational consortium with over 150 members from different industries, including IBM, is developing a collaborative federated standard for the exchange and authentication of user information. The standard builds on Oasis' Security Assertion Markup Language (SAML) and provides security features such as opt-in account linking, permission-based sharing of user details (attributes), security profiles and simple session management, which could be used across diverse types of devices and software platforms.

Image Source: Adapted from E. Damiani, S. De Capitani di Vimercati and P. Samarati, “Managing Multiple and Dependable Identities”, *IEEE Internet Computing*, Nov.-Dec. 2003, p. 30

Sources: E. Damiani, S. De Capitani di Vimercati and P. Samarati, “Managing Multiple and Dependable Identities”, *IEEE Internet Computing*, Nov.-Dec. 2003; G. Goth, “Identity Management Access Specs are Rolling Along”, *IEEE Internet Computing*, Jan.-Feb. 2005

Having recognized this problem, technology designers are currently working on privacy-enhancing technologies (PETs). The concept of PETs has emerged as one way to counteract threats posed by privacy-intruding devices. The term was coined in the seminal 1995 paper “Privacy-Enhancing Technologies: The Path to Anonymity” by Ann Cavoukian and John Joseph Borkin.⁶⁶ PETs are either stand-alone solutions helping individuals and companies protect their privacy or add-on features designed to enhance the privacy of an existing system. Eventually, PETs may address the privacy concerns and promote the principles of protection identified above. PETs that have already been introduced and some PETs on trials include:

- **Tag “killing”:** The possibility of “killing” is available for all classes of the EPC tags, even for the simplest and cheapest.⁶⁷ “Killing” means rendering tags permanently inoperative at the time of purchase. Therefore, tag “killing” is not suitable for the rental of cars, bicycles, DVDs or books, as the tag must last the product’s whole lifetime. Moreover, if such a radical approach prevails, it will bury troves of useful infotainment, lifestyle, healthcare and safety applications.⁶⁸ Customers would also relinquish other benefits of tags, such as the opportunity to return items to a store without receipt (e.g. thereby avoiding desperate searches for the tiny slip when it is most needed), recover

personal belongings lost in the house or a car, or monitor their kids in the playground. More broadly, killing RFID tags at the consumer edge of the supply chain would undermine the very notion of the Internet of Things. Happily, there are PET solutions available for RFID users where privacy is more or less balanced with the benefits of this technology.

- **Blocker tag:** One of the earliest efforts to protect data on RFID tags was made in 2003 by RSA Security with their “blocker tag”. The blocker tag prevents unauthorized readers from scanning other tags in their proximity. It confuses the reader by sending out distorted information, clogging or causing collisions at the reader and preventing the reader from getting valid responses from regular tags. At the point of purchase, all tagged items can be packed into a bag equipped with a blocker tag so that their information remains illegible to third-party readers encountered on the customer’s route. RSA intends to license the technology to multiple retailers, system integrators and RFID manufacturers.⁶⁹ The technology thus preserves the after-sale benefits associated with RFID, while protecting consumer privacy. There is also a downside: a jamming device like this can accidentally disable legitimate systems.⁷⁰ It should be noted, however, that currently, commercial applications of blocker tags have not yet been announced.
- **Privacy bit:** The concept of the privacy bit is based on mature technology for Electronic Article Surveillance (EAS). EAS is embodied in small tags attached to shelved items and has been widely used by the retail sector for theft prevention. At the cash register, sales clerks deactivate the tags or an alarm sounds when the item is carried out of the store. Likewise, a logical privacy bit can be allocated to an RFID tag. Prior to purchase, this bit is deactivated in the shop. At the point of sale, it is switched “on”, thereby deactivating the tag. Anti-theft systems at the exit gate will ignore the tags whose privacy bit is “on”. Used together with a properly configured reader, a privacy bit will allow the safe usage of legitimate RFID applications beyond the counter.⁷¹
- **Watchdog tag:** A sophisticated PET is now under development by the Distributed Systems research group under the auspices of Swiss Federal Institute of Technology in Zurich (ETH Zurich). It aims to give consumers visibility over the whole process of tag detection. For this, the tag is enhanced with additional power, a screen and an external communication channel. It can be carried either as a separate device or integrated into the mobile phone. Specifically, it will decode commands transmitted by readers, fetching details such as the identity of the data collector, the location of the reader, and the original purpose of the data collection. The use of a simple representation format will allow users to easily detect unauthorized eavesdroppers and block communication.⁷²
- **Encryption:** For household applications that monitor high-value belongings, a request-response model is being developed using encryption to prevent third-party spoofing. Transponders and readers share the same encryption algorithm. At the start of communication, the reader randomly generates a 40-bit number and sends it to the transponder; based on that number, both the reader and the transponder generate a 24-bit response. If identical, information exchange can resume. These devices may be configured so that, after a number of false attempts, transponders become inoperable.⁷³
- **Zero Knowledge:** This technology (developed by Open Business Innovation in Denmark) incorporates a new layer of cryptographic functions for identity proofs in RFID chips, in addition to the existing EPC approach. The new chips have two operating modes: an EPC mode, in which it provides all the necessary information for logistics operations; and a “privacy mode”, which is turned on at the point of sale. Once the tagged item is purchased, the seller “transfers” control over a one-time key to the new owner of the tagged item that allows him to release information in controlled situations (such as when the product needs to be serviced or is recalled). The advantage of the ‘zero knowledge’ approach is that the users control how the tag operates, by turning its privacy mode on (so that it acts as a “killed” tag) or simply switching back to the EPC mode when needed. The tag will only provide the information needed for the required transaction, keeping all other consumer data private. The new tag will use existing infrastructure, requiring only a software upgrade for readers at the point of sale.⁷⁴
- **Privacy Preferences:** Yet another approach is the use of the Platform for Privacy Preferences (P3P) of the World Wide Web Consortium (W3C), which allows users to choose their preferred privacy settings that are used later to respond to tracking and reading devices and to provide consent to data collection by matching data collection purposes to users’ preferences. However, this type of automatic consent or dissent requires users to construct a series of different scenarios for data collection, which may be cumbersome.

Perhaps the most encouraging sign is the increased amount of research focused on the development of privacy-enhancing devices, which builds privacy into the early design stage and does not relegate it to a mere afterthought following development. Although the legislative principles and privacy-enhancing technologies cover all areas of privacy protection, there is still much work to do to ensure that the challenges presented by enabling technologies are addressed adequately. Industry self-regulation, the preferred approach of countries such as the United States, as well as other market-based solutions, can complement the protection provided by legislative action and technological improvements.

Market-based solutions

In addition to legislative and technological developments, a number of market-based solutions are emerging, which are all the more important given the role self-regulation can play in finding lasting, workable solutions that are acceptable to consumers. The industry is catching up with the implementation of consumer-oriented policies, including consumer education and awareness of privacy issues. IBM, for instance, has recently announced the launch of RFID privacy consulting services to help companies implement privacy-abiding RFID policies and instigate effective internal and external communication of RFID-related privacy issues.⁷⁵ Other businesses are implementing privacy-oriented policies as a result of economic incentives or legislative requirements from other countries with whom they wish to do business. For instance, the United States Department of Commerce created the “Safe Harbor Privacy Principles” (2000)⁷⁶ to facilitate the compliance of American companies with the requirements of the European Union “Data Protection Directive”. If an American company wants to conduct business in the EU or to collect and transfer data in countries within Europe, it needs to subscribe to these Principles and continue its compliance, under penalty of fines of up to USD 12'000 a day imposed by the United States Federal Trade Commission.

The European Directives and the Safe Harbor Principles encouraged the implementation of privacy-certification programmes, such as TRUSTe, WebTrust and the Better Business Bureau (BBBOnLine) programme, which had already existed for the certification of trust of commercial websites. The seal of certification provided by these programmes confirms to users that businesses meet minimum behavioural standards regarding their practices.⁷⁷

Businesses have also created coalitions to promote self-regulation relating to privacy, such as the Online Privacy Alliance (OPA). OPA is composed of more than 100 major business organizations, including AOL Time Warner, Microsoft, America Online, and IBM. This group is pushing for the disclosure of the form and purpose of data collection, customer control over how the data is used and overall data accuracy. However, there is no real monitoring of whether, and how well, companies are actually following these tenets as part of their own privacy policies. To be effective, self-regulation requires an enforcement framework that facilitates communication between consumers and companies, from dispute resolution to consumer education and awareness. A third party should also verify and monitor enforcement, as in the certification programmes discussed above.⁷⁸

One of the OECD principles that requires close attention by the business community is the accountability of the data collector. Many companies do not bother to notify their customers when a security breach has occurred in their data files. Their lack of vigilance does not have a direct impact on the financial status of the company, as they are isolated from the financial consequences of such breaches. But this situation is already changing. In 2004, California passed a law requiring businesses to disclose breaches in the protection of their customer's personal data.

According to the Washington Post, by June 2005, more than 50 million user accounts had been exposed to the possibility of identity fraud as the result of data breaches in large data broker companies in the United States, such as Axiom, ChoicePoint, CardSystem Solutions and Lexis Nexis, as well as in the records kept by financial institutions, universities and hospitals.⁷⁹ Before the law was passed by the State of California, breaches were rarely made public. A survey conducted in the United States by the Pew Research Center in August 2000 found that ninety-four per cent of the respondents supported sanctions against companies for the violation of privacy policies.⁸⁰ The fear of class-action suits of clients whose data have been breached is prompting more companies to adopt stringent security and privacy policies.

Based on California's lead, some members of the United States Senate are now proposing legislation against identity theft at the federal level.⁸¹ Senator Dianne Feinstein, one of the sponsors of this legislation, points to incidents such as the alleged breach of confidentiality affecting some 40 million credit card accounts managed by CardSystem Solutions, as a "clear sign that industry's efforts to self-regulate when it comes to protecting consumers' sensitive personal data are failing."⁸²

Industry associations and individual companies have also taken a proactive approach to protect users against the annoyance of unsolicited messages. In mobile telephony, the Mobile Marketing Association (MMA) has promoted the adoption of a Code of Conduct among its industry members based on the "Six C's of Privacy": Choice, Control, Constraint, Customization, Consideration and Confidentiality. The Code provides consumers with the ability to opt-in and opt-out of receiving mobile marketing; it also allows them to set limits on the type of messages received, based on their own preferences. To improve relationships between mobile operators and advertisers, the Code compels its members to provide information of perceived value to the customer, to use analytical segmentation tools to optimize message volume and to align their privacy policies. Mobile operators in the United States, Japan and Europe have also taken measures to combat mobile spammers and empower subscribers to join the battle. Some of these measures include spam filters, hotlines and other tools that allow users to control the receipt and blockage of e-mails and SMS messages.⁸³

One of the implications of the Internet of Things is that that marketing will become more location and time-specific. It has already moved from the shop (from discounts and pamphlets on offer at the shop) to the home (flyers through the post box, unsolicited phone calls). Using the data provided by the Internet of Things, offers for baby clothes could be sent directly to the homes of young parents on the basis that nappies have been purchased for the occupants of that particular home. Alternatively, prompts for car cleaning products and services could be triggered as you drive past a car wash. More detailed and customer-specific information as to a person's preferences could be used by retailers to strengthen customer relationships, but only if the information is used responsibly and with customers' consent. As with mobile marketing, operators could seize the initiative and take steps to persuade their customers of the mutual benefit in responsible marketing.

Spam and marketing, like the technologies themselves, will become more pervasive, but potentially more focused. This would be similar to customer profiling (the projection of multiple customers' preferences based on type, social class, salary etc.), but extend into the detailed recording of an individual customer's preferences. For example, if supermarkets became aware of the consumption pattern of an individual consumer through the restocking orders sent by the fridge, that specific customer could receive tailored sales and marketing offers relating to his or her preferences. This information could also be used to 'educate' or modify consumers' preferences (e.g. if you like pineapple, you might wish to try papaya). There are also potential benefits to more detailed and more accurate information about consumers' preferences.

Consumers in arms

Although the developers of RFID, sensors and nanotechnologies are increasingly aware of the impact of these technologies on personal privacy, there are still some vendors, manufacturers, retailers and government institutions that have overlooked potential threats to privacy. It is left to the discretion of the rank-and-file consumers, the people carrying and using items with embedded RFID tags, as well as for privacy lobbyist organizations, to raise concerns about the implications of increased surveillance and personal data collection. Research by Cap Gemini Ernst & Young (2004) revealed key areas of consumer concern related to the use of RFID, as illustrated in Box 4.7.

With the support of consumer advocacy and privacy protection groups, consumers have engaged in a fierce battle against the looming privacy violations possible with RFID tagging⁸⁴ (Box 4.8). Some consumer initiatives even go as far as promoting a complete ban on the use of RFID in the public part of stores.⁸⁵

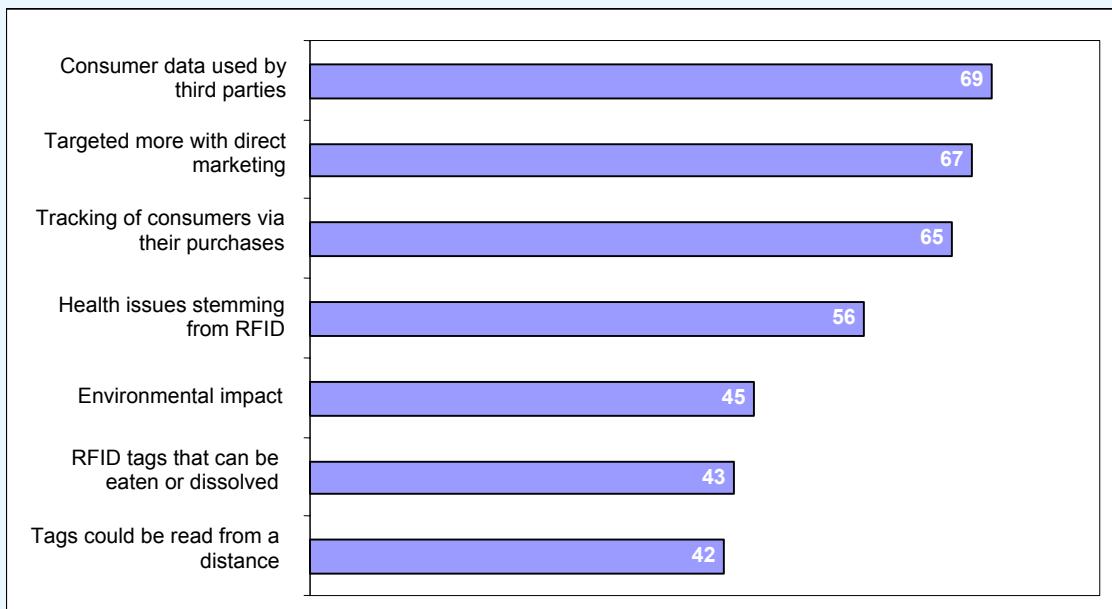
As mentioned earlier, privacy abuses stem in part from incomplete or asymmetric information between data collectors and data subjects. Privacy and human rights organizations [such as the Electronic Frontier Foundation (EFF), Consumers Against Supermarket Privacy Invasion and Numbering (CASPIAN), the Privacy Rights Clearing House and the Electronic Information Privacy Organization (EPIC)] are seeking to combat this by providing consumers with information and resources on the potential threats emanating from emerging technologies. Their activities in promoting civil liberties and privacy rights for the new millennium

make them key stakeholders in the design of new legislation governing privacy. EPIC, for instance, has testified before Congress in enquiries regarding information privacy, advocating privacy legislation.⁸⁶ Other organizations have a more focused approach, fighting for consumer rights in a specific sector, technology or privacy concern. CASPIAN, for instance, is a consumer grass-root organization that began as a reaction to the use of supermarket loyalty customer cards to invade customer privacy rights. Its interests have now extended to the use of RFID tags in retail stores and supermarket chains (Box 4.8).

Box 4.7: Consumer concerns related to RFID

Unauthorized use of personal data causes greatest concern

While the issue of consumer privacy under threat from RFID is generating heated discussion, companies are trying to discover the different fears of consumers relating to this particular technology. Understanding consumers is critical to the implementation of retail applications of RFID, as it helps to introduce new services smoothly and strengthen companies' reputation (see the example of Marks & Spencer outlined in Box 4.8). The chart below gives some idea of consumer fears of RFID, based on a CapGemini survey.



Source: ITU, adapted from Cap Gemini Ernst & Young, "RFID and Consumers: Understanding Their Mindset", 2004

Finally, consumers can effect changes in the implementation of business' privacy policies simply through their wallets, by avoiding those companies that do not comply with privacy and data security legislation. If the notification of privacy and security breaches is actually imposed at the federal level in the United States and elsewhere, consumers may act against those companies that betray their trust. Stephanie Perrin from Zero Knowledge Systems in Canada points out that in this respect, "many companies are doing polling and discovering that customers will leave them if they feel that there is a breach of trust."⁸⁷ Poor publicity and the loss of clients can result in losses as high as ten per cent of the company's market capitalization, according to Gary Clayton, founder and CEO of Jefferson Data Strategies, a privacy and data protection consulting firm.

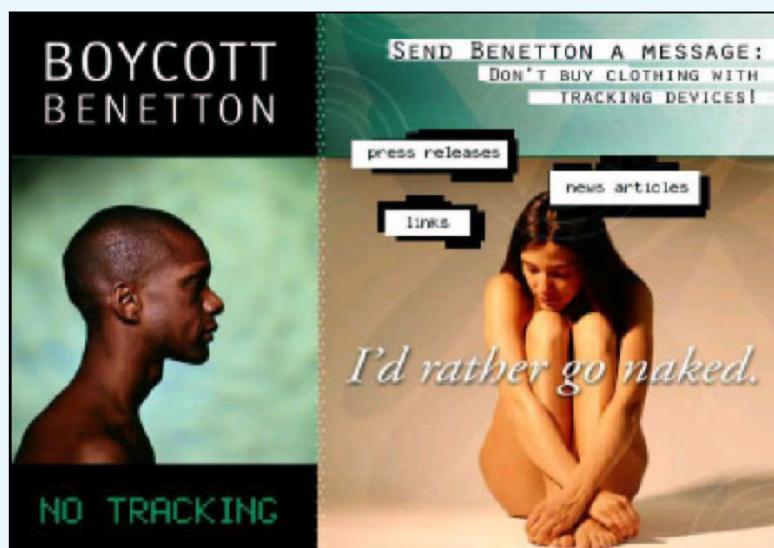
Once consumers are better informed and have more stringent legal control over their personal data, they will have a better chance of taking more rational decisions about the management of this valuable asset in the world of pervasive computing and surveillance.

4.4 Socio-ethical considerations

All new technological developments have some effect on society, whether desired or undesired. Similarly, social norms affect the direction of innovation and the diffusion of technology. Society as we know it will certainly be transformed by the diversification and widespread adoption of ubiquitous communications, RFID, nanotechnology, sensor technologies and smart objects. Beyond their implications for privacy protection, these technologies raise a number of other important socio-ethical issues.

Box 4.8: RFID: Big Brother's new gadget?

Retailers' efforts raise consumer concerns



The RFID privacy war was unleashed in 2003, when a group of consumers announced a boycott of Benetton. Already at that time, "Advertising Age" cited research whereby 78 per cent of consumers expressed worries about the likely breaches of privacy.

Despite these trends, Benetton and Philips initiated a pilot study whereby several million RFID tags were sewn into women's underwear apparel. Under vigorous consumer pressure, the trial only survived three weeks. Later that year, Wal-Mart had to withdraw from tracking Gillette products. Similarly, Metro ended its trial of customer movement tracking through the use of loyalty cards.

Other retailers, on the other hand, are trying to use consumer RFID privacy concerns to their own advantage. Marks & Spencer continuously points out the fact that they use RFID only to monitor stock levels, not for anti-theft or customer/employee monitoring. No label scanning is made at checkout, so garments cannot be associated with specific customers. Further, labels with RFID chips are made visible to consumers, so customers can easily detach them.

Image Source: S. Spiekerman and O. Berthold, "Maintaining privacy in RFID enabled environments", Humboldt University
Sources: Advertising Age, "P&G products to wear wire", 15 December 2003; Chain Store Age, "Trend Watch", July 2005

The Internet of Things will enable levels of convenience (e.g. in the home, in the car, and in the shop) that are far ahead of current services, and are likely to have a significant positive impact on quality of life. Sensor technologies and tagged objects in a smart home could help care for children, the elderly and the infirm. They could also allow flexible working hours and reduced commuting times, thereby encouraging family time. But the revolutionary capacity of "anywhere, anytime, anyone and anything" communications may raise some concerns about the future of social norms and ethical values. As seen above, institutions, regulation and policy-making may not be moving fast enough to keep up with rapid technological innovation. The same can be said about individuals and society as a whole – is society evolving fast enough to adapt to these new technologies? This raises another important question – do individuals and society (like laws and regulations) have to adapt at the same pace as the technology they use?

One of the most common fears is that new technologies are fostering a growing atmosphere of surveillance. There are of course different forms of surveillance, but the most prevalent today are technologically mediated forms. Such forms currently include, *inter alia*, video capture in public places, government records, biometric information (e.g. fingerprints), location and navigation technologies (e.g. GPS and even mobile communications that allow the capture of basic location information). These do not necessarily occur in isolated forms, but usually work within larger systems of surveillance (e.g. security systems, governance systems). New forms, such as RFID tags, are already beginning to make their appearance on clothing to enable retailers to track product use – these may not be automatically deactivated after purchase. Similar tags and sensors on other items such as food products and household appliances open up new mechanisms for tracking and monitoring human behaviour.

In the interest of governance and social order, technology is a growing mechanism for mediating surveillance. Technological surveillance has far-reaching implications, particularly in an increasingly ubiquitous network environment – one in which not only people are connected and tracked, but the things they come in contact with are as well. Often, it seems, computer records (particularly data and records relating to companies) are treated with much more respect than information pertaining to individuals (e.g. the location of individuals and their shopping habits).

Whether real or imaginary, an environment of surveillance can instil distrust and fear in humans, creating heightened anxiety in the exercise of choice and the making of decisions, no matter how small. Since decision-making is essential to individual self-fulfilment and self-expression, it is also crucial to societal advancement as a whole. On the other hand, suspicion and paranoia detract from healthy social intercourse, as well as creativity and overall human development. Moreover, although the creation of a network of smart things will further automate daily tasks, the complete automation of human activity is not a desirable outcome. Whether implanted with an electronic code or not, each human is unique and should be treated as such. There is little to gain from an increasingly conformist and uniform society. Individuality and self-expression are important catalysts for societal progress. A techno-political environment (in which individuals become mere numbers) must not be encouraged. Moreover, some numbered individuals may be included, while others might be excluded, in many cases in an arbitrary and automated fashion. This form of “social sorting”⁸⁸ has led to the creation of an industry devoted to the clustering of various populations, breeding further discrimination and fear.

Furthermore, as communications between people become increasingly mediated by technology (e.g. SMS), content must not give way to form: traditional forms of intimacy and human contact must not be lost. In many instances, like the technical devices that facilitate them,⁸⁹ human relationships are increasingly transient and ephemeral.⁹⁰ The mobile phone is an early example of this – many people now prefer to text each other than phone each other. Many sociologists point to the increasing use of voicemail and call screening: overall, a growing resistance to human face-to-face or even vocal interaction.

A further implication relates to the evolution of human capabilities. As sensor technologies become increasingly sophisticated, they may replace human abilities to sense the environment. The human nose, for instance, includes a thousand sensor genes,⁹¹ but today’s human being only uses thirty per cent of these as many are no longer required (e.g. for hunting or escaping physical danger in the wild). Recent genetic studies have confirmed a decline in the number of functional olfactory receptor genes from primate evolution to humans. One can wonder whether the human sense of smell will evolve further, as sensors begin to replace human noses to detect fire, rotten food, and even good wine. Before the invention of writing, human beings were able to memorize lengthy texts and detailed information. Many argue that human memory, too, has diminished, as many people today cannot even remember telephone numbers due to the memory-dialling function of their mobile phones. Research into even more complex memory aids, such as memory amplifiers, is under way (Box 4.9).

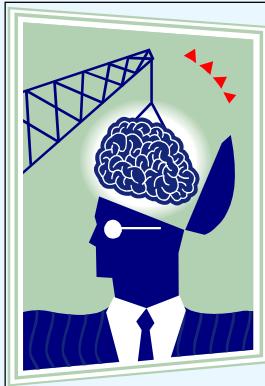
Similar to developments in smart and sensitive things, nanotechnology also promises a host of innovative applications, in fields ranging from health care to semiconductors. Although the technology is still in its infancy, and many of its potential applications relatively unknown, there has been much speculation about its implications. Nanotechnology can increase personal security and safety (through the surveillance of criminal activity and environmental monitoring), but it can also compromise privacy (as seen above) and raises a number of other concerns, such as:

- **Bio-medical concerns:** Bio-nanotechnology promises a future in which virtually any disease can be treated and even cured through action at the cellular and molecular levels, thereby enhancing the physical limits of the human body. However, will such treatment be available only to the rich? In addition, to what extent should we manipulate the human body? Up to which point should a human life be extended? To what extent should a race of “super-humans” be created?
- **Environmental hazards:** One of the main concerns of nanotechnology is its environmental impact. Some studies have found that the smaller the particle, the more toxic it can become, and of course, the more easily it can enter the human body⁹² through the skin, breathing or ingestion. Most researchers agree that further research is needed – for example, Rice University in Houston, Texas has set up the Center for Biological and Environmental Nanotechnology to study the environmental risks associated with nanomaterials and their effect on the environment and living organisms.⁹³
- **“Grey Goo” theory:** Since he first mentioned his “grey goo” theory, which was widely reported, Eric Drexler has conceded that the possibility of runaway self-replicating nanorobots cannot happen by accident.⁹⁴ However, his 2004 article appeared in a specialized nanotechnology journal, and as such, did not receive much public notice.⁹⁵

Not surprisingly, given the bleak “machine against human” references in literature and pop culture, there remains a certain fear of the robot, too, and indeed, of any form of excessive automation. The smart home, which may contain some robotic elements, promises to increase quality of life through communications access, context awareness and functionality. However, the social dynamics and relationships within the home make it a more vulnerable and volatile setting than, for instance, offices or public spaces.⁹⁶ Residents of a smart home will have to relinquish control over their most intimate contexts. The question is, as for other smart technologies, how much delegation of control is too much? How much monitoring of daily activities should be permitted? Moreover, further questions related to system reliability, usability, accountability and liability will have to be addressed as humans increasingly delegate control to automated decision-making tools⁹⁷ and even memory-enhancing tools (Box 4.9).

Box 4.9: Total recall

Amplifying our memories



Automatic memory enhancement is a new futuristic “hot spot” in ICTs today. One comes across such catchy labels as a “life-long diary”, “memory amplifier”, “remembrance agent” or even “memory prosthesis”. These and other notions refer to a tiny but powerful wearable device that continuously interacts with other similar devices, capturing individual experiences, arranging them in an easy-to-retrieve fashion and, ultimately, bringing up past reminiscences and facts relevant to the users’ current contexts.

In the mid-1990s, one of the leading research institutions in memory enhancement, MIT Media Lab, introduced a proactive reminder system called the “wearable remembrance agent”. The projects “Memory Glasses” and “Memory Prosthesis” also emanate from the MIT Labs. A network of British scientists is currently running a similar “Memories for Life” programme.

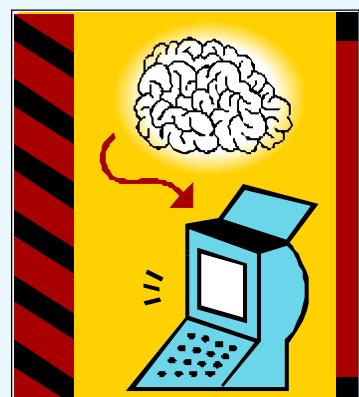
Since the late 1990s, research into memory automation has been largely driven by the R&D departments of major IT companies who sensed its commercial potential.

Examples of projects, either completed or still in progress include:

- “Factoids” at Compaq;
- “SPECs” (Small Personal Everyday Computers) at HP Labs;
- “MyLifeBits” and “SenseCam” at Microsoft Research;
- “Forget-me-Not” at Xerox;
- “Lifeblogs” at Nokia.

Nokia’s project is yet more evidence of the growing trend towards the convergence of mobiles and PCs, whereby phones are transforming into a truly multifunctional device with ever-increasing storage and processing capabilities.

Defence institutions have also taken interest in memory enhancement research. DARPA (The Defence Advanced Research Projects Agency) has recently made a call for proposals for its ASSIST (Advanced Soldier Sensor Information System and Technology) programme. The programme’s objective is to enhance the capture, classification and retrieval of battlefield information – a combination of video, audio, motion and location – by soldier-worn sensors. ASSIST runs under the aegis of the DARPA’s “LifeLog” programme, a research in cognitive computing aimed at elaborating solutions for capturing and analyzing war-fighters’ experiences.



Interestingly, the wave of memory enhancement research dates back to the groundbreaking article “As We May Think” written in 1945 by Dr Vannevar Bush, a man touted as the internet Godfather. Challenging scientists to optimize access to the vast accumulated base of scientific knowledge, he inspired them to enhance the human memory in general through further automation.

Image Source: Microsoft Office Clip Art

Sources: V. Bush, “As we may think”, *The Atlantic Monthly*, 1945; M. Lamming and D. Bohm “SPECs: Personal Pervasive Systems”, June 2003; B. J. Rhodes, “The wearable remembrance agent: a system for augmented memory”, *Personal Technologies Journal*, 1997; DARPA; Compaq

Further ethical considerations relate to the influence and dependability of information. As communication technologies become ubiquitous, the flow of information will be increasingly influential. Today's disseminators of information (e.g. search engines) already wield considerable power, in terms of which information is made available and in which order of priority.⁹⁸ Often, information can be wrong, outdated, unavailable or presented out of context. Currently, these problems are limited to the World Wide Web. But as information begins to flow out from every device and thing, who will ultimately retain control over its dissemination? Care must be taken not to allow the disseminator(s) of this wealth of information to be governed by commercial interests, but rather by the public interest.

In the future retail world, customer profiling mentioned earlier may become commonplace. The promise that users will receive the information best suited to their profile has great potential, for both retailers and consumers. However, profiling implies that information might be deliberately withheld from users, when they are not seen as a "valued recipient[s] of such information" (i.e. social sorting).⁹⁹ This threatens notions of universal equality, human rights and privacy. Who decides which information is available to whom?

Given the rapid pace of current technological innovation, it is also important to ensure that the divide between the technological "haves" and "have-nots" does not widen. The current digital divide not only relates to inequalities of access to telephones and the internet, but it now includes mobile phones, RFID, and sensors. Far from being a single divide, it is a patchwork of varying levels of access to ICTs.¹⁰⁰ New fields such as nanotechnology might serve to widen this divide, if more developing countries do not invest within their own borders, e.g. like India and China. Implications for developing countries are discussed in more detail in Chapter 5.

The emerging technologies underlying the Internet of Things offer many benefits for users and businesses alike. However, their growing complexity and availability will have a significant impact upon society. It is only through increased awareness of the far-reaching implications of these new technologies, particularly in the field of socio-ethics, that humanity itself can be preserved in an increasingly pervasive and automated technological environment.

4.5 Conclusion

The enabling technologies driving the Internet of Things pose a number of challenges, but also offer multiple benefits. For these technologies to be truly ubiquitous in a pervasive network of interconnected things, standardization of technologies and communications protocols is fundamental. While some success has been achieved in the standardization of RFID, standardization in nanotechnology and sensor technologies remains fragmented. There is scope for further involvement by national and international standard-setting bodies to promote greater harmonization in standards. Furthermore, the sheer scale and capacity of new technologies to record information creates new challenges for privacy and data protection. An individual's right to privacy, as well as their right to freedom from interference, can only be safeguarded through timely and coordinated action by government, market-based suppliers and consumer organizations.

These enabling technologies will be effective tools for business and personal life, but they must remain tools, and should not supplant important human needs and activities such as social interaction, affiliation or the sense of belonging.¹⁰¹ In an environment of technological ubiquity, belonging and identity linked with a place (cultural and geographic) is giving way to a sense of belonging to a network, e.g. an internet chat room, a blog. With mobile phones, users can be contacted regardless of their physical location.¹⁰² The creation of an Internet of Things will further enable the creation of home environments away from home. In this respect, the individual will in some sense become an organic portal. As such, technology goes beyond the status of a mere tool, and begins to reflect identity and inner consciousness.¹⁰³ But true human identity stems from non-technical origins, such as culture, education, and personality. As networks expand and become increasingly invisible, the boundaries between the real and virtual worlds blur, as do boundaries between real and virtual identities, between the inner and the outer self. Although technology will play a greater role in *identifying* individuals, it must never play a greater role in *defining* individuality or humanity.

Endnotes

- ¹ "Standardization", Encyclopedia Britannica from *Encyclopaedia Britannica Online*, available at: <http://www.search.eb.com>.
- ² "Standard", Internet.com, available at: <http://www.webopedia.com/TERM/S/standard.htm>.
- ³ International Organization for Standardization , available at: <http://www.iso.org>.
- ⁴ The Executive Summary of key findings in English is available at: <http://www.astm.org/> and <http://www.normung.din.de>.
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- ⁸ See <http://www.itu.int> and <http://www.iso.org/>.
- ⁹ ISO has a Joint ISO/IEC technical committee (JTC 1) working on information technologies, a technical committee on nanotechnologies (ISO TC-229) and one working on physical device control, including sensors (ISO TC-184, SC1-WG8). At ITU, the Radiocommunication and Telecommunication Standardization Bureaux have study groups examining issues related to sensors, telebiometrics and RFID.
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5 CHAPTER FIVE: OPPORTUNITIES FOR THE DEVELOPING WORLD

5.1 Introduction

As previous chapters have illustrated, technologies enabling the emerging Internet of Things are beginning to make their appearance across the globe. It might be easy to limit the present discussion to the industrialized world, but that would be short-sighted. Although most developing countries have little foreign investment in this burgeoning field and few comprehensive national research initiatives, the emerging technologies discussed in this report have the potential to offer many economic, societal and environmental benefits. In this context, the developing world merits special attention. The present chapter explores this important opportunity for the countries that comprise eighty per cent of the world's population, or some 4.9 billion people as of 2000¹.

5.2 Developing economies as users and innovators

The industrialized world has for quite some time been investing in research and development of technologies underlying the Internet of Things. Concrete applications are already on the market and are continuously being improved. At the same time, many emerging economies are quickly catching up with these developments. They are also forging ahead with their own governmental and private sector initiatives for technological diffusion in specific areas. Nanotechnology and RFID are increasingly seen as key drivers for promoting sustainable development² and improving the quality of life. It goes without saying that developing economies are not only important users of enabling technologies for the Internet of Things, but also the drivers of innovations.

5.2.1 Is the Internet of Things relevant for the developing world?

Due to limited resources and purchasing power, developing countries have typically been late adopters of new technologies and applications, although mobile phones and Short Message Service (SMS) are notable exceptions. Clearly, they stand to benefit from research and development (R&D) efforts in the industrialized world. A heterogeneous group, developing countries often have divergent priorities and aspirations in relation to the future landscape of the Internet of Things. The more advanced countries in this group, aware of its potential benefits, are promoting innovation and R&D with a tangible preference for RFID and nanotechnology, and some interest in sensors. Other countries are benefiting from technology transfer from more industrialized neighbors. These advances, although promising, are just the beginning, and governments and industry will need to work together to ensure stable and sustainable growth.

What are the promises of these new technologies for disadvantaged populations? Clean water, safe food, medication, cleaner forms of energy, sustainable resources – these are all “things” that can improve the quality of people’s lives. The converging platform of the Internet of Things could provide effective and efficient tools for improving the human condition in developing countries and ensure their inclusion on the international stage. New technologies such as RFID, sensors and nanotechnology will mean better health, greater opportunities, extended access and improved possibilities for international trade. They will also help create solutions for some of the most serious and chronic problems faced by less developed countries.

What matters most to many developing economies is not the future effervescence of value-added gadgets and applications, but rather, the potential benefits to achieve significant improvements in the everyday lives of their citizens. There are different ways to approach enabling technologies, e.g. to promote technology, to re-invent technology or even to ignore technology. Developing countries will not all take the same approach, focus on the same priorities or use the same measures to address challenges, as each country will be largely influenced by its own background – historical, cultural, developmental, political – as well as its R&D needs, physical and institutional infrastructure, demographics and economy.

For many developing countries, nanotechnology and sensors are already recognized as addressing some of their most pressing needs. A recent study³ summarized the top ten nanotechnology applications with the greatest potential to benefit developing countries in the years to come (Table 5.1). At the top of the list is energy (storage, production and conversion). Energy production can be greatly improved through the use of solar and fuel cells and innovative hydrogen storage systems. Semi-conducting polymers also have the

potential to reduce energy costs. In the Asian region, Sri Lanka in particular has conducted extensive research in this area.⁴

Another vital concern for many developing countries is access to safe water. Contaminated water causes a host of diseases, such as diarrhoea and cholera. In an effort to find solutions, the Hindu University in Banaras (India) has developed a system for water purification based on carbon nanotube filters. Other methods of water purification involve nano-electrocatalytic systems and nanomagnetic particles.⁵ Sensors, too, can play a vital role in protecting the population in remote and rural areas. The deployment of a network of wireless sensors could enable the measurement of environmental data for forwarding to the global internet, thereby allowing researchers to easily identify first signs of contamination.⁶ Some of these applications for healthcare and sanitation in support of the Millennium Development Goals are discussed in Section 5.4 below.

Table 5.1: What can nanotechnologies really do in the developing world?

Top ten nanotechnology applications for developing countries

1	Energy storage, production and conversion
2	Agricultural productivity enhancement
3	Water treatment and remediation
4	Disease diagnosis and screening
5	Drug delivery systems
6	Food processing and storage
7	Air pollution and remediation
8	Construction
9	Health monitoring
10	Vector and pest detection and control

Source: A. Singer, Salamanca-Buentello and A.S. Daar, "Harnessing nanotechnology to improve global equity", *Issues in Science and Technology*, Summer 2005

The developing world is approaching emerging technologies in line with other strategic priorities, such as integration into the global economy, international competitiveness and the growth of industrial exports. Firms in less industrialized countries closely monitor innovations in the industrialized world and adopt key technologies. The flourishing applications of RFID discussed in Chapter 2 of this Report, particularly those relating to global trade opportunities, have aroused enormous interest in these countries and are now beginning to be deployed. The next section examines the role of developing countries as users of enabling technologies.

5.2.2 Applying the technology

Technological advances in developing countries are often stimulated through government support and the use of innovative technologies by local enterprises, either independently or through strategic alliances with overseas companies, Multi-National Corporations (MNCs), and international organizations. A number of developing countries are not only applying the enabling technologies that make up the Internet of Things, but also innovating and adapting them to their own purposes – on their own terms, in their own way, and for their own advantage. This section examines a few of the applications that have been adopted by developing countries in the fields of RFID, sensors and nanotechnologies.

Developing economies in the Middle East and Asia are introducing RFID deployments. At the strategic crossroads between the Middle East and Europe, Turkey is a good example of an emerging market-driven economy. The country's enterprises and governmental institutions alike view RFID as a technology offering growing business opportunities. Payments at gas stations, vehicle tracking and access control are a few examples of successful domestic deployment of the technology (Box 5.1).

Other evidence of successful RFID deployments comes from Thailand, where the National Electronics and Computer Technology Centre (NECTEC) conducts research into new RFID-based applications. A new RFID

solution for car park security has recently been developed by the Centre's researchers.⁷ On leaving a car in the parking lot, the driver is issued a tag with the time, date and vehicle's registration number; when the driver returns, the security guard scans the data on the tag to confirm the driver's ownership of the car.

Box 5.1: Turkey goes RFID

A growing number of industries in Turkey are reaping the benefits of RFID



Turkish business actively interacts with the largest Western RFID suppliers. One of the early RFID applications in Turkey was a joint project between a major University in Istanbul and the Israeli/US-based company SuperCom for the establishment of the so-called "Smart Campus". The key tool in the project was RFID-enabled smart cards loaded with various applications: access control, time and attendance monitoring and electronic payments. The roll-out was completed by the end of 2004.

Other pioneering examples of RFID deployment in Turkey are:

- The Turkish retail industry is catching up with RFID deployment for supply chain management. One of the first Tesco stores to try RFID on its DVD boxes was Turkey's Tesco Kipa.
- In early 2005, a new motor vehicle control system involving 2'100 cars was rolled out in Turkey. The system is dimensioned for controlling eight access lanes. The transponders are mounted onto the vehicle windshield and can be read from a distance of up to 12 metres.

With such vigorous growth in deployment, local industry is quickly building expertise in RFID technology. Litum Technologies was the first Turkish company in Turkey to offer RFID solutions for vertical industries. It has yet to be seen whether Turkish food and pharmaceutical sectors will follow suit. Applications of RFID for food and drug manufacturing are particularly promising, as the problem of drug and beverage counterfeiting is considered by some to have reached catastrophic proportions in the country.

Image Source: iFrance

Sources: UsingRFID.com, "RFID deployed for access to 2100 vehicles in Turkey", 24 January 2005; UsingRFID.com, "Turkish University opts for RFID access control", 22 September 2004; The E-Business Executive Daily, "A Case for RFID", March 2005; Information Week, "Europe tries on RFID", 15 June 2005

In India, the buoyant apparel industry has started to look into RFID to improve its supply-chain efficiency and stock and shop-floor management to reduce costs and comply with international standards, especially in premium products. One of the India's largest retailers, Pantaloons, launched a pilot project introducing RFID at its Tarapore factory to boost the company's efficiency.⁸ The Philippines has begun to explore the marketing and retail benefits of RFID technology. Grocery stores in the country are typically very small, with not much room for shopping carts. To address this problem, scientists have developed and tested a self-service scanning system for baskets, with a potential anti-theft system. The system even includes a feature for packing goods after the scanning is over.⁹

The deployment of innovative applications fosters international trade. Hundreds of Chinese companies are integrating RFID into their value-chains in order to comply with Wal-Mart requirements, as one telling example. South America, another important exporter to the United States, is also rapidly adopting RFID in its traditional industries. For example, Brazil is home to the first Hewlett-Packard Centre of Excellence specializing in RFID, launched in 2003,¹⁰ and Mexico has also succeeded in developing some key innovations for RFID, including RFID-based chips to control access and track items (Box 5.2).

Yet RFID is not the only technology being adopted. Tech-savvy emerging economies in Europe have begun commercializing elements of nanoscience and nanotechnology. An interesting example comes from the Czech Republic, where a machine that can mass-produce woven fabrics made from nanofibres has been developed locally (Box 5.3). This patented machine is now being commercially produced for the wider market. The nanofabric it produces has widespread applications in filtering and protective clothing.

In South America, an increasing number of companies are successfully implementing technologies other than RFID into their business processes. In the area of sensor technologies, Brazil is developing its own high-tech solutions. One of its most strategic exports, coffee, is now subject to testing by sensors for the purpose of overall quality control. The aptly named “electronic tongue” is far superior to the human tongue in terms of sensitivity. Chilean scientists have developed a similar application (Box 5.4). Brazilian scientists established contacts with local business representatives in order to foster the transfer of knowledge on sensors from scientific labs onto the market. In spring 2005, Mexico launched a pilot project deploying RFID sensor networks in Mexican ports to reduce cargo theft.¹¹ Cargo theft costs the Mexican freight industry an estimated USD 1 billion a year.¹² The wireless sensor network, aimed at ensuring cargo security, will enable port staff to monitor cargo within the territory of the port and keep track of containers that enter and leave. In Colombia, Asocebu, the largest livestock farming association, injects RFID tags into the cows’ legs, so that important indicators, such as the weight of each individual animal, can be monitored daily.¹³

Box 5.2: Mexico gets innovative

Mexican entrepreneurs enter the global RFID market



There are some examples of entrepreneurs in developing countries that have succeeded in entering the global market of the Internet of Things. One example is BNC from Mexico. Within five years of operation, it became Mexico’s leading manufacturer and supplier of RFID tags and an innovator in the field of RFID-based applications. This firm sells its products in Mexico, the United States, South America and Asia. Some of the most innovative of BNC’s applications include RFID tags for law enforcement officials (to control access to high security locations), a secure system to positively authenticate the authorized use of weapons in Honduras, and RFID-based border crossing systems and vehicle control projects. In 2003, BNC was recognized by the magazine *Endeavor* as one of Mexico’s fifteen most dynamic developing enterprises. This enabled the BNC to expand. In 2004, it merged with Single Chip Systems creating Neology – The RFID Security Provider.

In this way, BNC has become a vertically integrated provider of RFID systems in Mexico and USA. In the meantime, Neology is still expanding. Its end-to-end solution in the vehicle registration sector has become the *de facto* standard.

Image Source: Greg Whitesell, ADS

Source: Innovation Mexico, available at: <http://www.innovationmexico.com>

Thus, by adapting key technical innovations to their own way of doing business, companies in developing countries stand to benefit from more efficient and less costly production processes.

Box 5.3: Czech nanospiders

Machine for the mass production of nanofibres

The Czech company Elmarco S.R.O., in cooperation with Liberec Technical University, has developed a machine called a nanospider that weaves nanofibre textiles on an industrial scale. This artificial fabric is made of nanofibres with diameter 100-300 nm (10^{-9} mm, less than the wavelength of light). Nanofibre textiles are manufactured with spaces between fibres, so they let through air, but nothing else. Nanofibres offer potential in healthcare and defense, protecting against infection, toxic gases or chemical weapons, and they can even be deployed in bullet-proof jackets.



As filters, nanofibre materials have extensive applications in medicine for plastering, covering, tissue engineering, genetics and membrane defense against viruses and bacteria. This invention is a revolution in the field of textile industry and clothing – it will make clothing light, cheap, and even able to absorb sound.

Image Source: Svet Vedy

Source: CTK Daily News, “New Czech production technology provokes world interest”, 19 May 2005. See also <http://www.nanospider.cz>

Box 5.4: Wake up and smell the coffee

Electronic tongues and noses in Brazil and Chile

As mentioned in Chapter 2, sensors can serve to enhance, or even replace, human eyes and noses. Thanks to a Brazilian invention, this has been extended to the human sense of taste.

In 2001, Embrapa (Brazilian Agricultural Research Corporation) developed an “electronic tongue”, a taste sensor made of nanostructured conducting polymers for use in food quality control in the food and beverage industry. Allegedly, the tongue can detect sweet, salty, sour and bitter tastes. It has 1'000 times more sensitivity than a human tongue. It was even able to sense the difference between Cabernet Sauvignons of different years from the same vineyard. In Chile, a similar project is under way to test the quality, purity, and origin of wines through “electronic noses”, which can distinguish between different grapes and vintages. The system uses a standard chemical sensor and an artificial neural network.



For industries such as wine, coffee or tea production, human tasters are crucial for ensuring the quality of products. However, after several hours of tasting, the human senses of taste and smell lose their effectiveness. By contrast, electronic tongues and noses are always reliable and efficient.

Image Source: Birds of a Feather

Sources: CIO Magazine, “In Good Taste”, 15 May 2002; Gazeta Mercantil, “Nanotechnology Expands”, 30 June 2004; O Estado de São Paulo, “Brazil: Nanotechnology reaches Industry”, 19 November 2004; Technology Review, “Chile”, April 2005, at <http://www.technologyreview.com>

5.3 Space for the state in enabling the Internet of Things

The starting point, and indeed the prerequisite, for the adoption of new technologies in the developing world is the tight integration of ICT policy into strategies for economic development and governmental action. Firstly, regulators can undertake comprehensive ICT sector reform towards facilitating competition, market liberalization, de-monopolization and privatization of incumbents, as well as providing the population with universal access. In addition, a national government can foster a favourable investment climate for R&D through its strategy for investment, the design of an effective legal framework and the development of partnerships. The state has an important role in forming partnerships for technological innovation, and in nurturing budding high-tech development through the establishment of national science and technology parks.

5.3.1 Investing in the technology

Technological development is one of the integral components of economic development. Governments in the developing world recognize this. The government of India, for instance, is planning to increase its R&D spending from below one per cent of GDP to at least two per cent. China¹⁴ is currently allocating 1.2 per cent of GDP to research in ICTs, compared to 2.5-3.0 per cent in the more industrialized countries. Interestingly, in relative terms, Chile invests the same proportion of its GDP (if not more) as India or even China (Box 5.4). Colombia’s investment in ICTs, is also impressive: it represents 2.4 per cent of GDP and is set to grow further. In 2007, investment in the ICT industry by Colombian companies is forecast to be USD 2.7 billion, up from USD 2 billion in 2005 and USD 1.6 billion in 2004.

Nanotechnology, in particular, is an area of tremendous potential for developing nations. Developing countries in Asia were among the first to realize the importance of nanotechnology. What distinguishes them from the rest of the developing world is stronger coordination between the ICT industry and public funds. Between 2003 and 2007, the Chinese government will have invested about USD 240 million in nanoscience and nanotechnology, for instance. In addition, local authorities intend to spend another USD 360 million. India is projected to contribute USD 23 million to nanoscience research between 2003 and 2009.¹⁵ Both Asian giants are implementing large-scale national plans for nanoscience and nanotechnology (Box 5.5). Other developing countries in the region are also starting to explore wireless sensor networks and RFID technologies. Viet Nam’s Vice-Minister for Posts and Telecommunications, for example, recently announced that research has been initiated by the Vietnamese government into the prospects for the implementation of RFID and ubiquitous networks.¹⁶ In Africa, South Africa has set up the Nanotechnology Initiative, a national

network of academic researchers working in areas such as nanophase catalysts, nanofiltration, nanowires, nanotubes, and quantum dots. In 2004, the country's estimated spending on nanoscience was USD 6 million.¹⁷

Box 5.5: India and China race head to head to the Internet of Things

Government support key to global competitiveness



China ranks third in the world after the United States and Japan in terms of the number of nanotech patents. The development of nanoscience in China was inspired by the Chinese Ministry for Science and Technology. It has been further facilitated and carried out by an impressive array of institutions: the National Steering Committee for Nanoscience and Nanotechnology, the National Nanoscience Coordination Committee and 11 institutes of the Chinese Academy of Sciences, including the world-famous Wang's institute of physics. The research hub is located in Beijing, while the industrial base is concentrated in Tianjin. Applied science very quickly finds its way to production lines and consumers. Haier, China's largest home appliance manufacturer, is integrating nanotech materials in refrigerators, televisions and computers. Other companies manufacture water- and oil-proof textiles that withstand shrinking and discoloration.

India's Nanotechnology Program also involves a whole range of governmental institutions, such as the Department for Science and Technology, the Ministry of Defense, the Institute of Smart Materials, Structures and Systems, the Indian Institute of Technology, the Saha Institute of Nuclear Physics and many more. India's approach is different from China's in that government support is more strongly focused on fundamental and knowledge-intensive science rather than applied science, and research is currently being fostered in areas such as micro-electromechanical systems, nanostructure synthesis, DNA chips, quantum computer electronics, carbon nanotubes etc. India holds numerous nanotechnology patents and has achieved impressive results in various biomedical applications, e.g. drug delivery systems for cancer and eye disease.



Image Source: CIA Factbook

Source: A. Singer, Salamanca-Buentello, and S. Daar, "Harnessing nanotechnology to improve global equity", *Issues in Science and Technology*, Summer 2005

In South America, nanotechnology has become an important priority for technological development. The Brazilian nanotechnology initiative was set up in 2001 and has become an integral part of the country's industrial, technological and commercial policy. There are four research networks in the country, which have already been awarded 17 patents¹⁸, largely due to funding provided by the Ministry of Science and Technology. Two virtual institutes have been created, with USD 7 million allocated for nanoscience and nanotechnology in 2004. It is expected that the total budget for the 2004-2007 will reach USD 25 million.¹⁹

Not only do national science programmes benefit from governmental support, but so does local business. Many high-tech enterprises have flourished on government orders, for instance those related to e-initiatives such as ID cards. The e-Russia programme, for example, will have invested USD 2.4 billion by 2009 for the development of Russia's ICT sector. Programme tendering is under way for the best solution for national ID cards with biometric sensors, valid for travelling to Europe and the United States.²⁰ The Nigerian Government recently launched and financed two ambitious programmes, the "Nigerian Software Development Initiative" and "Software Nigeria", aimed at substituting technological imports with locally developed software, thereby preserving foreign currency reserves, and becoming a recognized global exporter of software products.²¹

5.3.2 The role of partnerships

As developing countries often lack financial and technical resources, international partnerships and technology transfer can be crucial to achieving development goals. Partnerships can capitalize on the role of new technologies for such countries, bearing in mind that inappropriate technologies run the risk of causing considerable harm.²² Technology transfer is an equally important mechanism, though its effectiveness suffers from a number of challenges. A lack of structure, decentralized data management, weak links between decision-makers and R&D communities and restrictions on free access to information (for strategic, political, economic or other reasons) all pose serious constraints to creation, sharing and dissemination of knowledge. Partnerships offer a strategic advantage over technology transfer, as they can overcome some of these

challenges, particularly in terms of information flow. Awareness and careful study of possible technological paths will allow these countries to harness the benefits of relevant technologies enabling the Internet of Things.

Israel provides an excellent example of international collaboration between high-income and emerging economies. Supported by the national government, the country is establishing an institutional framework for investment in knowledge-based start-ups. Recently, the Israeli Ministry of Industry, Trade and Labor signed a strategic collaboration agreement with IBM. Within the framework of the Agreement, the Ministry intends to connect Israeli start-ups with multinational companies. It will select the most promising start-ups, so they can “deploy, optimize and develop customized solutions based on IBM’s open technology”.²³ Meanwhile, a joint project launched by Motorola and the Israeli-based Cima Nanotech is targeting the development of next-generation RFID, with emphasis on cost-effectiveness and ease of manufacturing. Project implementation will require USD 2.4 million. The BIRD Foundation (Israel-US Binational Industrial Research and Development) has already invested USD 1 million.²⁴

African businesses have also benefited substantially from partnerships. In Namibia, for instance, cooperation between local meat producers, foreign partners and international non-governmental organizations (NGOs) has resulted in a cross-continental project involving the use of RFID technology for tracking beef (Box 5.6). In Nigeria, wireless sensor technologies have been deployed for the long-range monitoring of Nigeria’s Shell Petroleum oil wells and facilities in the Niger Delta.²⁵ Small, battery-powered, and capable of long-range communications, wireless sensors have proven to be highly effective for use in dense Nigerian jungles and thick swamps. They go unnoticed by potential thieves or vandals, in contrast to previous generations of remote monitoring systems based on solar power panels. The new system improves reservoir management, prolongs reservoir life, provides real-time monitoring and surveillance of remote wells, and can avert disasters in the drilling of new wells. Engineers are able to access the company’s intranet from any location. Early testing results have shown that the wireless sensor system has resulted in a more than one per cent increase in production, the equivalent of USD 29 million in annual revenues (taking into account the prices for petrol at the moment of testing).

Box 5.6: Tracking beef in Namibia

International cooperation helps launch RFID project in Africa

For Namibia, beef is one of the main items of export to the EU. In December 2004, within the framework of the Smart and Secure Tradelanes (SST) initiative, more than fifty containers of frozen beef and chicken exported from Namibia to the United Kingdom were tracked and monitored by a sensor-enabled RFID system. The main function of the RFID sensors was to help in the detection of tampering, and to ensure visibility of meat shipments. Tagging containers with RFID sensors ensured the quality of meat that had to travel thousands of kilometres from Namibia to the UK, and helped to prevent theft.

RFID sensor bolts attached to each container provided and stored real-time information across the entire delivery chain: the location of a container, its integrity status (whether it had been tampered with or whether the seal had been broken en route), how long it stayed a certain point, as well as the name of employee who had sealed it. At each checkpoint, when leaving the plant or being loaded into a ship or truck, information was recorded by stationary and wireless readers. RFID wireless sensor networks can be integrated into other networks to provide security and real-time visibility across international shipping lanes. By mid-2005, similar projects had been implemented in more than fifteen ports around the world, and more than 2000 containers had been sealed with active RFID sensor bolts.



Image Source: IFAD Photolibrary

Source: *RFID Journal*, “African beef gets tracked”, 10 December 2004

In South America, Argentina has recently announced that, in partnership with Lucent Technologies, it will spend USD 10 million on nanotechnology over the next five years.²⁶ Meanwhile, local authorities in Brazil are exploring the benefits of RFID. The “Instituto de Pesquisas Tecnologicas” in Sao Paulo has joined forces with Motorola to develop a public safety system for individual identification, based on RFID.²⁷

Creating links between science and business is an important challenge faced by both developed and developing economies. It is of vital importance for governments to facilitate the smooth operation of the value chain from scientific research to market (see Figure 3.1 in chapter 3). Governments play an important role as intermediaries in the interaction of science and business. In particular, they facilitate the adoption of regulatory and socio-economic frameworks, ranging from ICT innovation legislation to the establishment of science parks, where teams of developers are in constant cooperation with business to accelerate the commercialization and introduction of high-tech products and applications to market (Box 5.7). Where governments show strong commitment, countries quickly adopt leading technological positions.

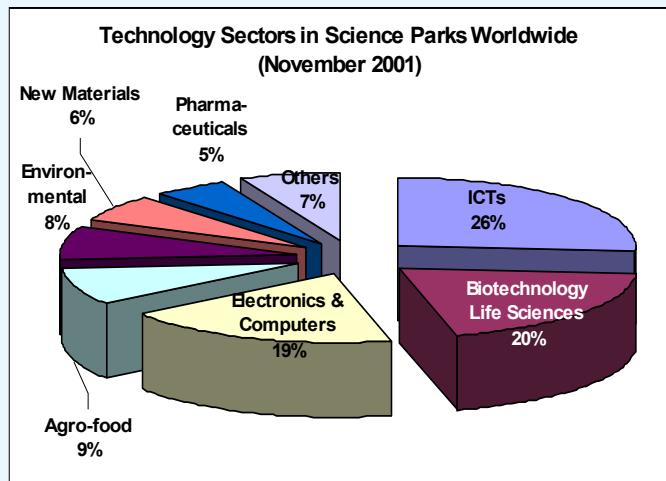
Many less developed countries distinguish between R&D policies that focus on the generation of new knowledge, and industrial policies that focus on building and manufacturing capabilities.²⁸ Convergence of these two approaches could foster the broad use of existing technologies, while building a foundation for long-term R&D efforts. A typical characteristic of R&D in developing countries is the scarcity of investment in the emerging technologies, given that such investment could be considered as taking precedence over other pressing needs. Therefore, it becomes increasingly important for the industrialized world to actively support late adopters and emerging economies in the developing world in discovering the tremendous potential of new technologies for overcoming the digital and other types of “divides”.

Box 5.7: From lab to market

Introducing the science park

One of the main problems that developing countries face is a lack of entrepreneurial effort to bring technology from lab to market. One of the solutions for fostering cooperation between business circles and institutions for scientific development is the science park. Science parks are also known as technology parks, science towns, technopoles, technology precincts, science cities, research parks, innovation centres, etc. Bringing together a cluster of independent bodies and support organizations operating in the same field, science parks normally have the following features:

- stimulation of technological innovation for the sake and benefit of the society;
- proximity to and links with universities and other research centres;
- provision of value-added services; and
- management by specialized professional staff.



In some cases, science parks include business incubators, enabling them to transfer technologies to the market and encourage the growth of knowledge-based businesses. Research areas are diverse, but as the graph shows, more than half of all research efforts are directed to development in areas enabling the smart world and ambient computing.

The oldest and most famous science parks in the developed world are Silicon Valley in the United States and the science parks in Sophia Antipolis (France) and Tsukuba Science City (Japan).²⁹ The United States is the leading country by the number of science parks, with more than 150, followed by Japan with 111. China started its science park development in the 1980s, and today has around 100 parks. By way of comparison, in Romania there are 19 technology transfer centres and 14 scientific and technology parks.

Figure Source: Technology Sectors in Science Parks, November 2001, International Association of Science Parks
Source: UNESCO Overview Science Parks around the World, at <http://www.unesco.org/pao/s-parks/overview.htm>

The success of India's IT industry is often associated with the International Technology Park (BITP) in Bangalore. Bangalore is one of the biggest outsourcing centres in India, and hosts more than 1'500 companies involved in the provision of IT services and the development of software. Dubbed the Silicon Valley of Asia, the city of Bangalore contributes 34 per cent of all national software and IT service exports. BITP is a host to companies such as American Express Services, AOL Member Services, IBM Global Services, Intel, Lucent, Sanyo, Sony, Tyco and others. It is one of the main destinations for outsourcing worldwide and, every month, more than 40 companies on average continue to set up operations there. Also located in Bangalore, the Electronics City is an industrial park occupying 1.3 square kilometres, home to more than a hundred IT companies, including Motorola, Infosys, Siemens, Wipro, etc. Currently, India accounts for 45 per cent of the world's IT outsourcing market; in 2004, the country exported IT services and software amounting to USD 17.5 billion. The annual turnover of Indian IT companies reached USD 12.5 billion by 2003 and analysts forecast this will rise to USD 50 billion by 2007. Each of the so-called Indian "Big Five" (TCS, WIPRO, Infosys, Satiam and MphasiS) earns at least USD 700 million per year.

In the former Soviet Union, the establishment and promotion of technological research centres was a powerful way of leveraging extensive human capital with advanced scientific knowledge and engineering skills.³⁰ The first technology parks emerged in Russia in the late 1980s and were based on models developed in the United States. Today, Russia's 78 technology parks concentrate on topics as diverse as the production of IT software, the development of mobile content, biotechnologies and robotics. In order to boost research in nanotechnology, which has so far been quite fragmented, the Russian Government has planned to invest USD 500 million over the coming years.³¹ To this end, a national investment fund will be launched and four new technoparks will be set up in Moscow, St. Petersburg, Nizhny Novgorod and Novosibirsk, with nanotech as a priority branch of research.

In Central Asia, Kazakhstan, despite its strong scientific base, lacks strong ties between business and science. This means that the process from an innovative idea to the final product can take an unacceptably long time. There are more than 544 scientific research institutes in the country, of which 80 per cent are focused on fundamental research and only 20 per cent are involved in applied science. The government is now making efforts to correct this bias, through, *inter alia*, the adoption of a "Strategy of Industrial and Innovation Development for 2003-2015". Within the framework of this strategy, the IT Science Park "Alatau" has been established, aiming to replicate the Indian Bangalore model. Currently, the park is engaged in more than 60 projects.³² More than 30 corporations have shown interest in participating in this Science Park, and Hewlett-Packard, IBM, Microsoft, Samsung, Sun Microsystems and Thales have already signed collaboration agreements.³³

This section has illustrated the potentially crucial role that governments, in collaboration with the private sector, can play in shaping and diffusing emerging technologies in the developing world. It is only through this collaboration, both domestically and globally, that the developing world will find the tools to apply the various technologies underlying the Internet of Things.

5.4 Common development goals and the World Summit on the Information Society

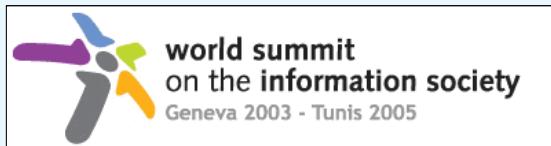
Aware of the growing necessity of concerted action to overcome the most urgent problems of the developing world, in 2000 the United Nations proposed the Millennium Development Goals (MDGs). These goals represent an unprecedented promise by world leaders to address, in a single package, the key issues of peace, security, development, human rights and fundamental freedoms.³⁴ The MDGs represent a consensus vision of sustainable development, and, in particular, can serve as useful guidelines for science communities to address development challenges.³⁵ At the 2005 G8 Summit, calls were made for the adoption of a coherent approach to nanotechnology applications for the developing world and Least Developed Countries (LDCs).

In line with the global commitment to the MDGs, the World Summit on the Information Society (WSIS)³⁶ is focusing on ICT development through building national e-strategies, guaranteeing universal, ubiquitous and affordable access to ICTs and encouraging wide dissemination and sharing of information and knowledge. In the context of the least developed countries (LDCs), in particular, WSIS commitments go far beyond technological diffusion – there is a pledge for common action towards poverty alleviation,

the enhancement of human potential and overall development through ICTs and other related and emerging technologies (Box 5.8).

Box 5.8: A Summit of Solutions with special focus on the developing world

World Summit on the Information Society (WSIS), Geneva 2003 - Tunis 2005



The United Nations World Summit on the Information Society (WSIS) is targeting the growing digital divide between developed and developing countries, and mobilizing global efforts to identify and implement solutions for people all over the world, with a special focus on developing countries. The ITU serves as the lead UN agency for organizing the Summit.

The first phase of the WSIS in Geneva was committed to laying the foundation for “building a people-centered, inclusive and development oriented Information Society, where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life” (paragraph 1, *Declaration of Principles*). The *Plan of Action* sets out concrete commitments extending the power of ICTs and the achievement of the UN Millennium Development Goals (MDGs).

The second phase in Tunis in November 2005 is a “Summit of Solutions” aimed at the concrete follow-up and implementation of the Plan of Action and building partnerships to allow people to share in the benefits of ICTs. One of the main targets is to make ICTs accessible to more than half of humanity by connecting remote communities, civil society institutions, academia, governments and business by 2015. One of the solutions needed might already be within our reach – emerging technologies enabling the Internet of Things offer key opportunities for the development of countries, empowering them to take appropriate action and respond in a timely manner to grave deficiencies.

Source: WSIS, at <http://www.itu.int/wsis/>

Science and technology have played an important role in reducing mortality rates and improving lives in the period 1960-1990, as is clearly illustrated by the 2001 Human Development Report of the UN Development Programme (UNDP).³⁷ Since the early 1990s, emerging technologies have demonstrated even greater potential to address traditional challenges in the developing world and to accelerate the development processes at all levels. Nanotechnology offers the greatest potential benefits to less developed countries. Most importantly, it promises to provide easy and cheap access to, *inter alia*, clean water, safe food, drugs, health monitoring, basic facilities, and clean energy. These areas are examined in more detail below.

5.4.1 Clean water and treatment of waste

According to the 2004 UN Human Development Report, 1.1 billion of people worldwide do not have access to safe drinking water. Waterborne diseases and water-related illnesses kill over five million people a year worldwide, of which 85 per cent are children.³⁸ Most deaths are caused by cholera, diarrhoea and dysentery due to contamination of the drinking water. This is one the main application areas of nanotechnology, in that it can help filter contaminated water, salt water and all forms of wastewater to create safe drinking water.³⁹

Many research projects have been deployed all over the world for effective water quality control. Using nanotechnology, Seldon Laboratories of Vermont developed a “nanomesh” fabric made of fused carbon nanotubes that can filter out all bacteria, viruses, and other waterborne pathogens. It is also supposed to remove lead, arsenic, and uranium.⁴⁰ For water purification, nanomembranes offer the possibility of an efficient removal of pollutants and germs. In parallel, nanoporous ceramic filter membranes for the sterilization of treated water have been developed by the company Argonide with the support of the Small Business Innovation Research (SBIR) project of National Aeronautics and Space Administration (NASA). These nanomembranes are based on nanostructured aluminium fibres, and can remove viruses very efficiently. They are also less susceptible to pore blockage than conventional membranes.⁴¹ Given the poor quality of water resources in many areas, this application could be of great value in improving health and sanitation in developing countries⁴² (Box 5.9).

Researchers at the Rensselaer Polytechnic Institute and Banaras Hindu University in India have devised a simple method to produce filters that efficiently remove micro- to nano-scale contaminants and germs from

water and heavy hydrocarbons from petroleum. Made entirely of carbon nanotubes, the filters are easily manufactured using a novel method for controlling the cylindrical geometry of the structure. Nano-membranes and nano-clays are inexpensive, portable and easily cleaned systems that purify, filter and desalinate water more efficiently than conventional bacterial and viral filters.⁴³

Box 5.9: Nano-water

Water Purification System in Bangladesh



An estimated 10'000 tons of sludge from wastewater treatment plants are generated globally each day. Simultaneously, tens of millions of people in West Bengal, India and Bangladesh have been drinking arsenic-contaminated water for the past two decades. Moreover, in many districts in Bangladesh there is a high concentration of natural arsenic in the wells. These two problems have stimulated research aimed at developing a combined process whereby iron is recovered from waste sludge and used to remove arsenic from drinking water. The Donnan Membrane process is shown to be effective in recovering up to seventy per cent of iron used in coagulants and generally lost in waste sludge. Furthermore, ion exchange resins are efficient in removing metal ions from the solution.

Another team based at Oklahoma State University in the United States has developed a method of using zinc oxide nanoparticles to remove arsenic from water that could address the problem of natural arsenic pollution in wells, which is particularly widespread in Bangladesh.

Picture source: UNICEF

Sources: Lee Blaney, "Reducing, Reusing and Recycling on the Nano-scale", 18 April 2005, at <http://www.sustainus.org>; The Meridian Institute, "Nanotechnology and the Poor: Opportunities and Risks", 2005 at <http://www.nanoandthepoor.org>

This technology would be particularly useful in the case of shipwrecked petroleum tankers and would allow for a clean-up of the environment in a cost-efficient way. Since many developing countries lack basic funding for environmental action, local population in these countries would experience the benefit of this invention first-hand, in terms of a cleaner environment. Moreover, due to environmental interdependence, there would be wider benefits, both for neighbouring countries and globally.

Nano-sensors could also be used for the cost-efficient monitoring of water thanks to significant improvements in their sensitivity and reduced power consumption, compared to the existing sensor products and technologies. Next-generation monitoring systems could prevent or minimize the negative impact of pollution (such as the arsenic contamination in Bangladesh) enabling continuous assessment of different parameters. Automated control over all elements (aerators, pumps, alarms and other electrical devices) allows greater flexibility for targeted action in response to specific needs, e.g. aerators can be turned on (day or night), when pollution exceeds certain levels. Together with continuous monitoring, automated control keeps the system operating efficiently without the need for human surveillance. Multiple communication options are available for transmitting data to the central computer, including radio, telephone, mobile phone, voice-synthesized phone, satellite, and Ethernet. Systems can be programmed to transmit alarms or report site conditions.⁴⁴

Smart sensors have much to offer developing countries. The Mälardalens University in Västerås in Sweden has supported an advanced research project for the development of smart sensors for water quality control. When identifying contaminants, it is important to choose the right kind of water treatment. The advantage of smart sensors is that they can immediately determine the quality of water and recommend a suitable treatment. The sensors are portable, reliable, cost-effective, robust, battery-operated and easy to handle.

In many less developed countries, both surface water and ground water contain biological and chemical contaminants. Although about 52 per cent of the world's population live in rural areas, the appropriate technology for measuring the type and degree of hazardous contaminants in water for households is lacking.⁴⁵ There are neither prospects for clean water supply nor proper control of the water quality. The development of appropriate water purification and water quality control technologies is essential for developing countries. These goals for safe water are reflected in the objectives set out in the Millennium Development Goals.⁴⁶

5.4.2 Better healthcare

Nanotechnology holds much promise for healthcare, an issue of particular importance in the developing world, where curable and preventable diseases abound due to poor sanitary conditions. In addition to improving basic living conditions through cleaner air, water and soil, nanotechnology can help diagnose and prevent diseases early, and even facilitate on-site or remote surgical intervention.

Disease diagnosis and treatment

Nanometre-sized quantum dots, for instance, could be used to tag molecules for the verification of the status of the disease.⁴⁷ The tests could be carried out without the need to use expensive special equipment and sterile laboratory conditions, which are often unavailable in rural and remote areas.

Furthermore, quantum dots and other nanomaterials could help develop inexpensive miniaturized devices for medical diagnosis. The size of these devices means that they could be easily used in remote regions, and even be remotely monitored. Vaccination that has greatly reduced child mortality in developing countries⁴⁸ could be administered in a more controlled and targeted manner using nanoparticle delivery systems.⁴⁹

AIDS remains uncontestedly one of the biggest calamities for the developing world. Over 4.3 million people were infected with the virus in 2004, of which 570'000 are children. Many of those infected are living in extreme poverty, receive no treatment and have no access to medical care. The HIV/AIDS pandemic has been particularly deadly in some countries in Africa and Haiti, with estimated infection rates between 4 and 9 per cent of the population.⁵⁰ Nanotechnologies used in handheld devices are being developed to treat the disease (Box 5.10), as are developments in topical gels using nano-scale polymers.

Box 5.10: Better life for HIV patients

A cheap, fast and portable way of monitoring HIV



A research team led by John T. McDevitt at the University of Texas in the United States aims to develop a handheld device that could greatly improve HIV treatment for people living in poor rural areas with few medical resources. To assess whether and when to give HIV patients antiretroviral drugs, healthcare workers need to monitor the level of a particular type of immune cell in the blood. The prototype needs one drop of the patient's blood for a fast and reliable analysis. A microscopic tool similar to a digital camera takes a picture of the blood sample and a microchip counts the number of immune cells automatically. The whole test takes about ten minutes.

The current standard test for this in developed countries is costly and requires considerable equipment and technical expertise. However, nanotechnology promises better health monitoring at a marginal price and seems to be well adapted to the context and needs of developing countries. In the future, the inclusion of internet access technologies could enable the swift delivery of this information to central health monitoring databases.

Image Source: UNAIDS

Source: Scidev , "Handheld Device Could Monitor HIV Cheaply", 19 July 2005, at <http://www.scidev.net>

The World Health Organization (WHO) has recently estimated that one-third of the world's population still lacks access to essential drugs⁵¹, mainly due to limited availability and high cost. However, nanotechnology might soon provide solutions to these deficiencies (Box 5.11) and could one day lead to cheaper, more effective and wide-spectrum drugs.

For example, in drug delivery, nano-scale materials can provide encapsulation systems that protect and secrete the enclosed drugs in a slow and controlled manner. This could be a valuable solution in countries that do not have adequate storage facilities and distribution networks. It could help patients on complex drug regimes who cannot afford the time or money to travel long distances for a medical visit.⁵²

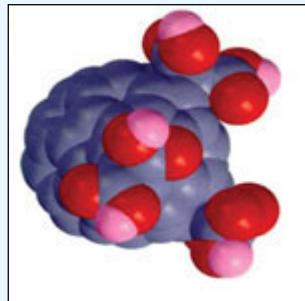
Nanotechnology combined with sensing could also provide a number of appropriate solutions for developing countries in the field of health, and in drug production in particular. Ireland's National Microelectronics Research Centre is leading a project for the development of integrated sensors for the screening of antibiotic resistance. The overall aim of this project is the development of multi-sequence DNA sensor arrays for the identification of multi-drug resistant strains of tuberculosis.⁵³ Addressing malaria and tuberculosis is

particularly essential for improving health and security in the least developed countries, particularly in Africa.⁵⁴

The technologies enabling the Internet of Things could also improve the quality and reliability of conventional drugs in the developing world. RFID tagging could combat diluted or counterfeit drugs. According to INTERPOL, about 60 per cent of counterfeit medicine cases occur in developing countries in anti-malarial drugs, antibiotics and antiretroviral drugs against AIDS.⁵⁵ Mass serialization using RFID to identify all drug products could prove a powerful tool to ensure the safety and security of drug supplies in developing countries. A unique number for each pallet, case and package would allow drug purchasers to immediately determine the drugs' authenticity. However, the integration of an RFID system requires the availability silicon tags, antennae, tag readers, and software allowing the identification of the medicine and its associated data. Acquiring and integrating RFID systems into current manufacturing and distribution processes needs considerable planning, experience, and investment of resources.⁵⁶ Nevertheless, the potential of RFID for securing drugs is worth exploring, as cheaper and safer drugs are essential in combating disease in developing countries.

Box 5.11: Nano-drugs

Miniature nano-drug factory



During the past two decades, the fields of molecular biology and biotechnology have undergone a revolution. We come across products of this revolution almost every day: in food, clothes, and pharmaceuticals. It all began in 1973, when Herb Boyer and Stan Cohen produced a chimeric organism. A chimera is an organism composed of two or more kinds of genetically dissimilar cells. The researchers transplanted an antibiotic resistance gene from a frog into a bacterial cell thus “engineering” an antibiotic-resistant organism. In 1980, molecular biologists inserted the human gene for interferon (an antiviral agent) into bacteria. When the transformed bacteria reproduced, a miniature drug factory was formed. This meant that previously costly unavailable drugs could be mass-produced inexpensively, e.g. insulin for diabetics.

This “miniature drug factory” could be very beneficial for developing countries, as it has the capacity to produce as many different drugs as required. It could respond rapidly to the particular needs of medical treatment. Local medical specialists would not be limited by available stock and delayed deliveries to provide the most efficient response. The cost of the device will be marginal compared to its utility, in terms of lives saved and improved overall health conditions. Theoretically, this invention could help local professionals and communities to regain control from large pharmaceutical companies over manufacturing of badly-needed drugs.

Image Source: cSixty

Source: Highlights from “DNA-The Blueprint of Life” at <http://www.easternct.edu/>

Surgery with Things

Robotics is still considered a costly solution for implementation by developing countries, especially compared with the cost of labour in such countries. Still the invention of a self-replicating robot able to manufacture and recycle everyday objects is worth noting (Box 5.12). And in telemedicine systems, robotics could provide remote populations with emergency access to medical assistance.

Robotic surgical systems are being developed to provide surgeons with unprecedented control over sophisticated high precision instruments (Box 5.13). This is particularly useful for minimally invasive surgery. These techniques could benefit a number of patients in under-served areas of the developing world. In these countries, medical centres and staff are generally insufficient, compared to the number of potential patients. Among other problems, post-operative complications occur frequently, as patients are discharged early.

Health monitoring

Nanotechnology combined with sensors can offer implantable and/or wearable sensing systems for continuous and accurate medical monitoring. Using nano-sensors, an efficient pest detection control system could be implemented, reducing the incidence of disease and mortality. Complementary microprocessors and

miniature devices can be coupled with sensors to diagnose disease, transmit information and administer treatment automatically if required.⁵⁷

These kinds of devices could greatly improve health conditions in remote communities with limited access to medical healthcare. The prices of nano-devices should fall over time and allow the more widespread diffusion of these technologies to developing countries, as was the case with mobile telephony.

Box 5.12: A robot that self-replicates

A revolutionary machine can copy itself and manufacture everyday objects



The “self-replicating rapid prototyper” or *RepRap*, is the brainchild of Dr Adrian Bowyer, a senior lecturer in mechanical engineering at the University of Bath in the UK. It is based on rapid prototyping technology commonly used to manufacture plastic components in industry from computer-generated blueprints – effectively a form of 3D printer.

A revolutionary machine that can copy itself and manufacture everyday objects quickly and cheaply could transform industry in the developing world, according to its creator. With just a computer and a single *RepRap*, the needs of a small-sized community could be met. The machine could build items ranging

in size from a few millimetres to around thirty centimetres, such as plates, dishes, combs and musical instruments. Larger or more complicated items could be assembled from smaller parts, and by adding extra parts such as screws and microchips.

“It is the first technology that we can have that can simultaneously make people more wealthy while reducing the need for industrial production”, the inventor states.

The technology could help solve some of the recycling issues commonly associated with plastics: not only can the machine copy itself, but it can also make its own recycler. When you break something you can just feed it into the recycler, which then breaks it down to its raw materials and re-builds it. The key ecological advantage is that it cuts down on the transportation necessary both to manufacture products and to dispose of them. Every household would have its own recycling set-up. This solution is well-suited to developing countries where environmental sustainability is a severe challenge.

To encourage that development, Bowyer plans to make the design of the *RepRap* available online and free to use, in much the same way as open source software (like the Linux operating system or Mozilla’s Firefox browser).

Image Source: University of Bath (UK)

Source: CNN, “The Machine that Can Copy Anything”, 2 June 2005, at <http://edition.cnn.com/2005/TECH>

Box 5.13: Remote robotic surgeon

An automated machine able to perform complex interventions through remote control

In 2005, the Johns Hopkins’ hospital in the UK took robotic surgery to new heights, when it used the Da Vinci surgical robot to perform live organ transplantation. Whereas more simple surgeries have been attempted with Da Vinci before, a live organ transplant is even more complex, due to the risk of damaging the living tissue, as well as managing the blood flow during the process. The remote operation is performed by an operating physician sitting in front of a console, controlling the movements of the robotic “hands”.



Telesurgery still needs critical medical facilities at the physical operation point. Nevertheless, this kind of technique, if regular, could optimize surgery intervention practices. One key advantage is that surgeons will no longer need to make long trips for a single operation. Remote or hardly accessible areas could be covered without excessive cost. In the future, wireless communication links will further enhance the utility of the system.

Image Source: Engadget.com

Sources: Engadget.com, “Da Vinci Robot Performs Organ Implant”, 19 May 2005, at <http://www.engadget.com>. See also BBC News, “US seeks battlefield robot medic”, 29 March 2005, at <http://news.bbc.co.uk/>

For monitoring health, RFID is already being used in the developed world on patient bracelets, medical equipment and even implanted under human skin. Complete medical records, including a patient's genetic background, previous medical treatments or interventions, and current medication could all be stored on a tiny RFID tag. In remote areas, where there are very few medical practitioners for a great number of patients, or where there is only occasional medical presence, this technology has the potential to enable timely intervention and treatment, and reduce medical mistakes.⁵⁸

Disaster Prevention

The Asian tsunami disaster of December 2004 has raised awareness of the growing need for disaster prevention and early warning systems. Effective and extensive information systems are needed, covering all vulnerable countries, in particular in the Asia-Pacific region. A number of countries, such as Bangladesh, Maldives, Myanmar, Kiribati, Samoa, Vanuatu and the Solomon Islands, are threatened by the rise in sea levels or tropical cyclones.⁵⁹

Even though industrialized countries in the region support anti-tsunami research and have deployed infrastructure based on satellite technology (with a web of more than 12'000 sensors), the majority of low-lying countries do not dispose of reliable early warning systems. The high cost of implementing such projects is a serious constraint. Even where there is a computer and a satellite network of sensors able to spot such deadly waves, most developing countries lack the infrastructure to ensure that coastal residents are warned in time to reach higher ground.⁶⁰ There is a call for personal or community small warning-stations to be installed and connected to global networks. With data transfer processes highly automated and combined with RFID, a great loss of life could be avoided in the future. Moreover, given that mobile teledensity in the developing countries of South East Asia is constantly growing⁶¹, mobile communication systems and applications, including the Short Message Service (SMS) could be successfully adapted to warn people of incoming threats, e.g. earthquakes, tropical cyclones or tsunamis.

In addition, the repercussions of other man-made constraints in many developing countries could also be limited through emerging technologies. For instance, the risk of landmines has been considerably reduced thanks to automated snake-like robots (Box 5.14).

5.4.3 High-tech for energy

Applications of nanotechnology in renewable and sustainable energy (such as solar and fuel cells) could provide cleaner and cheaper sources of energy for the developing world (Box 5.15) and improve both human and environmental health.⁶² Moreover, given that economic development and energy consumption are closely linked, nanotechnology could help developing countries move towards energy self-sufficiency, and make the benefits of economic growth more accessible.⁶³

Research projects under way are also exploring methods to generate hydrogen fuel cells. Nanoptek's hydrogen generation technology produces hydrogen gas from water using only sunlight. This unique technology promises higher efficiency, longer life cycles, and lower cost than competing technologies for hydrogen generation. Furthermore, Nanoptek's "point-of-use" hydrogen generation reduces the problems of hydrogen transport and storage.⁶⁴

One of the main applications of this key innovative process is responding to the common goal of producing clean, abundant, and low-cost hydrogen fuel to supply hydrogen cars using internal combustion engines.

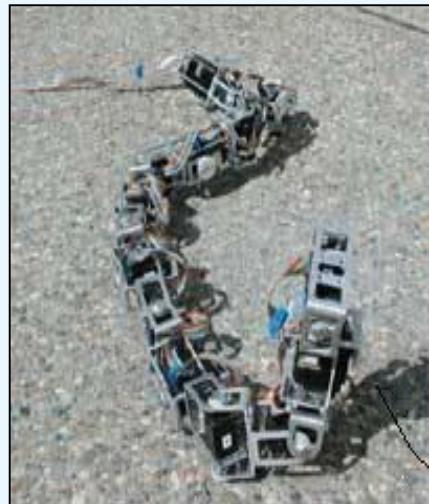
Both these developments could have a huge impact on the environmental performance of developing countries over the long-term, minimizing the harm of traditional non-renewable energies like oil and coal. The financial benefits are great: water and light are cheap if not free raw materials for energy production – the decrease in the cost of production in developing countries without oil and coal reserves would be significant. Over the longer term, this nano-solution would be even more valuable, given that the reserves of those resources continue to dwindle.⁶⁵ Also, energy storage systems based on nanotechnology can store energy produced at off-peak times for use at peak times, using nanoparticles and nanotubes for batteries and fuel cells.

Box 5.14: Snake-like robots save lives and limbs

Snakebots on the cutting edge of robotics provide solutions for rescue and repair

Leading researchers from the Carnegie Mellon University in Pittsburgh, Pennsylvania, have been focusing on the design of a snakebot – a snakelike robot able to collect and analyse a wide range of data and take action according to particular needs.

Small and very strong by design, the snakebot measures just five centimetres (two inches) in diameter. The use of levelled gears around its circumference allows the serpentine robot many more degrees of movement than conventional robots – including the ability to move efficiently in three-dimensional space using “gaits”, or the cyclic forms of locomotion of real snakes. Locomotion strategies designed to enable the snakebot to interact with its environment and propel itself forward are under development – these would allow it to consider the surrounding conditions and constraints in real time. The robot may eventually become a self-powered device with its own logic – able to use an array of sensors to determine autonomously how and where it should move to accomplish its tasks. A wireless connection to a computing hub is another promising option for control and targeted intervention.



This diverse functionality means that the snakebot may soon become a highly effective tool for applications such as the complicated and dangerous task of disposing unexploded bombs and landmines, as well as disarming explosives while minimizing the danger to humans. The snakebot could penetrate a bomb or a landmine and disarm it while preventing a detonation. 110 million mines are thought to be scattered around the world, killing or maiming 15'000 to 25'000 people every year in the developing world.

Such serpentine robots could also be used for rescue operations in disaster areas. The snakebot, at home in those dangerous and cramped environments inaccessible to rescue personnel, could find survivors and lead rescue operations during natural and man-made disasters. Another valuable function of the snakebot is its capacity to repair everything from battleship engines to the human body. Whether in large ships or complex machinery, they can execute checks of hundreds of parameters and intervene where repairs are needed. Like arthroscopic surgery on the engine, which has to penetrate inaccessible spaces to fix technical problems, snakebots could make on-the-spot repairs, including laser welding. In future, similar robots might work on the most complex machine of all, the human body, and perform surgical intervention in the field.

Image Source: NASA

Source: National Geographic, “Snakelike Robots May Fight Terror, Save Lives”, 11 March 2003, at <http://news.nationalgeographic.com/news/>

5.4.4 Safer food and produce

Given recent concerns over mad cow disease and avian flu, governments have been paying more attention to food safety and traceability. The European Commission published its White Paper on Food Safety in 2000⁶⁶, which declared food safety to be the primary responsibility of producers. In this context, it was recommended that all food ingredients become increasingly traceable.

For developing countries wishing to export food products around the world, reliable systems should be put into place to manage food origin and traceability, both in the middle and longer term. Many developing countries still lag behind with no possibility to certify the safety of the national commercial output. If increased regulation in this field persists and developing countries do not introduce similar safety standards, their export of food products could be at risk.

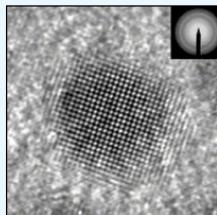
Improving plastic film coatings for food packaging and storage will mean less waste and better quality for remote communities in developing countries. Available stock could thus be used when most needed, for instance in the case of droughts or other natural disasters harming agricultural livestock.

In agriculture, nanotechnology can help make food products cheaper and their production more efficient and sustainable, as it uses fewer chemicals and less water.⁶⁷ In the least developed countries, arid natural

conditions negatively affect quality of life and agriculture. In countries such as Afghanistan, Burundi, Comoros, Equatorial Guinea and Zambia, the malnutrition rate is 50 per cent or more.⁶⁸ This is one of the major reasons why researchers in both developed and developing countries are working on crops that are able to grow under “hostile” conditions, including fields with high salt levels (due to climate change and rising sea levels) or low levels of water. This is done through the manipulation of the genetic material of crops through biological interventions on a nano-scale.⁶⁹

Box 5.15: Nanotechnology solar cell

A unique energy solution for developing countries



A new generation of solar cells that combines nanotechnology with plastic electronics has been launched following the development of a semiconductor-polymer photovoltaic device. Research behind the invention was conducted at the United States Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California at Berkeley. Hybrid solar cells will be cheaper and easier to produce than their semiconductor counterparts, and could be made, similarly to pure polymers, in a nearly infinite variety of shapes.

As long as sunlight remains one of the very few abundant and available resources in developing countries, the implementation of such products would be highly valuable as they could easily provide cheap energy while guaranteeing environmental sustainability.

Image Source: Daily University Science News

Source: Daily University Science News, “Nanotechnology Plus Plastic Electronics: Solar Cells”, 1 April 2002, at <http://unisci.com/>

Furthermore, tiny nano-based sensors can offer the possibility of monitoring pathogens on crops and livestock, as well as measuring crop productivity. Nano-particles can increase the efficiency of fertilizers. However, such developments may also increase the ability of potentially toxic substances, such as fertilizers, to penetrate deep layers of the soil and travel over greater distances.⁷⁰

5.5 Conclusion

This chapter has laid out multiple examples of the applications and innovations of enabling technologies for the Internet of Things in developing economies. These enabling technologies can play a major role in reducing poverty and overcoming the digital divide. Health and environmental conditions could be similarly improved. In general, the Internet of Things is a powerful catalyst for sustained economic growth. It does not take much imagination to consider that its applications will not only drive costs down, but also offer lucrative revenue opportunities.

With their diverse range of cultures⁷¹, countries in the developing world continue to have different incentives and priorities for adopting strategies for technological development. For some, the most pressing need is survival, pure and simple. For others, it is the improvement in standards of living. For others still, there is a push for global competitiveness and growth of exports. This holds even more true, given that, as stated above, countries with similar circumstances may opt for a different pace and trajectory towards the Internet of Things. It is therefore crucial for the industrialized world not to impose a biased or uniform strategic vision on developing economies.

That being said, it is worth noting that the industrialized world can play a pivotal role in the technological growth of developing economies. However, as the adoption of technologies varies across countries, approaches to international cooperation will also differ. This chapter demonstrates that, for some of the less developed countries, in the absence of adequate institutional infrastructure and an effective legislative framework relating to foreign investment, direct technology transfer is currently the best solution. This task is being undertaken more recently under the goals set out by WSIS and the MDGs. Alternatively, for the more advanced developing countries, technological developments are stimulated by the international expansion of multi-national ICT companies⁷², either in the form of local representation, mergers, acquisitions or joint ventures.

Furthermore, the effectiveness of foreign investment depends very much on government policies and openness to cooperation. National governments can act as catalysts for growth from within: by providing adequate funding for research, development and commercialization of innovative technologies or otherwise facilitating investment and fostering partnerships with local entrepreneurs.

Current technological progress towards the Internet of Things may be one of the biggest the world has ever seen.⁷³ As a result of this seismic shift, the traditional dominance of industrialized countries in scientific and technological innovations will weaken, in favour of less wealthy but no less tech-savvy nations. The diverse applications discussed in this chapter demonstrate that developing countries, far from being left out of the vision of the Internet of Things, are experiencing a steady transition in the application and use of emerging technologies. In many developing countries, ICTs already contribute significantly to the growth of GDP. Taking into account the speed with which today's cutting edge of science moves forward, an increasing number of developing countries could raise their economic performance and standard of living to levels associated with more industrialized economies.

In order for the developing world to reap the many benefits promised by the vision of the Internet of Things, sustained international cooperation and the strong commitment of local authorities are required. In other words, for such enabling technologies to play their important role, institutional effectiveness has to be coupled with a converged network of private-public and local-global partnerships.

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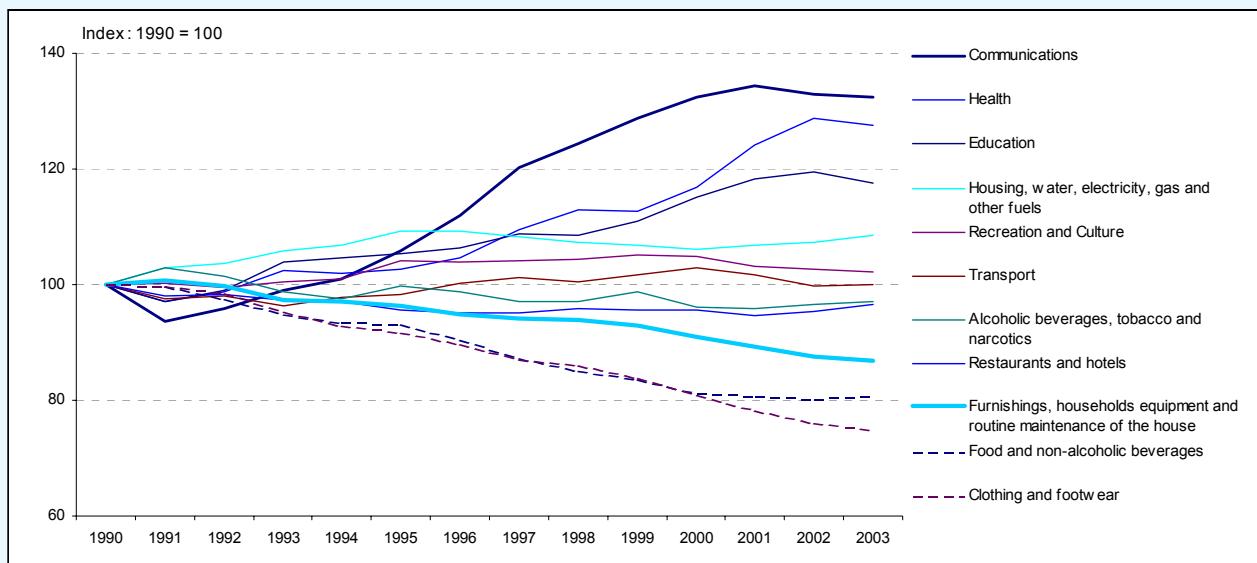
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6 CHAPTER SIX: THE BIG PICTURE

The internet as we know it is set to transform radically. From an academic network for the chosen few, it will become a fully pervasive, interactive and intelligent system. Real-time communications will be possible not only by humans but also by objects at anytime and from anywhere. As such, the new Internet of Things creates a host of exciting opportunities. The overall revenue generated by the markets pursuant to the Internet of Things is already large and is growing rapidly. This trend can be expected to continue for the foreseeable future. But the more long-term significance is that the Internet of Things will provide a platform for the development of new market opportunities outside the traditional purview of the telecommunication sector. Moreover, for users, the connection of individual things to a network will mean that the real world will become increasingly easier to manage by virtual design, thereby increasing user convenience and quality of life, while streamlining important business processes. Although prices will keep falling, there is little doubt that communications will continue to be the fastest growing sector of the global economy as it has been for the last decade (Figure 6.1).

Figure 6.1: Less eating, more connecting

Change in the relative size of selected service sectors, 1990-2003 in OECD economies (1990 = 100)



Source: OECD

6.1 Imagine the future...

But what does it all mean in a concrete sense for a citizen of the future? Let us imagine for a moment a day in the life of Rosa, a 23-year-old student from Spain, in the year 2020.

Rosa has just quarrelled with her boyfriend and needs a little time to herself. She decides to drive secretly to the French Alps in her smart Toyota to spend a weekend at a ski resort. Before her trip, Rosa plans to go shopping. But it seems she must have her car checked – the RFID sensor system in the car has alerted her of possible tyre failure caused by under-inflation. The RFID sensor system is required by road safety legislation adopted many years back. Rosa drives to the nearest Toyota maintenance centre. As she passes through the gates, a diagnostic tool using sensors and radio technology conducts a comprehensive check of her car and asks her to proceed to a specialized maintenance terminal. The terminal is equipped with fully automated robotic arms and Rosa confidently leaves her beloved car behind in order to get some coffee. The “Orange Wall” beverage machine knows all about Rosa’s love of ice coffee and pours it out after Rosa waves her internet watch for a secure payment.

When she gets back, a brand new pair of rear tyres has already been installed. RFID tags integrated in the new tyres store such information as each tyre's unique identification, manufacturer, date and place of replacement, and information about the car. In addition, like all tyres, they come equipped with sensors to monitor pressure, temperature and deformation. Any discrepancies will be reported to the intelligent dashboard control system. As a complimentary service, the garage offers to cover Rosa's Toyota with a special coat of nanoglazing for corrosion protection and dirt resistance.

The robotic guide then prompts Rosa on the privacy-related options associated with the new tyres. The information stored in her car's control system is intended for maintenance purposes but can be read at different points of the car journey where RFID readers are available. However, since Rosa does not want anyone to know (especially her boyfriend) where she is heading, such information is too sensitive to be left unprotected. She therefore chooses to have the privacy option turned on to prevent unauthorized tracking.

Finally, Rosa is able to attend to her shopping. She drives to the nearest mall. She wants to buy a new snowboard jacket with embedded media player. She is particularly concerned about catching a cold (since her exams are coming up) and luckily, the new multimedia jacket also comes equipped with weather-adjusting features. The resort she is heading towards also uses network of wireless sensors to monitor the possibility of avalanches, so she feels both healthy and safe.

At the French-Spanish border, there is no need to stop, as Rosa's car contains information on her driver's licence and passport, which is automatically transmitted to the minimal border control installations.

Suddenly, Rosa gets a video-call on her sunglasses. She pulls over and sees her boyfriend who begs to be forgiven and asks if she wants to spend the weekend together. Her spirits rise and, on impulse, she gives a speech command to the navigation system to disable the privacy protection, so that her boyfriend's car might find her location and aim directly for it. Even in a world that is full of smart interconnected things, it is human feelings that continue to rule.

6.2 An interactive ecosystem

As seen above, solutions that exploit the advantages of human-to-thing and thing-to-thing communications hold great potential. Dynamic innovation in this field will lead to the expansion of communication systems and further miniaturization which in turn will drive costs down. Lower costs will stimulate demand and exert network effects towards adoption on a mass scale.

The Internet of Things is set to become an integral part of human existence, as more and more things gain the ability to think, connect, communicate and take action (Figure 6.2). The left-hand circle in Figure 6.2 shows how the development of the Internet of Things creates a new ecosystem driven by a number of key players: suppliers, users, think-tanks and regulators. These players operate within a constantly adapting economic and legal system, which establishes a framework for their endeavours.

Market forces emanating from a competitive environment will serve to foster the growth of the Internet of Things. On the other hand, a restrictive anti-competitive regulatory environment, or one that surrenders too much personal privacy, might hinder market development. There is little doubt that a thriving environment for the Internet of Things will have important implications, for specific industries and the economy as a whole. The enabling technologies and applications discussed in this report – RFID, sensors, smart technologies and nanotechnology – have the potential to bring about a revolution in existing market structures and mechanisms. Central to this revolution is the enhanced availability of information about both people and things, in terms of volume, accuracy and periodicity. Rapid change in this regard may also require legal frameworks to be revisited, as antiquated mechanisms for consumer and data protection may fall short of technological possibilities.

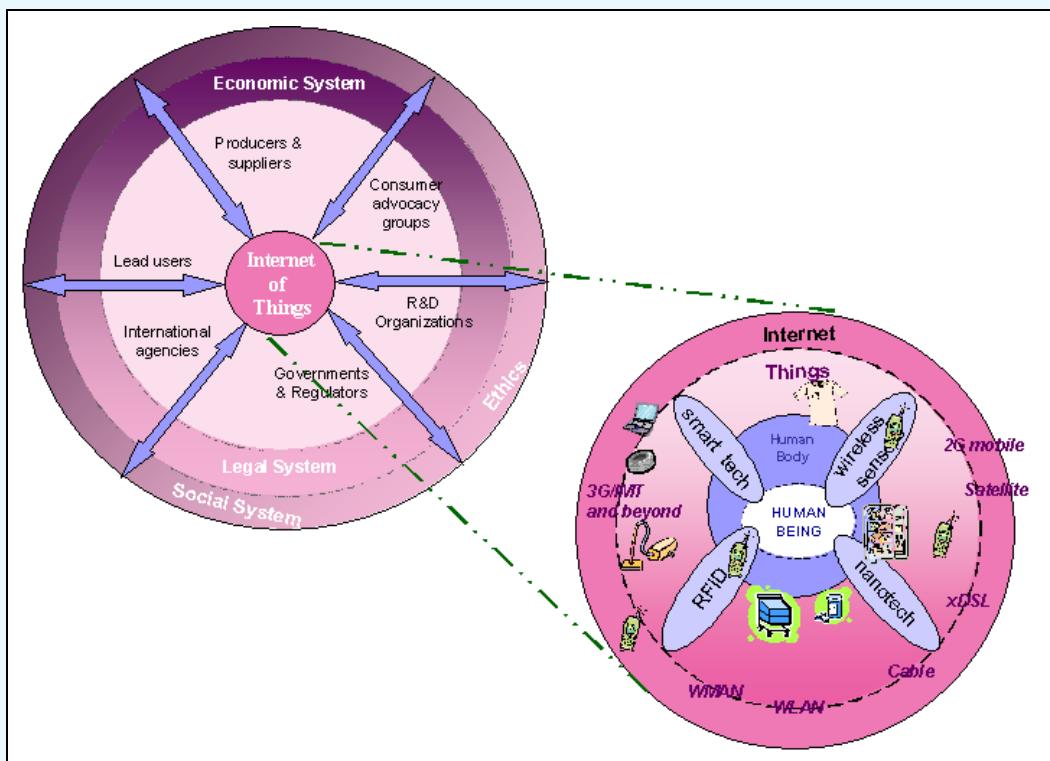
Any market system must exist in a wider social context. Societal norms and ethics will have an influence on technological diffusion. Similarly, technology can serve to change how society functions and how humans behave. We are all becoming more dependent on technology in our lives – from the electric toothbrush to the mobile phone – and there is not necessarily anything threatening about this. It is simply more efficient and convenient. But ensuring that people remain at the centre means letting them make judgments and giving

them choice. There should always be a choice to do something with or without electronic assistance: a form of “manual override”. In this context, there is a role for legal systems to protect the right to choose. Freedom of choice, for instance about privacy, should not become a commodity available only at a price. Moreover, technical means to defend consumer interests should also be made available to complement legal ones.

That being said, when working in the spirit of public interest, an enabling economic, legal and social system can give rise to a healthy and robust technological landscape. The right-hand circle in Figure 6.2 zooms in on the technical aspects of the Internet of Things, and shows how the four key enabling technologies discussed in this report can work together to connect individual things to a global network in an unobtrusive manner. In this way, not only will portable ICT devices be linked to the global internet, but so too will ordinary everyday objects. Moreover, innovations in chip and sensor technologies will endow these things with intelligence to enhance further their utility in the global network. With increased micro-processing power and intelligence at the edges of networks, things will be able to act independently, and take autonomous decisions based on sensory information. They will also gain connectivity to the global network through various network technologies (and typically a combination of these) such as IMT-2000/3G and wireless broadband.

Figure 6.2: The Internet of Things – A new ecosystem

Key interactions and technical architecture



Note: WLAN stands for Wireless Local Area Network (e.g. Wi-Fi) and WMAN for Wireless Metropolitan Area Networks (e.g. WiMAX).

Source: ITU

As mentioned above, the human being remains at the core of this technical vision. His or her needs will be pivotal to future innovations in a user-centric internet. Similarly, technology and markets cannot exist independently of the over-arching principles of a social and ethical system. Indeed, the Internet of Things will have a broad impact on many of the processes that characterize our daily lives. Over time it may lead to a more widespread (and increasingly invisible) use of technology, simultaneously influencing our behaviour, preferences and even values.

6.3 A better world?

The advent of the Internet of Things is set to create a plethora of innovative applications and services, which will serve to enhance quality of life and reduce inequalities while providing new revenue opportunities for a host of enterprising businesses. For the telecommunication industry, it is an opportunity to capitalize on existing success stories, such as mobile and wireless communications, but also to explore new frontiers. Still, in a new world increasingly mediated by technology, we must ensure that the human core to our activities remains untouched. On the road to the Internet of Things, this can only be achieved through people-oriented strategies or, in other words, tighter linkages between those that create the technology and those that use it. The resulting technological era will make us better equipped to face the challenges that modern life throws our way.

The Internet of Things

Statistical Annex

November 2005



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INTRODUCTION TO ANNEX

Data are presented for 206 economies with populations greater than 40'000 and where sufficient data are available.

Economies are grouped by their United States dollar (US\$) income levels in 2002:

Gross National Income (GNI) per capita of:

<i>Low</i>	US\$ 735 or less
<i>Lower middle</i>	US\$ 736-2'935
<i>Upper middle</i>	US\$ 2'936-9'075
<i>High</i>	US\$ 9'075 or more

The income level classification is based on the World Bank methodology. Economies are shown in alphabetical order within their income group in the tables. See Table A for a list of economies in alphabetical order and their location in the tables.

The data cover the public telecommunications sector. Due to differing regulatory obligations for the provision of data, a complete measurement of the sector for some economies cannot be achieved. Data for major telecommunication operators, covering at least 90 per cent of the market, are shown for all economies. More detailed information about coverage and country specific notes together with a full time-series from 1960, 1965, 1970, 1975-2003 is contained in the ITU World Telecommunication Indicators Database, available separately online or on CD-ROM.

Data refer to the reporting period that is closest to the end of year indicated. See Table A for the fiscal year reporting period used in each country.

Telecommunication data are supplied by an annual questionnaire sent to telecommunication authorities and operating companies. These data are supplemented by annual reports and statistical yearbooks of telecommunication ministries, regulators, operators and industry associations. In some cases, estimates are derived from ITU background documents or other references; estimates are shown in italic. Pricing data are obtained from service provider websites and by correspondence.

Demographic and macro-economic data are provided by the relevant international organizations identified in the *Technical notes*.

The following signs and symbols are used in the tables:

<i>Italic</i>	Year other than that specified or estimate.
k	Thousands (i.e., 1'000).
M	Millions (i.e., 1'000'000).
B	Billions (i.e., 1'000'000'000).
US\$ or USD	United States dollars. See the <i>Technical notes</i> for how US\$ figures are obtained.
%	Per cent.
-	Zero or a quantity less than half the unit shown. Also used for data items that are not applicable.
...	Data not available.
CAGR	Compound Annual Growth Rate. See the <i>Technical notes</i> for how this is computed.

The absence of any sign or symbol indicates that data are in units.

Comments and suggestions relating to the World Telecommunication Indicators should be addressed to:

Market, Economics and Finance Unit
Telecommunication Development Bureau
International Telecommunication Union
Place des Nations
CH-1211 Geneva 20
Switzerland

Fax: +41 22 730 6449
E-mail: indicators@itu.int

Additional information about Telecommunication Indicators can be found at the ITU's World Wide Web site at <http://www.itu.int/ITU-D/ict/>.

TABLE A: LIST OF ECONOMIES

<i>Economy</i>	<i>Location</i>	<i>Fiscal year</i>	<i>Region</i>	<i>Economy</i>	<i>Location</i>	<i>Fiscal year</i>	<i>Region</i>
Afghanistan	1	Ending 31.12	Asia	Fiji	81	Ending 31.12	Oceania
Albania	64	Ending 31.12	Europe	Finland	166	Ending 31.12	Europe
Algeria	65	Ending 31.12	Africa	France	167	Ending 31.12	Europe
Andorra	151	Ending 31.12	Europe	French Guiana	168	Ending 31.12	Americas
Angola	2	Ending 31.12	Africa	French Polynesia	169	Ending 31.12	Oceania
Antigua & Barbuda	152	Beginning 01.04	Americas	Gabon	127	Ending 31.12	Africa
Argentina	118	Ending 30.09	Americas	Gambia	21	Beginning 01.04	Africa
Armenia	66	Ending 31.12	Asia	Georgia	22	Ending 31.12	Asia
Aruba	153	Ending 31.12	Americas	Germany	170	Ending 31.12	Europe
Australia	154	Ending 30.06	Oceania	Ghana	23	Ending 31.12	Africa
Austria	155	Ending 31.12	Europe	Greece	171	Ending 31.12	Europe
Azerbaijan	3	Ending 31.12	Asia	Greenland	172	Ending 31.12	Europe
Bahamas	156	Ending 31.12	Americas	Grenada	128	Ending 31.12	Americas
Bahrain	157	Ending 31.12	Asia	Guadeloupe	129	Ending 31.12	Americas
Bangladesh	4	Ending 30.06	Asia	Guam	173	Ending 31.12	Oceania
Barbados	158	Beginning 01.04	Americas	Guatemala	82	Ending 31.12	Americas
Belarus	67	Ending 31.12	Europe	Guernsey	174	Ending 31.12	Europe
Belgium	159	Ending 31.12	Europe	Guinea	24	Ending 31.12	Africa
Belize	119	Beginning 01.04	Americas	Guinea-Bissau	25	Ending 31.12	Africa
Benin	5	Ending 31.12	Africa	Guyana	83	Ending 31.12	Americas
Bermuda	160	Beginning 01.04	Americas	Haiti	26	Ending 31.12	Americas
Bhutan	6	Ending 31.12	Asia	Honduras	84	Ending 31.12	Americas
Bolivia	68	Ending 31.12	Americas	Hong Kong, China	175	Beginning 01.04	Asia
Bosnia	69	Ending 31.12	Europe	Hungary	130	Ending 31.12	Europe
Botswana	120	Beginning 01.04	Africa	Iceland	176	Ending 31.12	Europe
Brazil	70	Ending 31.12	Americas	India	27	Beginning 01.04	Asia
Brunei Darussalam	161	Ending 31.12	Asia	Indonesia	28	Ending 31.12	Asia
Bulgaria	71	Ending 31.12	Europe	Iran (I.R.)	85	Beginning 22.03	Asia
Burkina Faso	7	Ending 31.12	Africa	Iraq	86	Ending 30.06	Asia
Burundi	8	Ending 31.12	Africa	Ireland	177	Beginning 01.04	Europe
Cambodia	9	Ending 31.12	Asia	Israel	178	Ending 31.12	Asia
Cameroon	10	Ending 31.12	Africa	Italy	179	Ending 31.12	Europe
Canada	162	Ending 31.12	Americas	Jamaica	87	Beginning 01.04	Americas
Cape Verde	72	Ending 31.12	Africa	Japan	180	Beginning 01.04	Asia
Central African Rep.	11	Ending 31.12	Africa	Jersey	181	Ending 31.12	Europe
Chad	12	Ending 31.12	Africa	Jordan	88	Ending 31.12	Asia
Chile	121	Ending 31.12	Americas	Kazakhstan	89	Ending 31.12	Asia
China	73	Ending 31.12	Asia	Kenya	29	Ending 30.06	Africa
Colombia	74	Ending 31.12	Americas	Kiribati	90	Ending 31.12	Oceania
Comoros	13	Ending 31.12	Africa	Korea (Rep.)	182	Ending 31.12	Asia
Congo	14	Ending 31.12	Africa	Kuwait	183	Ending 31.12	Asia
Costa Rica	122	Ending 31.12	Americas	Kyrgyzstan	30	Ending 31.12	Asia
Côte d'Ivoire	15	Ending 31.12	Africa	Lao P.D.R.	31	Ending 31.12	Asia
Croatia	123	Ending 31.12	Europe	Latvia	131	Ending 31.12	Europe
Cuba	75	Ending 31.12	Americas	Lebanon	132	Ending 31.12	Asia
Cyprus	163	Ending 31.12	Europe	Lesotho	32	Beginning 01.04	Africa
Czech Republic	124	Ending 31.12	Europe	Liberia	33	Ending 31.12	Africa
D.P.R. Korea	16	Ending 31.12	Asia	Libya	133	Ending 31.12	Africa
D.R. Congo	17	Ending 31.12	Africa	Lithuania	134	Ending 31.12	Europe
Denmark	164	Ending 31.12	Europe	Luxembourg	184	Ending 31.12	Europe
Djibouti	76	Ending 31.12	Africa	Macao, China	185	Ending 31.12	Asia
Dominica	125	Beginning 01.04	Americas	Madagascar	34	Ending 31.12	Africa
Dominican Rep.	77	Ending 31.12	Americas	Malawi	35	Ending 31.12	Africa
Ecuador	78	Ending 31.12	Americas	Malaysia	135	Ending 31.12	Asia
Egypt	79	Ending 31.12	Africa	Maldives	91	Ending 31.12	Asia
El Salvador	80	Ending 31.12	Americas	Mali	36	Ending 31.12	Africa
Equatorial Guinea	18	Ending 31.12	Africa	Malta	186	Ending 31.12	Europe
Eritrea	19	Ending 31.12	Africa	Marshall Islands	92	Ending 31.12	Oceania
Estonia	126	Ending 31.12	Europe	Martinique	187	Ending 31.12	Americas
Ethiopia	20	Ending 30.06	Africa	Mauritania	37	Ending 31.12	Africa
Faroe Islands	165	Ending 31.12	Europe	Mauritius	136	Ending 31.12	Africa

<i>Economy</i>	<i>Location</i>	<i>Fiscal year</i>	<i>Region</i>	<i>Economy</i>	<i>Location</i>	<i>Fiscal year</i>	<i>Region</i>
Mayotte	137	Ending 31.12	Africa	Solomon Islands	52	Beginning 01.04	Oceania
Mexico	138	Ending 31.12	Americas	Somalia	53	Ending 31.12	Africa
Micronesia	93	Ending 31.12	Oceania	Singapore	197	Beginning 01.04	Asia
Moldova	38	Ending 31.12	Europe	Slovak Republic	145	Ending 31.12	Europe
Mongolia	39	Ending 31.12	Asia	Slovenia	198	Ending 31.12	Europe
Morocco	94	Ending 31.12	Africa	South Africa	104	Beginning 01.04	Africa
Mozambique	40	Ending 31.12	Africa	Spain	199	Ending 31.12	Europe
Myanmar	41	Ending 31.12	Asia	Sri Lanka	105	Ending 31.12	Asia
Namibia	95	Ending 30.09	Africa	St. Kitts and Nevis	146	Beginning 01.04	Americas
Nepal	42	Ending 15.7	Asia	St. Lucia	147	Beginning 01.04	Americas
Neth. Antilles	188	Ending 31.12	Americas	St. Vincent	106	Beginning 01.04	Americas
Netherlands	189	Ending 31.12	Europe	Sudan	54	Ending 31.12	Africa
New Caledonia	190	Ending 31.12	Oceania	Suriname	107	Ending 31.12	Americas
New Zealand	191	Ending 30.06	Oceania	Swaziland	108	Beginning 01.04	Africa
Nicaragua	43	Ending 31.12	Americas	Sweden	200	Ending 31.12	Europe
Niger	44	Ending 31.12	Africa	Switzerland	201	Ending 31.12	Europe
Nigeria	45	Ending 31.12	Africa	Syria	109	Ending 31.12	Asia
Northern Marianas	139	Ending 31.12	Oceania	Taiwan, China	202	Ending 31.12	Asia
Norway	192	Ending 31.12	Europe	Tajikistan	55	Ending 31.12	Asia
Oman	140	Ending 31.12	Asia	Tanzania	56	Ending 31.12	Africa
Pakistan	46	Ending 30.06	Asia	TFYR Macedonia	110	Ending 31.12	Europe
Palestine	96	Ending 31.12	Asia	Thailand	111	Ending 30.09	Asia
Panama	141	Ending 31.12	Americas	Togo	57	Ending 31.12	Africa
Papua New Guinea	47	Ending 31.12	Oceania	Tonga	112	Ending 31.12	Oceania
Paraguay	97	Ending 31.12	Americas	Trinidad & Tobago	148	Beginning 01.04	Americas
Peru	98	Ending 31.12	Americas	Tunisia	113	Ending 31.12	Africa
Philippines	99	Ending 31.12	Asia	Turkey	114	Ending 31.12	Europe
Poland	142	Ending 31.12	Europe	Turkmenistan	115	Ending 31.12	Asia
Portugal	193	Ending 31.12	Europe	Uganda	58	Ending 30.06	Africa
Puerto Rico	194	Ending 31.12	Americas	Ukraine	116	Ending 31.12	Europe
Qatar	195	Ending 31.12	Asia	United Arab Emirates	203	Ending 31.12	Asia
Réunion	196	Ending 31.12	Africa	United Kingdom	204	Beginning 01.04	Europe
Romania	100	Ending 31.12	Europe	United States	205	Ending 31.12	Americas
Russia	101	Ending 31.12	Europe	Uruguay	149	Ending 31.12	Americas
Rwanda	48	Ending 31.12	Africa	Uzbekistan	59	Ending 31.12	Asia
S. Tomé & Principe	49	Ending 31.12	Africa	Vanuatu	117	Ending 31.12	Oceania
Samoa	102	Ending 31.12	Oceania	Venezuela	150	Ending 31.12	Americas
Saudi Arabia	143	Ending 31.12	Asia	Viet Nam	60	Ending 31.12	Asia
Senegal	50	Ending 31.12	Africa	Virgin Islands (US)	206	Ending 31.12	Americas
Serbia and Montenegro	103	Ending 31.12	Europe	Yemen	61	Ending 31.12	Asia
Seychelles	144	Beginning 01.04	Africa	Zambia	62	Beginning 01.04	Africa
Sierra Leone	51	Ending 31.12	Africa	Zimbabwe	63	Ending 30.06	Africa

1. Basic indicators

	Population	GDP		Total telephone subscribers			
		Total	Density	Total	per capita		
		(M)	(per km ²)	(B US\$)	(US\$)		
	2004	2004	2004	2003	2003		
1	Afghanistan	24.93	31	20.7	919	236.7	1.18
2	Angola	14.08	11	10.0	715	429.1	2.99
3	Azerbaijan	8.45	98	3.9	497	2'766.5	32.75
4	Bangladesh	149.67	1'039	51.7	382	5'154.5	3.44
5	Benin	6.92	61	2.8	413	302.7	4.31
6	Bhutan	2.33	50	0.5	734	47.4	2.04
7	Burkina Faso	13.39	49	4.2	345	479.4	3.58
8	Burundi	7.07	254	0.6	85	87.9	1.23
9	Cambodia	14.48	80	4.1	293	534.7	3.78
10	Cameroon	16.30	34	10.6	670	1'172.2	7.21
11	Central African Rep.	3.91	6	1.0	265	70.0	1.79
12	Chad	8.85	7	2.7	329	77.5	0.96
13	Comoros	0.79	424	0.2	303	15.2	1.91
14	Congo	3.82	11	3.6	1'018	337.0	9.63
15	Cote d'Ivoire	16.90	52	11.7	711	1'518.7	9.13
16	D.P.R.Korea	22.78	195	15.7	670	916.0	3.87
17	D.R. Congo	54.42	23	7.5	143	570.0	1.08
18	Equatorial Guinea	0.51	18	2.6	4'778	51.1	9.41
19	Eritrea	4.30	35	0.6	146	59.3	1.38
20	Ethiopia	72.42	59	6.3	96	532.8	0.77
21	Gambia	1.46	137	0.4	270	138.3	10.42
22	Georgia	5.07	73	3.3	673	1'523.8	30.03
23	Ghana	21.38	90	4.4	217	2'008.3	9.39
24	Guinea	8.62	3	2.9	381	137.7	1.78
25	Guinea-Bissau	1.54	36	0.2	173	11.8	0.92
26	Haiti	8.44	304	2.8	339	540.0	6.40
27	India	1'081.23	341	591.5	560	91'260.0	8.44
28	Indonesia	222.61	116	208.7	970	39'990.0	17.96
29	Kenya	32.42	56	14.4	453	2'845.4	8.78
30	Kyrgyzstan	5.21	26	1.9	379	534.4	10.61
31	Lao P.D.R.	5.79	24	1.9	338	279.2	4.82
32	Lesotho	1.80	59	1.1	524	196.2	10.90
33	Liberia	3.49	30	0.6	174	8.8	0.28
34	Madagascar	17.90	30	1.1	67	343.3	2.10
35	Malawi	12.34	131	2.0	192	315.1	2.55
36	Mali	13.41	9	3.4	318	474.9	4.28
37	Mauritania	2.98	3	1.0	365	389.1	14.14
38	Moldova	4.26	126	1.5	407	1'650.4	38.71
39	Mongolia	2.63	2	1.2	483	457.1	18.60
40	Mozambique	19.18	24	3.9	217	513.3	2.77
41	Myanmar	50.10	80	10.3	193	516.9	0.96
42	Nepal	25.72	182	5.9	247	579.3	2.25
43	Nicaragua	5.60	46	4.1	754	953.1	17.03
44	Niger	12.42	10	2.4	194	172.4	1.39
45	Nigeria	127.12	138	48.4	393	10'174.7	8.00
46	Pakistan	157.32	196	69.6	465	9'900.0	6.29
47	Papua New Guinea	5.84	13	3.4	628	77.0	1.41
48	Rwanda	8.48	322	1.8	210	134.0	1.64
49	S.Tomé & Principe	0.16	170	0.1	331	11.8	7.76
50	Senegal	10.34	53	5.1	506	804.8	7.77
51	Sierra Leone	5.17	71	1.1	216	91.0	1.84
52	Solomon Islands	0.49	16	0.3	616	7.7	1.62
53	Somalia	10.31	16	135.0	1.37
54	Sudan	34.33	14	14.0	426	2'077.5	6.02
55	Tajikistan	6.30	44	1.2	188	292.8	4.48
56	Tanzania	37.67	40	9.7	282	1'189.8	3.37
57	Togo	5.02	88	1.5	301	280.6	5.61
58	Uganda	26.70	111	6.4	251	1'236.6	4.63
59	Uzbekistan	26.48	59	6.5	257	2'037.9	7.96
60	Vietnam	82.48	250	39.0	480	15'084.9	18.29
61	Yemen	20.73	109	11.3	563	1'870.1	9.02
62	Zambia	10.92	15	3.7	338	329.4	2.94
63	Zimbabwe	12.93	33	0.8	65	714.5	5.53
Low income		2'600.66	99	1'255.8	466.4	207'647.6	7.98

1. Basic indicators

		Population		GDP		Total telephone subscribers	
		Total (M) 2004	Density (per km2) 2004	Total (B US\$) 2003	per capita (US\$) 2003	Total (000s) 2004	per 100 inhabitants 2004
64	Albania	3.19	111	4.1	1'332	1'355.0	44.10
65	Algeria	32.34	14	66.2	2'085	3'641.0	11.47
66	Armenia	3.05	102	2.8	738	785.8	25.75
67	Belarus	9.85	47	17.8	1'805	4'189.3	42.43
68	Bolivia	8.97	8	7.9	935	2'426.2	27.04
69	Bosnia	4.19	82	7.0	1'836	1'988.0	51.88
70	Brazil	180.66	21	505.3	2'864	107'987.2	59.78
71	Bulgaria	7.83	71	19.9	2'550	7'499.9	95.80
72	Cape Verde	0.47	117	0.6	1'407	139.2	29.49
73	China	1'313.31	137	1'409.3	1'091	647'267.0	49.29
74	Colombia	44.91	39	79.1	1'808	19'168.6	42.68
75	Cuba	11.33	99	17.1	1'518	844.0	7.45
76	Djibouti	0.71	31	0.6	894	33.2	4.97
77	Dominican Rep.	8.87	181	16.5	1'906	3'470.2	39.47
78	Ecuador	13.19	29	27.2	2'076	6'156.4	46.66
79	Egypt	73.39	70	71.4	1'040	17'107.2	24.44
80	El Salvador	6.61	309	14.9	2'251	2'720.4	41.13
81	Fiji	0.85	46	1.0	1'164	211.9	25.66
82	Guatemala	12.66	116	24.7	2'008	4'300.4	33.97
83	Guyana	0.77	4	0.7	835	246.6	32.16
84	Honduras	7.10	62	6.9	1'021	1'078.6	15.41
85	Iran (I.R.)	69.79	42	135.5	2'042	17'947.7	27.06
86	Iraq	25.86	57	695.0	2.87
87	Jamaica	2.68	234	8.1	3'084	2'700.0	100.90
88	Jordan	5.61	58	9.9	1'814	2'211.9	39.41
89	Kazakhstan	15.40	6	30.0	1'894	5'258.9	34.14
90	Kiribati	0.09	130	-	464	5.0	5.68
91	Maldives	0.33	1'101	0.6	2'258	144.7	44.13
92	Marshall Islands	0.06	31	0.1	1'893	5.1	9.38
93	Micronesia	0.11	78	0.3	2'370	17.0	15.77
94	Morocco	31.06	45	43.7	1'452	10'645.4	35.60
95	Namibia	2.01	2	2.9	1'523	414.0	20.59
96	Palestine	3.69	612	3.0	873	1'331.7	36.14
97	Paraguay	6.02	15	6.0	1'018	2'051.1	34.59
98	Peru	27.57	21	60.6	2'208	6'142.4	22.28
99	Philippines	81.41	276	80.4	992	36'373.4	44.01
100	Romania	22.28	94	56.9	2'626	14'604.5	65.55
101	Russia	142.40	8	347.4	2'370	73'493.0	50.20
102	Samoa	0.18	63	0.3	1'428	23.8	13.05
103	Serbia and Montenegro	10.52	103	15.6	1'451	7'415.0	70.49
104	South Africa	45.21	38	104.2	2'293	21'681.0	46.76
105	Sri Lanka	19.22	294	18.2	947	3'202.4	16.62
106	St. Vincent	0.12	311	0.4	3'162	76.0	62.79
107	Suriname	0.44	3	1.0	1'879	294.1	67.00
108	Swaziland	1.08	62	2.0	1'871	131.2	12.57
109	Syria	18.22	98	19.4	1'133	5'005.0	27.47
110	TFYR Macedonia	2.07	80	3.4	1'705	1'301.0	62.42
111	Thailand	63.47	123	143.2	2'270	34'724.0	54.71
112	Tonga	0.10	149	0.1	1'322	14.6	14.67
113	Tunisia	9.94	61	25.0	2'527	4'766.5	47.97
114	Turkey	72.32	93	239.9	3'392	53'832.7	74.44
115	Turkmenistan	4.94	10	4.4	988	385.3	7.92
116	Ukraine	48.15	80	49.4	1'038	25'877.0	53.74
117	Vanuatu	0.22	15	0.2	1'113	17.3	7.96
Lower Middle Income		2'476.8	113	3'713.1	1'709	1'165'403.8	47.05

1. Basic indicators

		Population		GDP		Total telephone subscribers	
		Total (M) 2004	Density (per km2) 2004	Total (B US\$) 2003	per capita (US\$) 2003	Total (000s) 2004	per 100 inhabitants 2004
118	Argentina	38.87	14	129.7	3'426	22'212.4	57.14
119	Belize	0.26	11	1.0	3'340	131.5	50.39
120	Botswana	1.80	3	7.4	4'214	700.2	39.01
121	Chile	15.41	21	66.4	4'413	12'884.8	83.61
122	Costa Rica	4.25	83	17.5	4'193	2'266.3	53.35
123	Croatia	4.42	78	28.8	6'588	4'253.0	97.23
124	Czech Republic	10.23	130	90.4	8'863	14'221.3	139.07
125	Dominica	0.07	95	0.3	3'256	62.8	88.45
126	Estonia	1.31	29	9.1	6'720	1'699.8	129.95
127	Gabon	1.35	5	4.6	3'611	528.0	39.05
128	Grenada	0.10	299	0.4	3'908	76.0	73.80
129	Guadeloupe	0.44	258	502.5	116.60
130	Hungary	9.83	106	82.8	8'182	12'304.5	125.16
131	Latvia	2.29	36	11.1	4'783	2'167.7	94.82
132	Lebanon	3.71	341	16.7	4'988	1'518.0	42.76
133	Libya	5.66	3	19.4	3'484	877.0	15.86
134	Lithuania	3.42	53	18.4	5'315	4'241.6	123.09
135	Malaysia	24.88	75	103.2	4'099	19'058.2	76.61
136	Mauritius	1.23	661	5.7	4'628	863.8	70.06
137	Mayotte	0.17	444	31.7	19.78
138	Mexico	104.93	53	636.9	6'328	56'524.4	53.87
139	Northern Marianas	0.08	161	24.0	35.28
140	Oman	2.94	11	22.0	8'446	1'045.3	35.62
141	Panama	3.17	40	12.9	4'127	1'231.9	38.83
142	Poland	38.55	123	209.4	5'427	29'693.7	76.95
143	Saudi Arabia	24.92	10	212.6	9'432	12'870.9	51.65
144	Seychelles	0.08	200	0.7	8'348	70.4	86.94
145	Slovak Republic	5.41	110	32.7	5'120	5'525.6	102.19
146	St. Kitts and Nevis	0.05	176	0.4	7'611	28.5	60.64
147	St. Lucia	0.15	244	0.7	4'364	65.4	40.90
148	Trinidad & Tobago	1.31	255	10.7	8'246	969.1	74.15
149	Uruguay	3.24	17	11.2	3'461	1'600.0	49.37
150	Venezuela	26.18	29	95.5	3'788	11'767.4	44.96
Upper Middle Income		340.7	126	1'858.6	5'424	222'017.7	65.17

1. Basic indicators

		Population		GDP		Total telephone subscribers	
		Total (M) 2004	Density (per km2) 2004	Total (B US\$) 2003	per capita (US\$) 2003	Total (000s) 2004	per 100 inhabitants 2004
151	Andorra	0.07	181	97.0	115.15
152	Antigua & Barbuda	0.08	174	0.7	9'103	92.0	119.48
153	Aruba	0.09	592	90.1	85.03
154	Australia	19.91	3	505.7	25'436	27'321.0	137.20
155	Austria	8.12	97	3'465.7	429'243	11'753.0	144.74
156	Bahamas	0.32	23	4.8	15'442	325.9	102.82
157	Bahrain	0.74	1'042	7.6	11'312	841.3	113.85
158	Barbados	0.27	630	2.6	9'659	274.0	101.59
159	Belgium	10.34	338	301.3	29'048	13'888.3	134.33
160	Bermuda	0.06	1'211	2.1	33'469	86.0	132.21
161	Brunei Darussalam	0.37	63	4.3	12'447	225.4	65.92
162	Canada	31.74	3	735.6	23'381	33'296.0	104.88
163	Cyprus	0.81	87	13.1	17'638	1'058.9	131.21
164	Denmark	5.38	125	212.2	39'312	8'640.5	160.75
165	Faroe Islands	0.05	36	1.1	24'102	53.7	112.62
166	Finland	5.22	14	186.6	35'774	7'356.0	141.03
167	France	60.43	111	1'434.7	24'057	78'422.0	129.76
168	French Guiana	0.17	2	126.3	74.86
169	French Polynesia	0.25	63	3.9	16'310	143.2	58.34
170	Germany	82.53	231	2'392.4	28'987	125'866.0	152.52
171	Greece	10.98	83	203.4	18'530	16'201.7	147.60
172	Greenland	0.06	-	45.3	79.85
173	Guam	0.17	360	3.4	22'086	112.6	71.63
174	Guernsey	0.06	858	1.8	32'428	86.5	153.83
175	Hong Kong, China	7.12	6'700	156.6	22'994	11'928.4	167.65
176	Iceland	0.29	3	10.5	36'377	481.9	164.45
177	Ireland	4.00	58	119.3	29'976	5'799.1	145.01
178	Israel	6.56	310	110.3	16'307	10'187.5	148.46
179	Italy	57.35	190	1'187.1	21'024	88'707.0	154.69
180	Japan	127.80	338	3'991.8	31'324	150'261.9	117.58
181	Jersey	0.09	759	135.3	155.24
182	Korea (Rep.)	47.95	488	605.4	12'651	62'644.1	130.29
183	Kuwait	2.60	107	41.5	16'693	2'497.0	96.22
184	Luxembourg	0.46	177	31.1	67'850	899.0	199.13
185	Macao, China	0.47	19'622	7.9	17'616	606.4	129.85
186	Malta	0.40	1'253	4.7	11'818	498.3	124.57
187	Martinique	0.39	356	0.9	2'296	458.1	118.44
188	Neth. Antilles	0.22	278
189	Netherlands	16.23	394	418.9	25'866	22'682.0	139.78
190	New Caledonia	0.23	12	3.1	13'940	169.7	73.17
191	New Zealand	3.91	15	77.3	19'290	4'827.5	123.62
192	Norway	4.55	14	220.6	48'162	6'391.4	139.53
193	Portugal	10.07	110	168.3	16'708	14'537.7	144.34
194	Puerto Rico	3.90	433	44.2	11'519	3'076.5	79.73
195	Qatar	0.62	54	19.5	27'550	681.2	110.05
196	Réunion	0.77	301	1.3	1'893	721.1	98.65
197	Singapore	4.32	6'320	91.5	21'794	5'724.6	132.67
198	Slovenia	1.98	98	27.7	13'896	2'551.5	127.77
199	Spain	41.13	81	654.6	15'928	56'374.6	137.07
200	Sweden	8.89	20	301.5	33'586	15'674.0	174.62
201	Switzerland	7.16	173	267.5	36'738	11'525.0	160.90
202	Taiwan, China	22.76	632	289.8	12'821	36'290.1	159.43
203	United Arab Emirates	3.05	52	71.0	18'919	4'870.9	112.03
204	United Kingdom	59.43	243	1'558.1	26'369	94'800.0	159.52
205	United States	297.04	32	10'445.6	36'273	359'052.1	120.88
206	Virgin Islands (US)	0.11	321	110.4	101.01
High income		980.02	826	30'410.6	31'142	1'301'567.0	132.81
WORLD		6'398.15	305	37'238.1	9'320	2'896'636.1	45.27
<i>Africa</i>		<i>869.03</i>	<i>28</i>	<i>550.5</i>	<i>674</i>	<i>92'788.1</i>	<i>10.99</i>
<i>Americas</i>		<i>878.75</i>	<i>22</i>	<i>13'003.4</i>	<i>15'241</i>	<i>668'465.7</i>	<i>76.05</i>
<i>Asia/Pacific</i>		<i>3'819.72</i>	<i>126</i>	<i>8'661.0</i>	<i>2'357</i>	<i>1'250'700.8</i>	<i>33.32</i>
<i>Europe</i>		<i>798.55</i>	<i>34</i>	<i>14'427.8</i>	<i>27'022</i>	<i>851'838.7</i>	<i>106.17</i>
<i>Oceania</i>		<i>32.11</i>	<i>4</i>	<i>595.4</i>	<i>18'838</i>	<i>32'842.8</i>	<i>103.81</i>

Note: For data comparability and coverage, see the technical notes.

Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

2. Mobile subscribers

		Cellular mobile subscribers			As % of total telephone subscribers		
		(k)	CAGR (%)	Per 100 inhabitants	% Digital		
		2000	2004	2000-04	2004	2004	
1	Afghanistan	-	200.0	-	1.00	...	84.5
2	Angola	25.8	940.0	145.7	6.68	...	90.7
3	Azerbaijan	420.4	1'782.9	43.5	21.11	...	64.4
4	Bangladesh	279.0	4'327.5	98.5	2.89	...	84.0
5	Benin	55.5	236.2	62.1	3.36	100.0	78.0
6	Bhutan	-	17.8	-	0.77	100.0	37.6
7	Burkina Faso	25.2	398.0	99.3	2.97	100.0	83.0
8	Burundi	16.3	64.0	57.7	0.90	100.0	72.8
9	Cambodia	130.5	498.4	56.3	3.52	77.3	93.2
10	Cameroon	103.3	1'536.6	96.4	9.43	78.1	94.2
11	Central African Rep.	5.0	60.0	86.4	1.53	...	85.7
12	Chad	5.5	65.0	127.8	0.80	100.0	83.9
13	Comoros	-	2.0	-	0.25	...	13.1
14	Congo	70.0	442.2	58.5	11.58	100.0	98.4
15	Cote d'Ivoire	473.0	1'531.8	34.2	9.07	100.0	86.6
16	D.P.R.Korea
17	D.R. Congo	15.0	1'000.0	305.5	1.89	...	99.0
18	Equatorial Guinea	5.0	55.5	82.5	10.95	...	85.3
19	Eritrea	-	20.0	-	0.47	...	33.7
20	Ethiopia	17.8	178.0	77.9	0.25	26.9	29.0
21	Gambia	5.6	175.0	136.4	11.97	...	82.0
22	Georgia	194.7	840.6	44.1	16.57	...	55.2
23	Ghana	130.0	1'695.0	90.0	7.93	...	84.4
24	Guinea	42.1	111.5	38.3	1.44	100.0	81.0
25	Guinea-Bissau	-	1.3	-	0.10	...	10.8
26	Haiti	55.0	400.0	64.2	4.74	100.0	74.1
27	India	3'577.1	47'300.0	90.7	4.37	100.0	51.8
28	Indonesia	3'669.3	30'000.0	69.1	13.48	...	75.0
29	Kenya	127.4	2'546.2	111.4	7.85	100.0	89.5
30	Kyrgyzstan	9.0	300.0	140.3	5.76	...	43.1
31	Lao P.D.R.	12.7	204.2	100.3	3.53	100.0	73.1
32	Lesotho	21.6	159.0	64.7	8.83	100.0	81.0
33	Liberia	-	2.0	-	0.06	...	22.7
34	Madagascar	63.1	333.9	51.7	1.87	...	84.9
35	Malawi	49.0	222.1	45.9	1.80	100.0	70.5
36	Mali	10.4	400.0	149.0	3.60	...	84.2
37	Mauritania	15.3	522.4	141.7	17.53	...	93.2
38	Moldova	139.0	787.0	54.3	18.46	100.0	47.7
39	Mongolia	154.6	319.0	27.3	12.98	100.0	69.8
40	Mozambique	51.1	708.0	93.0	3.73	100.0	90.1
41	Myanmar	13.4	92.0	61.9	0.17	...	17.8
42	Nepal	10.2	179.1	104.6	0.70	100.0	30.9
43	Nicaragua	90.3	738.6	69.1	13.20	100.0	77.5
44	Niger	2.1	148.3	191.4	1.19	...	86.0
45	Nigeria	30.0	9'147.2	317.9	7.20	100.0	89.9
46	Pakistan	349.5	5'020.0	94.7	3.19	...	50.7
47	Papua New Guinea	8.6	15.0	32.4	0.27	...	19.5
48	Rwanda	39.0	150.0	40.0	1.77	100.0	86.6
49	S.Tomé & Principe	-	4.8	-	3.17	100.0	40.9
50	Senegal	250.3	1'028.1	42.4	9.94	100.0	81.8
51	Sierra Leone	11.9	113.2	111.7	2.28	...	82.5
52	Solomon Islands	1.2	1.5	8.9	0.31	...	19.3
53	Somalia	-	35.0	-	0.36	...	25.9
54	Sudan	23.0	1'048.6	159.8	3.04	100.0	50.5
55	Tajikistan	1.2	47.6	245.0	0.73	...	16.3
56	Tanzania	180.2	1'640.0	73.7	4.35	100.0	91.7
57	Togo	50.0	220.0	63.9	4.40	100.0	78.4
58	Uganda	126.9	1'165.0	74.1	4.36	100.0	94.2
59	Uzbekistan	53.1	544.1	78.9	2.05	...	24.1
60	Vietnam	788.6	4'960.0	58.4	6.01	100.0	32.9
61	Yemen	32.0	1'072.0	140.6	5.17	...	57.3
62	Zambia	98.9	300.0	32.0	2.75	100.0	77.2
63	Zimbabwe	266.4	397.5	10.5	3.07	100.0	55.6
Low income		12'401.1	128'450.7	79.9	5.09	96.43	65.3

2. Mobile subscribers

		Cellular mobile subscribers			As % of total telephone subscribers	
		(k)	CAGR (%)	Per 100 inhabitants	% Digital	telephone subscribers
		2000	2004	2000-04	2004	2004
64	Albania	29.8	1'100.0	233.0	35.8	100.0
65	Algeria	86.0	4'682.7	171.6	14.48	100.0
66	Armenia	17.5	203.3	84.7	6.66	100.0
67	Belarus	49.4	1'118.0	182.9	11.32	...
68	Bolivia	582.6	1'800.8	32.6	20.07	...
69	Bosnia	93.4	1'050.0	124.0	27.40	...
70	Brazil	23'188.2	65'605.0	29.7	36.32	99.4
71	Bulgaria	738.0	4'729.7	59.1	60.41	65.2
72	Cape Verde	19.7	65.8	35.1	13.94	100.0
73	China	85'260.0	334'824.0	40.8	25.49	100.0
74	Colombia	2'256.8	10'400.6	46.5	23.16	100.0
75	Cuba	6.5	75.8	84.5	0.67	...
76	Djibouti	0.2	23.0	364.2	3.44	100.0
77	Dominican Rep.	705.4	2'534.1	37.7	28.82	94.9
78	Ecuador	482.2	4'544.2	75.2	34.44	...
79	Egypt	1'359.9	7'643.1	54.0	10.92	100.0
80	El Salvador	743.6	1'832.6	25.3	27.71	...
81	Fiji	55.1	109.9	25.9	13.31	100.0
82	Guatemala	856.8	3'168.3	38.7	25.02	...
83	Guyana	39.8	143.9	37.9	18.77	...
84	Honduras	155.3	707.2	46.1	10.10	...
85	Iran (I.R.)	962.6	4'300.0	45.4	6.16	100.0
86	Iraq	-	20.0	-	0.08	...
87	Jamaica	367.0	2'200.0	56.5	82.21	...
88	Jordan	388.9	1'594.5	42.3	28.41	100.0
89	Kazakhstan	197.3	2'758.9	93.4	17.91	...
90	Kiribati	-	0.5	88.7	0.59	...
91	Maldives	7.6	113.2	96.2	34.53	100.0
92	Marshall Islands	0.4	0.6	10.2	1.11	...
93	Micronesia	-	5.9	-	5.44	-
94	Morocco	2'342.0	9'336.9	41.3	31.23	100.0
95	Namibia	82.0	286.1	36.7	14.23	100.0
96	Palestine	175.9	974.3	53.4	26.44	...
97	Paraguay	820.8	1'767.8	21.1	29.38	100.0
98	Peru	1'273.9	4'092.6	33.9	14.85	...
99	Philippines	6'454.4	32'935.9	50.3	39.85	...
100	Romania	2'499.0	10'215.4	42.2	45.85	100.0
101	Russia	3'263.2	74'420.0	118.5	51.61	99.9
102	Samoa	2.5	10.5	61.3	5.76	...
103	Serbia and Montenegro	1'303.6	4'729.6	38.0	44.96	100.0
104	South Africa	8'339.0	19'500.0	23.7	43.13	100.0
105	Sri Lanka	430.2	2'211.2	50.6	11.47	...
106	St. Vincent	2.4	57.0	121.6	47.07	100.0
107	Suriname	41.0	212.8	50.9	48.48	100.0
108	Swaziland	33.0	113.0	36.0	10.43	...
109	Syria	30.0	2'345.0	197.3	12.87	100.0
110	TFYR Macedonia	115.7	776.0	88.6	37.23	100.0
111	Thailand	3'056.0	28'000.0	74.0	44.12	...
112	Tonga	0.2	3.4	331.7	3.38	100.0
113	Tunisia	119.2	3'735.7	136.6	37.59	95.4
114	Turkey	16'133.4	34'707.5	21.1	47.99	100.0
115	Turkmenistan	7.5	9.2	7.0	0.19	...
116	Ukraine	818.5	13'735.0	102.4	28.52	...
117	Vanuatu	0.4	10.5	131.6	4.84	...
Lower Middle Income		165'993.8	701'541.0	76.5	24.19	95.16
						57.6

2. Mobile subscribers

		Cellular mobile subscribers			As % of total telephone subscribers		
		(k)	CAGR	Per 100 inhabitants	% Digital	2004	
			2000	2004	2004	2004	
118	Argentina	6'487.9	13'512.4	20.1	34.76	...	60.8
119	Belize	16.8	97.8	55.3	37.45	...	74.3
120	Botswana	200.0	563.8	29.6	31.41	100.0	80.5
121	Chile	3'401.5	9'566.6	29.5	62.08	...	74.2
122	Costa Rica	211.6	923.1	44.5	21.73	98.7	40.7
123	Croatia	1'033.0	2'553.0	35.2	58.37	...	60.0
124	Czech Republic	4'346.0	10'771.3	30.9	105.33	...	60.5
125	Dominica	1.2	41.8	143.0	58.93	100.0	66.6
126	Estonia	557.0	1'255.7	22.5	96.00	100.0	73.9
127	Gabon	120.0	489.4	42.1	36.20	...	92.7
128	Grenada	4.3	43.3	78.2	42.05	...	57.0
129	Guadeloupe	169.8	323.5	38.0	74.32	...	60.6
130	Hungary	3'076.3	8'727.2	29.8	88.77	...	70.9
131	Latvia	401.3	1'536.7	39.9	67.22	100.0	70.9
132	Lebanon	743.0	888.0	4.6	25.01	...	58.5
133	Libya	40.0	127.0	47.0	2.30	100.0	14.5
134	Lithuania	524.0	3'421.5	59.9	99.29	100.0	80.7
135	Malaysia	5'121.7	14'611.9	30.0	58.74	...	76.7
136	Mauritius	180.0	510.0	29.7	41.36	100.0	59.0
137	Mayotte	-	36.0	-	21.56	...	78.3
138	Mexico	14'077.9	38'451.1	28.6	36.64	95.0	68.0
139	Northern Marianas
140	Oman	164.3	805.0	48.8	27.43	93.9	77.0
141	Panama	410.4	855.9	20.2	26.98	100.0	69.5
142	Poland	6'747.0	23'096.1	36.0	59.91	...	65.3
143	Saudi Arabia	1'375.9	9'175.8	60.7	36.82	...	71.3
144	Seychelles	26.0	49.2	17.3	60.78	100.0	69.9
145	Slovak Republic	1'243.7	4'275.2	36.2	79.07	...	77.4
146	St. Kitts and Nevis	1.2	10.0	69.9	21.74	...	29.9
147	St. Lucia	2.5	93.0	147.0	62.00	...	64.5
148	Trinidad & Tobago	161.9	647.9	41.4	49.57	...	66.9
149	Uruguay	410.8	600.0	9.9	18.51	...	37.5
150	Venezuela	5'447.2	8'421.0	11.5	32.17	...	71.6
Upper Middle Income		56'704.2	156'480.2	41.8	49.20	98.97	65.0

2. Mobile subscribers

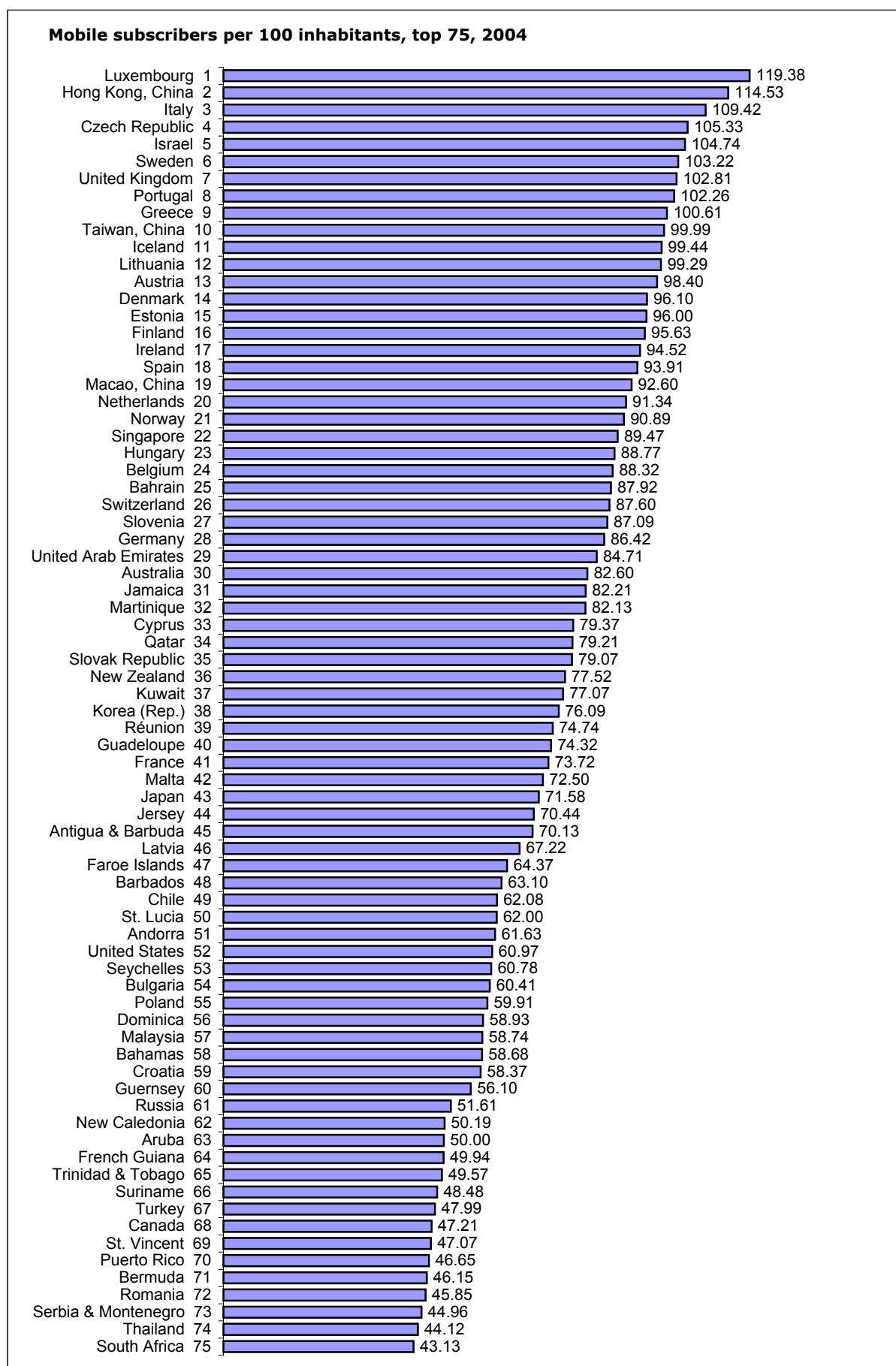
		Cellular mobile subscribers			As % of total telephone subscribers	
		(k)	CAGR	Per 100 inhabitants	% telephone	subscribers
			2000	2004	2004	2004
151	Andorra	23.5	51.9	30.1	61.63	100.0
152	Antigua & Barbuda	22.0	54.0	25.2	70.13	...
153	Aruba	15.0	53.0	88.0	50.00	...
154	Australia	8'562.0	16'449.0	17.7	82.60	100.0
155	Austria	6'117.0	7'990.0	6.9	98.40	99.8
156	Bahamas	31.5	186.0	55.9	58.68	...
157	Bahrain	205.7	649.8	33.3	87.92	100.0
158	Barbados	28.5	171.0	56.6	63.10	...
159	Belgium	5'629.0	9'131.7	12.9	88.32	100.0
160	Bermuda	...	30.0	...	46.15	...
161	Brunei Darussalam	95.0	137.0	20.1	40.06	100.0
162	Canada	8'727.0	14'984.4	14.5	47.21	...
163	Cyprus	218.3	640.5	30.9	79.37	...
164	Denmark	3'363.6	5'165.5	11.3	96.10	100.0
165	Faroe Islands	17.0	30.7	34.5	64.37	...
166	Finland	3'728.6	4'988.0	7.5	95.63	100.0
167	France	29'052.4	44'551.8	11.3	73.72	100.0
168	French Guiana	39.8	87.3	48.0	49.94	100.0
169	French Polynesia	39.9	90.0	50.2	36.67	100.0
170	Germany	48'202.0	71'316.0	10.3	86.42	100.0
171	Greece	5'932.4	11'044.2	16.8	100.61	...
172	Greenland	16.0	19.9	11.6	35.15	...
173	Guam	27.2	32.6	9.5	20.74	...
174	Guernsey	21.9	31.5	20.0	56.10	...
175	Hong Kong, China	5'447.3	8'148.7	10.6	114.53	...
176	Iceland	214.9	291.4	7.9	99.44	...
177	Ireland	2'461.0	3'780.0	11.3	94.52	100.0
178	Israel	4'400.0	7'187.5	13.1	104.74	...
179	Italy	42'246.0	62'750.0	10.4	109.42	...
180	Japan	66'784.4	91'473.9	8.2	71.58	100.0
181	Jersey	44.7	61.4	17.1	70.44	100.0
182	Korea (Rep.)	26'816.4	36'586.1	8.1	76.09	100.0
183	Kuwait	476.0	2'000.0	43.2	77.07	100.0
184	Luxembourg	303.3	488.8	21.1	106.50	100.0
185	Macao, China	141.1	432.4	32.3	92.60	100.0
186	Malta	114.4	290.0	36.3	72.50	100.0
187	Martinique	162.1	319.9	40.5	82.13	100.0
188	Neth. Antilles
189	Netherlands	10'755.0	14'821.0	8.3	91.34	100.0
190	New Caledonia	49.9	116.4	23.6	50.19	100.0
191	New Zealand	1'542.0	3'027.0	18.4	77.52	...
192	Norway	3'367.8	4'163.4	7.3	90.89	99.1
193	Portugal	6'665.0	10'300.0	11.5	102.26	100.0
194	Puerto Rico	926.4	1'800.0	39.4	46.65	58.5
195	Qatar	120.9	490.3	41.9	79.21	100.0
196	Réunion	276.1	565.0	27.0	74.74	...
197	Singapore	2'747.4	3'860.6	8.9	89.47	100.0
198	Slovenia	1'215.6	1'739.1	12.7	87.09	51.4
199	Spain	24'265.1	38'622.6	12.3	93.91	...
200	Sweden	6'372.3	9'302.0	9.9	103.22	...
201	Switzerland	4'638.5	6'275.0	7.8	87.60	100.0
202	Taiwan, China	17'873.8	22'760.1	6.2	99.99	100.0
203	United Arab Emirates	1'428.1	3'683.1	26.7	84.71	100.0
204	United Kingdom	43'452.0	61'100.0	8.9	102.81	100.0
205	United States	109'478.0	181'105.1	13.4	60.97	...
206	Virgin Islands (US)	35.0	41.0	8.2	37.51	...
High income		504'935.9	765'467.6	21.8	76.74	97.2
WORLD		740'035.0	1'751'939.5	55.0	38.81	96.9
Africa		15'634.8	76'530.1	49.1	8.81	91.2
Americas		181'938.0	372'700.4	19.6	42.41	22.4
Asia/Pacific		240'651.4	710'923.9	31.1	18.61	78.7
Europe		291'548.6	571'951.3	18.4	71.65	53.7
Oceania		10'262.2	19'833.8	17.9	61.77	84.5
2004						60.4

Note: For data comparability and coverage, see the technical notes.

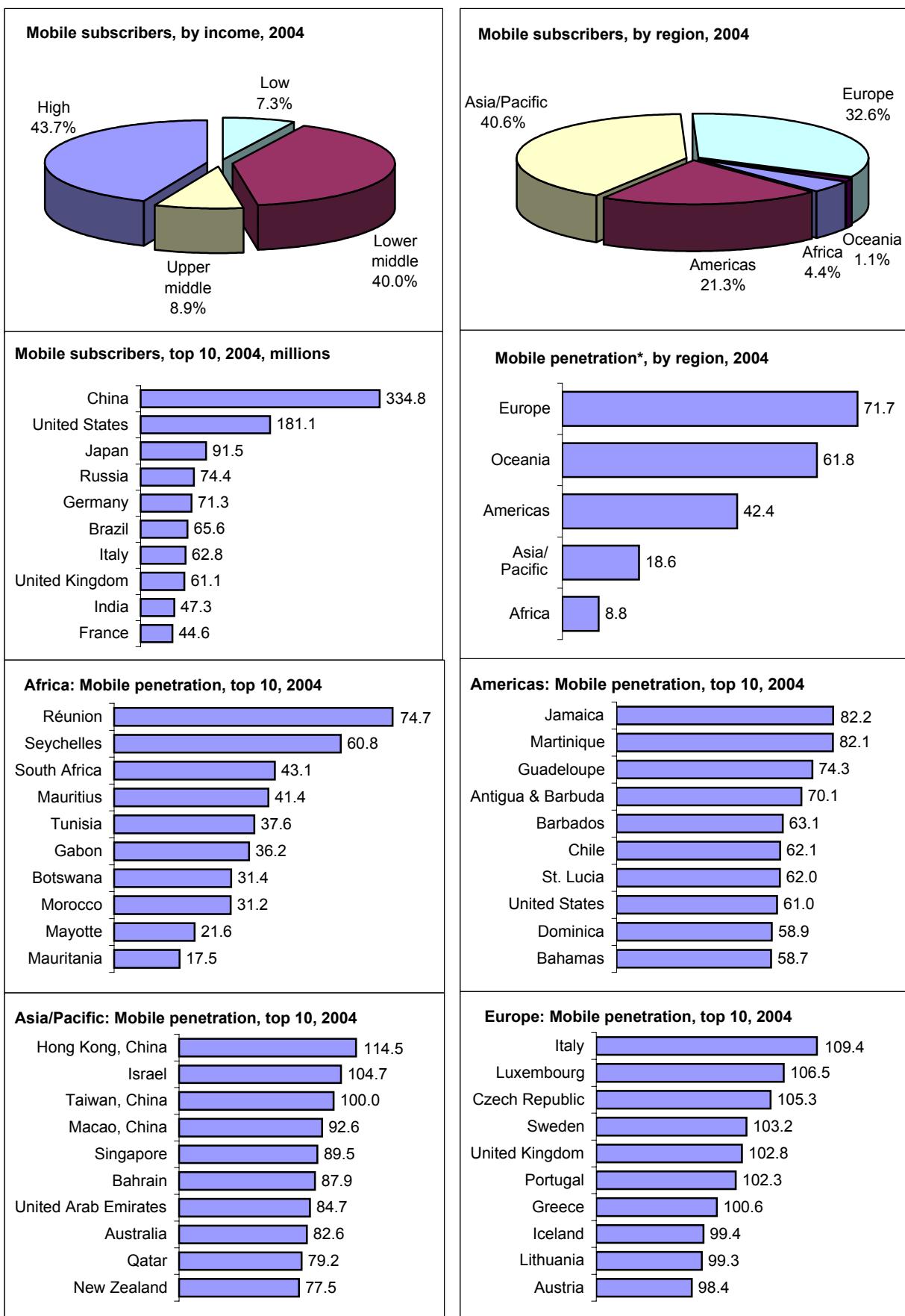
Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

2. Mobile subscribers



2. Mobile subscribers



* Penetration = subscribers per 100 inhabitants

3. Mobile prices

	<i>Connection charge (USD) 2005</i>	<i>Per minute local call (USD) 2005</i>		<i>Cost of a local SMS (USD) 2005</i>	<i>OECD low user basket (USD) 2005</i>	<i>As % monthly GNI 2005</i>
		<i>Peak 2005</i>	<i>Off-peak 2005</i>			
1	Afghanistan	30.00	0.13	0.20	10.86	...
2	Angola	...	0.27	0.10	10.87	0.13
3	Azerbaijan	14.22	0.24	0.04	9.33	0.12
4	Bangladesh	2.28	0.10	0.03	3.41	0.09
5	Benin	13.98	0.40	0.05	14.30	0.32
6	Bhutan	7.92	0.10	0.11	6.39	0.10
7	Burkina Faso	18.65	0.39	0.07	12.42	0.41
8	Burundi	9.24	0.19	0.17	11.75	1.57
9	Cambodia	...	0.09	0.03	3.96	0.15
10	Cameroon	9.31	0.43	0.13	16.37	0.25
11	Central African Rep.	37.23	0.19	0.18	12.49	0.48
12	Chad	7.45	0.34	0.05	13.21	0.61
13	Comoros	46.54	0.20	0.09	10.39	0.24
14	Congo	2.00	0.27	0.05	10.98	0.17
15	Cote d'Ivoire	18.65	0.73	0.09	21.21	0.33
16	D.P.R.Korea
17	D.R. Congo	2.00	0.27	0.05	10.98	1.10
18	Equatorial Guinea
19	Eritrea
20	Ethiopia	52.30	0.10	0.04	4.76	0.52
21	Gambia	15.06
22	Georgia	-	0.23	0.06	10.26	0.12
23	Ghana	10.25	0.26	0.07	10.09	0.32
24	Guinea	37.45	0.20	0.05	7.70	0.20
25	Guinea-Bissau	18.80	0.45	0.19	21.93	1.64
26	Haiti	-	0.12	-	4.30	0.13
27	India	2.25	0.04	0.03	2.53	0.05
28	Indonesia	...	0.11	0.03	4.00	0.04
29	Kenya	33.92	0.39	0.07	16.38	0.43
30	Kyrgyzstan	10.40	0.17	0.04	7.51	0.23
31	Lao P.D.R.	0.46	0.07	0.05	4.06	0.12
32	Lesotho	17.16	0.45	0.12	15.63	0.25
33	Liberia
34	Madagascar	5.68	0.21	-	8.39	0.34
35	Malawi	4.11	0.31	0.09	11.58	0.82
36	Mali	18.65	0.28	0.14	14.61	0.49
37	Mauritania	11.00
38	Moldova	17.00	0.39	0.05	16.16	0.27
39	Mongolia	1.44	0.20	0.02	8.59	0.17
40	Mozambique	...	0.28	0.07	10.68	0.51
41	Myanmar
42	Nepal	9.14	0.05	0.01	1.96	0.09
43	Nicaragua	...	0.43	0.05	16.88	0.26
44	Niger	...	0.45	0.07	16.68	0.87
45	Nigeria	7.35	0.19	0.23	13.77	0.42
46	Pakistan	4.19	0.06	0.02	2.68	0.05
47	Papua New Guinea	20.83	0.56	0.10	15.75	0.33
48	Rwanda	...	0.28	0.10	12.83	0.70
49	S.Tomé & Principe	53.49	0.26	0.24	16.73	0.54
50	Senegal	4.66	0.32	0.04	11.65	0.21
51	Sierra Leone	13.96	1.90	0.28	71.25	4.27
52	Solomon Islands	35.94	0.43	0.43	28.83	0.63
53	Somalia	...	0.12	0.02	5.15	...
54	Sudan	21.51	0.09	0.02	3.94	0.09
55	Tajikistan	10.00	0.15	0.60	23.32	1.00
56	Tanzania	6.32	0.34	0.05	13.55	0.49
57	Togo	16.78	0.23	0.14	11.77	0.37
58	Uganda	10.84	0.22	0.05	7.93	0.35
59	Uzbekistan	-	0.10	0.03	4.02	0.10
60	Vietnam	11.45	0.15	0.03	6.47	0.14
61	Yemen	22.12	0.11	0.07	5.93	0.12
62	Zambia	12.00	0.39	0.05	13.75	0.37
63	Zimbabwe	53.21	0.07	0.01	3.27	...
Low income		15.78	0.28	0.23	0.09	11.90
						0.46

3. Mobile prices

	<i>Connection charge (USD) 2005</i>	<i>Per minute local call (USD) 2005</i>		<i>Cost of a local SMS (USD) 2005</i>	<i>OECD low user basket (USD) 2005</i>	<i>As % monthly GNI 2005</i>
		<i>Peak 2005</i>	<i>Off-peak 2005</i>			
64	Albania	15.01	0.52	0.16	23.70	0.14
65	Algeria	5.39	0.19	0.07	8.95	0.05
66	Armenia	4.33	0.18	0.00	6.94	0.07
67	Belarus	16.44	0.42	0.11	16.04	0.09
68	Bolivia	3.72	0.22	0.04	5.73	0.07
69	Bosnia	28.00	0.16	0.04	6.75	0.04
70	Brazil	17.45	0.53	0.14	23.68	0.09
71	Bulgaria	6.35	0.50	0.11	21.82	0.10
72	Cape Verde	44.87	0.41	0.17	17.78	0.12
73	China	35.00	0.09	0.01	3.70	0.03
74	Colombia	19.70	0.26	0.03	10.45	0.06
75	Cuba	120.00	0.53	0.16	22.73	...
76	Djibouti	10.00	0.17	0.08	7.36	0.09
77	Dominican Rep.	3.20	0.27	0.03	11.17	0.06
78	Ecuador	10.00	0.55	0.06	21.00	0.12
79	Egypt	19.88	0.09	0.09	5.80	0.05
80	El Salvador	10.00	0.27	0.02	10.32	0.05
81	Fiji	52.66	0.98	0.12	42.77	0.19
82	Guatemala	...	0.13	0.03	5.85	0.03
83	Guyana	23.62	0.19	0.04	7.50	0.09
84	Honduras	12.69	0.32	0.00	12.13	0.14
85	Iran (I.R.)	...	0.06	0.05	3.20	0.02
86	Iraq	99.00	0.07	0.02	3.03	...
87	Jamaica	...	0.25	0.06	9.55	0.04
88	Jordan	28.21	0.13	0.04	6.75	0.04
89	Kazakhstan	3.97	0.32	0.06	11.45	0.06
90	Kiribati	...	0.48	0.04	12.71	0.16
91	Maldives	15.49	0.13	0.02	4.53	0.02
92	Marshall Islands	...	0.33	...	14.30	0.07
93	Micronesia	50.00	0.60	0.04	18.86	0.11
94	Morocco	3.38	0.38	0.09	15.95	0.13
95	Namibia	12.56	0.44	0.09	15.39	0.08
96	Palestine	4.46	0.20	0.07	9.59	0.10
97	Paraguay	...	0.21	0.02	6.83	0.07
98	Peru	7.58	0.58	0.08	22.63	0.12
99	Philippines	2.67	0.14	0.02	4.03	0.04
100	Romania	-	0.29	0.10	14.07	0.06
101	Russia	9.23	0.12	0.05	6.40	0.02
102	Samoa	9.76	0.27	0.07	7.68	0.05
103	Serbia and Montenegro	16.66	0.12	0.02	5.13	0.02
104	South Africa	23.75	0.42	0.13	14.96	0.05
105	Sri Lanka	21.54	0.08	0.02	2.78	0.03
106	St. Vincent	11.11	0.30	0.09	13.03	0.04
107	Suriname	6.50	0.25	0.05	10.77	0.06
108	Swaziland	10.21	0.41	0.13	16.75	0.12
109	Syria	7.62	0.16	0.19	11.73	0.12
110	TFYR Macedonia	4.95	0.48	0.05	11.78	0.06
111	Thailand	4.85	0.12	0.07	6.71	0.03
112	Tonga	9.90	0.10	-	3.71	0.02
113	Tunisia	7.68	0.16	0.05	6.49	0.03
114	Turkey	14.30	0.10	0.10	6.62	0.02
115	Turkmenistan	8.54	0.11	0.07	5.11	0.05
116	Ukraine	7.00	0.15	0.02	6.16	0.06
117	Vanuatu	36.85	0.18	0.18	12.36	0.11
Lower Middle Income		18.67	0.28	0.24	0.10	11.36
						0.07

3. Mobile prices

	<i>Connection charge (USD) 2005</i>	<i>Per minute local call (USD) 2005</i>		<i>Cost of a local SMS (USD) 2005</i>	<i>OECD low user basket (USD) 2005</i>	<i>As % monthly GNI 2005</i>
		<i>Peak 2005</i>	<i>Off-peak 2005</i>			
118 Argentina	51.49	0.24	0.24	0.04	10.03	0.03
119 Belize	20.25	0.43	0.30	0.13	16.85	0.05
120 Botswana	6.58	0.33	0.16	0.05	9.83	0.03
121 Chile	37.38	0.47	0.47	0.09	19.41	0.05
122 Costa Rica	...	0.10	0.10	0.00	3.76	0.01
123 Croatia	44.22	0.35	0.33	0.06	13.88	0.03
124 Czech Republic	8.40	0.32	0.32	0.16	16.76	0.02
125 Dominica	...	0.30	0.28	0.07	12.51	0.04
126 Estonia	-	0.28	0.15	0.08	9.76	0.02
127 Gabon	5.59	0.48	0.29	0.14	17.33	0.05
128 Grenada	...	0.30	0.26	0.09	13.10	0.04
129 Guadeloupe	25.07	0.62	0.71	0.15	29.19	...
130 Hungary	4.11	0.34	0.20	0.18	13.86	0.02
131 Latvia	27.55	0.18	0.10	0.15	9.13	0.02
132 Lebanon	15.00	0.40	0.40	0.27	22.94	0.06
133 Libya	183.61
134 Lithuania	1.76	0.20	0.20	0.05	8.60	0.02
135 Malaysia	2.66	0.15	0.12	0.03	5.84	0.02
136 Mauritius	16.38	0.10	0.10	0.02	4.52	0.01
137 Mayotte
138 Mexico	0.94	0.37	0.37	0.65	33.26	0.06
139 Northern Marianas
140 Oman	23.38	0.14	0.12	0.03	5.48	0.01
141 Panama	14.95	0.35	0.35	0.11	15.99	0.04
142 Poland	0.95	0.21	0.21	0.00	7.53	0.01
143 Saudi Arabia	53.32	0.24	0.24	0.07	10.66	0.01
144 Seychelles	58.25	0.75	0.37	0.19	24.75	0.04
145 Slovak Republic	9.74	0.30	0.25	0.10	11.17	0.02
146 St. Kitts and Nevis	50.00	0.32	0.28	-	10.72	0.02
147 St. Lucia	11.11	0.30	0.26	0.09	13.03	0.04
148 Trinidad & Tobago	11.92	0.38	0.16	0.06	10.92	0.02
149 Uruguay	5.38	0.41	0.41	0.04	16.58	0.05
150 Venezuela	...	0.40	0.35	0.03	14.48	0.04
Upper Middle Income	25.55	0.33	0.27	0.10	13.73	0.03

3. Mobile prices

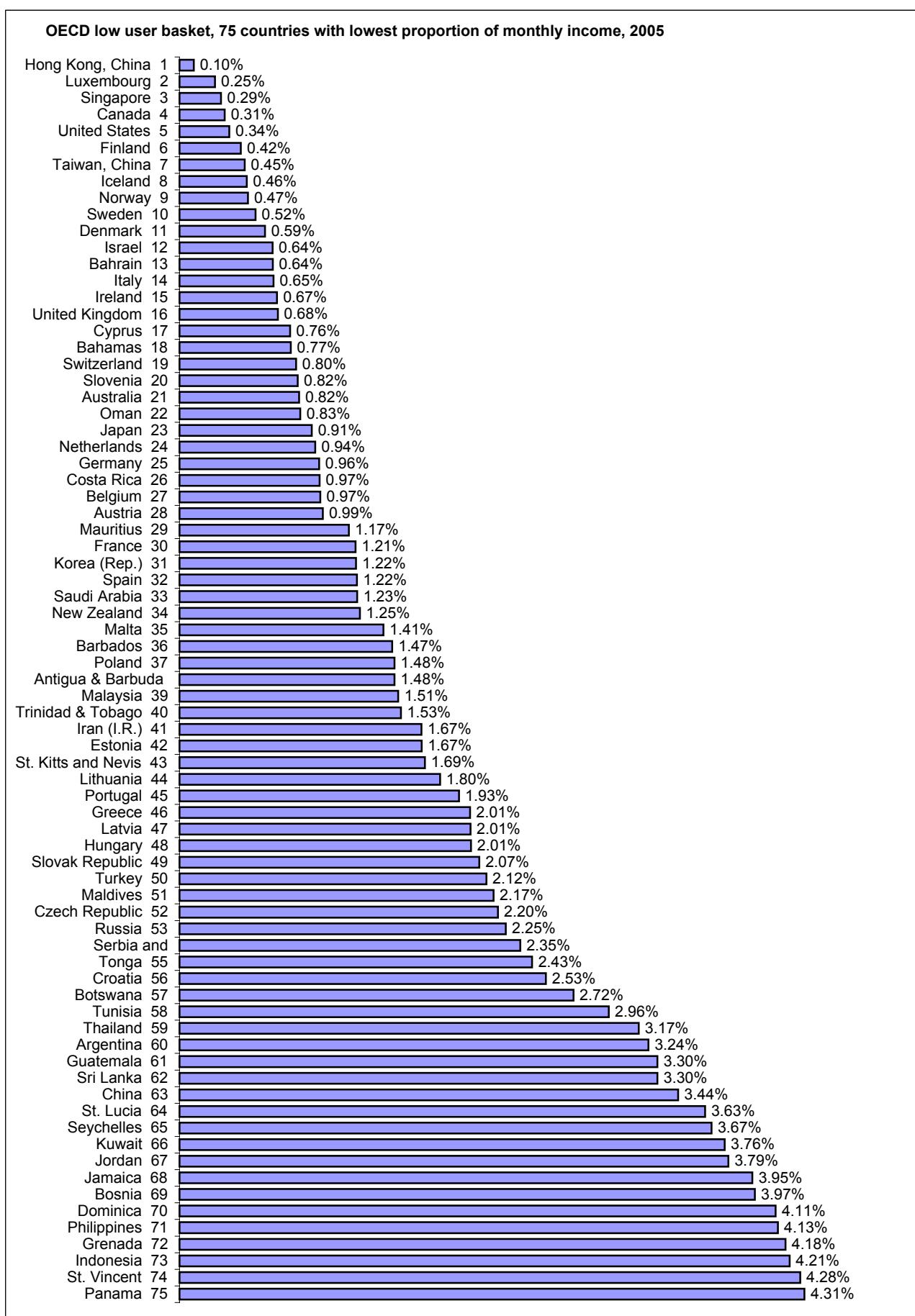
	<i>Connection charge (USD)</i>	<i>Per minute local call (USD)</i>		<i>Cost of a local SMS (USD)</i>	<i>OECD low user basket (USD)</i>	<i>As % monthly GNI</i>
	<i>2005</i>	<i>Peak 2005</i>	<i>Off-peak 2005</i>	<i>2005</i>	<i>2005</i>	<i>2005</i>
151	Andorra	-	0.41	0.19	0.15	14.68
152	Antigua & Barbuda	37.04	0.33	0.33	-	12.37
153	Aruba	28.25	0.40	0.18	0.08	12.28
154	Australia	22.91	0.36	0.36	0.19	18.48
155	Austria	25.07	0.71	0.38	0.28	26.62
156	Bahamas	59.70	0.33	0.15	0.05	9.55
157	Bahrain	21.22	0.12	0.10	0.09	6.66
158	Barbados	12.35	0.26	0.23	0.10	11.34
159	Belgium	12.53	0.46	0.46	0.26	25.10
160	Bermuda	-	0.50	0.50	0.10	21.55
161	Brunei Darussalam	29.43	0.24	0.12	0.06	7.79
162	Canada	21.03	0.33	0.04	0.06	7.36
163	Cyprus	26.26	0.10	0.10	0.25	11.19
164	Denmark	16.64	0.44	0.44	0.13	19.99
165	Faroe Islands	8.24	0.50	0.29	0.12	17.29
166	Finland	8.65	0.20	0.20	0.14	11.58
167	France	25.07	0.69	0.69	0.16	30.46
168	French Guiana	25.07	0.62	0.71	0.15	29.19
169	French Polynesia	26.59	1.04	1.04	0.42	51.22
170	Germany	50.07	0.61	0.36	0.24	24.16
171	Greece	7.52	0.41	0.41	0.41	27.75
172	Greenland	...	0.18	0.13	0.04	6.70
173	Guam	...	0.25	0.22	0.05	9.91
174	Guernsey	9.21	0.43	0.43	0.13	18.96
175	Hong Kong, China	3.87	0.04	0.04	0.03	2.21
176	Iceland	15.84	0.33	0.26	0.16	14.95
177	Ireland	6.14	0.69	0.25	0.16	19.23
178	Israel	34.95	0.17	0.17	0.10	9.31
179	Italy	16.29	0.24	0.24	0.19	14.11
180	Japan	-	0.72	0.72	0.05	28.27
181	Jersey	54.92	0.49	0.49	0.13	18.07
182	Korea (Rep.)	...	0.38	0.38	-	14.18
183	Kuwait	51.35	1.47	1.47	0.07	56.33
184	Luxembourg	-	0.28	0.16	0.15	11.49
185	Macao, China	50.00	0.25	0.25	0.25	16.77
186	Malta	14.22	0.34	0.34	0.06	14.37
187	Martinique	25.07	0.62	0.71	0.15	29.19
188	Neth. Antilles	28.41	0.51	0.51	0.15	23.30
189	Netherlands	25.07	0.56	0.36	0.29	24.74
190	New Caledonia	30.86	0.13	0.13	0.13	8.80
191	New Zealand	17.65	0.56	0.56	0.14	21.07
192	Norway	24.12	0.45	0.45	0.13	20.45
193	Portugal	-	0.56	0.56	0.10	23.06
194	Puerto Rico	...	0.35	0.35
195	Qatar	27.46	0.20	0.20	0.11	10.63
196	Réunion	12.53	0.36	0.36	0.19	18.58
197	Singapore	25.10	0.13	0.13	0.03	5.77
198	Slovenia	6.80	0.23	0.16	0.11	10.06
199	Spain	7.52	0.45	0.45	0.19	21.64
200	Sweden	27.03	0.66	0.05	0.17	15.65
201	Switzerland	22.84	0.86	0.72	0.16	32.33
202	Taiwan, China	21.10	0.17	0.09	0.03	4.99
203	United Arab Emirates	42.20	0.07	0.05	0.05	3.52
204	United Kingdom	18.41	0.37	0.37	0.18	19.20
205	United States	-	0.28	0.28	0.06	11.85
206	Virgin Islands (US)
High income		21.23	0.42	0.35	0.14	17.71
WORLD						
19.65						
0.32						
0.27						
0.10						
13.65						
0.17						
Africa						
21.25						
0.33						
0.26						
0.09						
13.31						
0.44						
Americas						
22.22						
0.36						
0.32						
0.08						
14.75						
0.06						
Asia/Pacific						
18.07						
0.19						
0.17						
0.07						
8.78						
0.09						
Europe						
15.02						
0.39						
0.31						
0.14						
16.41						
0.03						
Oceania						
30.42						
0.46						
0.40						
0.15						
0.44						
0.16						

Note: For data comparability and coverage, see the technical notes.

Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

3. Mobile prices: OECD low user basket as a proportion of average monthly income



4. 3G (IMT-2000) subscribers and networks

	IMT 2000 (3G) mobile subscribers			Network deployment			
	Total 3G subscribers 2004	3G as % of all mobile subscribers 2004	Rank 3G as % 2004	Standard	Launch date	Operators	
				3G as % 2004			
1	Angola	225'000	23.9	7	CDMA 2000 1x	21 January 2004	Movicel Telecom
2	Argentina	20'000	0.1	42	CDMA 2000 1x EV-DO	July 2005	Movicel Telecom
3	Australia*	769'000	4.7	10	CDMA 2000 1x	15 December 2003	Movistar Argentina
				CDMA 2000 1x EV-DO	2 December 2002	Telstra/Hutchison	
				CDMA 2000 1x	16 November 2004	Telstra	
				WCDMA	18 August 2004	Orange (Australia)	
4	Austria	202'000	2.5	21	WCDMA	15 April 2003	Hutchison H3G
				WCDMA	20 December 2003	ConnectAustria	
				WCDMA	5 May 2003	Hutchison H3G	
				WCDMA	25 April 2003	Mobilkom (V-fone)	
				WCDMA	April 2004	T-Mobile	
				WCDMA	19 February 2004	Tele.ring	
5	Bahrain	950	0.1	44	WCDMA	8 January 2004	MTC Vodafone Bahrain
6	Belarus	100'000	8.9	8	CDMA 2000 1x	10 February 2003	BelCel JV
7	Belgium	1'391	0.0	55	WCDMA	10 April 2004	Belgacom Mobile Proximus
8	Bermuda	17'400			CDMA 2000 1x	17 October 2003	Bermuda Digital Comm.
				CDMA 2000 1x EV-DO		Bermuda Digital Comm.	
9	Brazil	1'706'660	2.6	19	CDMA 2000 1x	12 December 2001	Vivo
				CDMA 2000 1x EV-DO	26 October 2004	Vivo	
10	Canada	7'400'000	49.4	2	CDMA 2000 1x	25 November 2002	Aliant Inc.
				CDMA 2000 1x	27 November 2002	MTS Mobility	
				CDMA 2000 1x	12 February 2002	Bell Mobility	
				CDMA 2000 1x	10 April 2003	SaskTel Mobil	
				CDMA 2000 1x	3 June 2002	Telus Mobility	
11	Chile	74'730	0.8	29	CDMA 2000 1x	11 August 2003	Movistar Chile
				CDMA 2000 1x	28 November 2002	SmartCom PCS	
				CDMA 2000 1x EV-DO	6 September 2004	SmartCom PCS	
12	China	8'711'300	2.6	18	CDMA 2000 1x	19 November 2002	China Unicom
13	Colombia	5'000	0.0	52	CDMA 2000 1x	15 April 2003	Movistar Colombia
14	Czech Republic	49'000	0.5	31	CDMA 2000 1x	2 August 2004	Eurotel Praha
				CDMA 2000 1x EV-DO	3 August 2004	Eurotel Praha	
15	Denmark	124'650	2.4	22	WCDMA	13 October 2003	H3G Denmark
16	Dominican Republic	30'000	1.2	27	CDMA 2000 1x	27 March 2003	Centennial Dominicana
				CDMA 2000 1x	3 December 2003	Verizon Dominicana	
17	Ecuador	200'000	4.4	13	CDMA 2000 1x	2 December 2003	Alegro PCS
				CDMA 2000 1x	4 December 2002	Movistar Ecuador	
18	Finland	7'361	0.1	43	WCDMA	13 October 2004	TeliaSonera
				WCDMA	23 November 2004	Elisa	
19	France	38'000	0.1	47	WCDMA	16 June 2004	SFR
				WCDMA	7 September 2004	Orange France	
20	Georgia				CDMA 2000 1x	November 2003	Iberiatel
21	Germany	245'000	0.3	34	WCDMA	5 May 2004	T-Mobile
				WCDMA	4 May 2004	Vodafone	
				WCDMA	1 July 2004	O2	
				WCDMA	18 June 2004	E-Plus	
22	Greece	9'250	0.1	48	WCDMA	23 January 2004	Vodafone
				WCDMA	27 January 2004	TIM-STET Hellas	
				WCDMA	26 May 2004	Cosmote	
23	Guam				CDMA 2000 1x	1 January 2004	Guamcell
				CDMA 2000 1x	20 September 2004	IT&E Wireless	
24	Guatemala	50'000	1.6	25	CDMA 2000 1x	20 May 2003	Movistar Guatemala
				CDMA 2000 1x EV-DO	4 June 2004	Movistar Guatemala	
				CDMA 2000 1x	15 July 2003	PCS Sercom (Telgua)	
25	Hong Kong, China	210'000	2.6	20	WCDMA	27 January 2004	Hutchison (3)
				WCDMA	21 December 2004	CSL	
				WCDMA	19 December 2004	SmarTone	
26	Indonesia	50'000	0.2	40	CDMA 2000 1x	12 September 2003	Bakrie Telecom
				CDMA 2000 1x	2 June 2004	Indosat StarOne	
				CDMA 2000 1x	8 December 2003	Mobile-8 Tel	
				CDMA 2000 1x	19 April 2004	Mandara Selular Ind.	
				CDMA 2000 1x	1 December 2002	Telkom Flexi Ind	
				CDMA 2000 1x	-	Wireless Industry	

4. 3G (IMT-2000) subscribers and networks

		Total 3G subscribers 2004	3G as % of all mobile subscribers 2004	Rank 3G as % 2004	Standard	Launch date	Operators
27	Ireland	3'000	0.1	49	WCDMA	July 2004	Vodafone
28	Israel*	1'823'000	25.4	5	WCDMA	1 October 2004	H3G
29	Italy	2'800'000	4.5	12	CDMA 2000 1x	30 September 2002	Telephone
					CDMA 2000 1x EV-DO	5 September 2004	Telephone
					WCDMA	6 June 2004	Cellcom Israel
					WCDMA	1 December 2004	Partner Communications
					WCDMA	3 March 2003	Hutchison H3G
					WCDMA	24 May 2004	TIM
					WCDMA	25 October 2004	Wind
					WCDMA	February 2004	Vodafone Omnitel
30	Jamaica				CDMA 2000 1x	-	Oceanic Digital Jam.
31	Japan*	25'700'000	28.1	3	CDMA 2000 1x	1 April 2002	KDDI
					CDMA 2000 1x EV-DO	1 October 2003	KDDI
					WCDMA	1 October 2001	NTT DoCoMo
					WCDMA	20 December 2002	Vodafone KK
32	Kazakhstan	100'000	3.6	14	CDMA 2000 1x	9 December 2003	Delacom Altel
33	Korea*, Rep. of	27'509'000	75.2	1	CDMA 2000 1x	1 October 2000	SK Telecom
					CDMA 2000 1x EV-DO	28 January 2002	SK Telecom
					CDMA 2000 1x	1 May 2001	KTF
					CDMA 2000 1x EV-DO	5 August 2002	KTF
					CDMA 2000 1x	1 May 2001	LG Telecom
					WCDMA	1 January 2004	SK Telecom
					WCDMA	1 January 2004	LG Telecom
34	Kyrgyzstan	CDMA 2000 1x	18 November 2003	AkTel-FONEX
					CDMA 2000 1x	4 quarter 2004	WinLine
35	Latvia	1'000	0.1	50	CDMA 2000 1x	1 October 2004	Tel Baltija (Triateli)
36	Luxembourg	3'810	0.7	30	WCDMA	June 2004	Tango SA (Tele2)
					WCDMA	June 2004	P&T Luxembourg (VOX)
37	Mauritius	500	0.1	46	WCDMA	29 November 2004	Emtel
38	Mexico	20'000	0.1	51	CDMA 2000 1x	14 July 2004	Iusacell
					CDMA 2000 1x	24 January 2004	Unefon
39	Moldova	3'000	0.4	32	CDMA 2000 1x	30 September 2002	JSC Interdnestrcom
40	Mongolia	990	0.3	35	CDMA 2000 1x	September 2004	SkyTel
					CDMA 2000 1x EV-DO	September 2005	SkyTel
41	Netherlands	27'000	0.2	38	WCDMA	16 June 2004	Vodafone Libertel
					WCDMA	11 October 2004	KPN Mobile
42	New Zealand	732'000	24.2	6	CDMA 2000 1x	22 July 2002	Telecom NZ
					CDMA 2000 1x EV-DO	8 November 2004	Telecom NZ
43	Nicaragua	20'000	2.7	17	CDMA 2000 1x	26 March 2003	Movistar Nicaragua
44	N. Marianas Islands				CDMA 2000 1x	1 January 2004	Saipancell Communicatio
45	Norway	7'000	0.2	39	WCDMA	1 December 2004	Telenor Mobil
46	Pakistan	CDMA 2000 1x	22 October 2004	PTCL
47	Panama	CDMA 2000 1x	4 December 2002	Movistar Panama
48	Peru	300'000	7.3	9	CDMA 2000 1x	27 November 2003	Movistar Peru
					CDMA 2000 1x EV-DO	October 2004	Movistar Peru
49	Poland	1'000	0.0	56	WCDMA	6 September 2004	Polkomtel
					WCDMA	25 November 2004	PlusGSM
50	Portugal	99'000	1.0	28	WCDMA	21 April 2004	TMN
					WCDMA	4 May 2004	Vodafone Telecel
					WCDMA	3 June 2004	Optimus
51	Puerto Rico	CDMA 2000 1x	4 April 2002	Sprint PR,
					CDMA 2000 1x	4 February 2003	Verizon Wireless
					CDMA 2000 1x EV-DO	-	Verizon Wireless
52	Romania	279'408	2.7	16	CDMA 2000 1x	1 December 2001	Telemobil
					CDMA 2000 1x EV-DO	26 October 2004	Zapp Mobil - Inquam
53	Russia	181'000	0.2	36	CDMA 2000 1x	16 Dec. 2002	Delta Telecom
					CDMA 2000 1x	-	Zao,
					CDMA 2000 1x	18 February 2004	Kuzbass Cell. Coms.
					CDMA 2000 1x	1 November 2003	Moscow Cell. Coms. RTC
					CDMA 2000 1x	10 May 2003	SOTEL-Video
					CDMA 2000 1x	-	UralWestcom
					CDMA 2000 1x	-	Volga Telecom

4. 3G (IMT-2000) subscribers and networks

		Total 3G subscribers 2004	3G as % of all mobile subscribers 2004	Rank 2004	Standard	Launch date	Operators
54	Slovenia	6'300	0.4	33	WCDMA	12 December 2003	Mobitel
55	South Africa	3'000	0.0	54	WCDMA	19 December 2004	Vodacom
56	Spain	77'000	0.2	37	WCDMA	1 November 2004	Amena
					WCDMA	November 2004	Vodafone
					WCDMA	24 May 2004	TelefonicaMoviles
57	Sweden	288'150	3.1	15	WCDMA	5 May 2003	Hutchison H3G
					WCDMA	1 June 2004	Tele2 AB-Comviq
					WCDMA	9 July 2004	Vodafone
					WCDMA	10 March 2004	TeliaSonera
58	Switzerland	10'000	0.2	41	WCDMA	9 September 2004	Swisscom Mobile
59	Taiwan, China	300'000	1.3	26	CDMA 2000 1x	29 July 2003	APBW
60	Thailand	615'000	2.2	24	CDMA 2000 1x	27 February 2003	CAT-Hutchison
61	Ukraine				CDMA 2000 1x	-	CST Invest Intertelecom
62	United Arab Emirates	5'370	0.1	45	WCDMA	24 December 2003	Etisalat
63	United Kingdom	2'832'000	4.6	11	WCDMA	3 March 2003	Hutchison 3G
					WCDMA	19 July 2004	T-Mobile
					WCDMA	19 July 2004	Orange
					WCDMA	November 2004	Vodafone
64	United States*	49'550'000	27.4	4	CDMA 2000 1x	9 March 2004	Northcoast PCS
					CDMA 2000 1x	29 April 2004	Carolina W Wireless
					CDMA 2000 1x	1 April 2004	Illinois Valley
					CDMA 2000 1x	1 February 2002	Metro PCS
					CDMA 2000 1x	11 August 2002	Sprint
					CDMA 2000 1x	12 November 2002	US Cellular
					CDMA 2000 1x	28 January 2002	Verizon Wireless
					CDMA 2000 1x EV-DO	1 October 2003	Verizon Wireless
					CDMA 2000 1x	15 Dec 2004	ClearTalk
					CDMA 2000 1x	24 May 2004	Alaska Com System
					CDMA 2000 1x EV-DO	15 June 2004	Alaska Com System
						-	Multiple others
					WCDMA	20 July 2004	Cingular Wireless
65	US Virgin Islands	CDMA 2000 1x	11 August 2002	Sprint US Virgin Islands
66	Uruguay	193	0.0	53	CDMA 2000 1x	31 March 2004	Movistar Uruguay
67	Uzbekistan	CDMA 2000 1x	July 2003	JSC Uzbektelecom
					CDMA 2000 1x	15 March 2004	Perfectum Mobile
					CDMA 2000 1x	8 October 2004	Telekom Mobile Inc.
68	Venezuela	200'000	2.4	23	CDMA 2000 1x	20 Nov. 2002	Movilnet Cantv
WORLD		133'744'413	8.0		166 networks		
<hr/>							
Africa	228'500	1.1	WCDMA		3'500	CDMA 2000 1x	225'000
Americas	59'543'983	16.5	WCDMA		50'000	CDMA 2000 1x	59'543'983
Asia	65'025'610	11.3	WCDMA		11'386'320	CDMA 2000 1x	53'639'290
Europe	7'395'320	1.5	WCDMA		6'781'912	CDMA 2000 1x	613'408
Oceania	1'501'000	7.7	WCDMA		543'000	CDMA 2000 1x	958'000

Note: For data comparability and coverage, see the technical notes.

Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

* Country had both WCDMA and CDMA 2000 1x commercial networks available at December 2004.

Kazakhstan - estimate for July 2005.

Mongolia - total number of data users from operator, but may not all be CDMA 1x subscribers.

5. Internet subscribers

	Internet subscribers			CAGR % 2000-2004	Dial-up		Broadband subscribers 2004
	Total 2004	per 100 inhabitants 2004	%		Total 2004	As % of total subscribers 2004	
1 Afghanistan	1'093	0.00	...		893	81.7	200
2 Angola	...	-
3 Azerbaijan	50'000	0.59	155.4	
4 Bangladesh	100'000	0.07	13.6	100'000	100.0	-	
5 Benin	6'379	0.09	21.1	6'315	99.0	64	
6 Bhutan	3'036	0.13	42.1	3'036	100.0	...	
7 Burkina Faso	14'238	0.11	45.3	14'084	98.9	154	
8 Burundi	840	0.01	-5.0	
9 Cambodia	7'152	0.05	19.2	6'733	94.1	419	
10 Cameroon	7'000	0.04	20.5	
11 Central African Rep.	2'000	0.05	29.8	
12 Chad	2'484	0.03	25.6	2'484	100.0	...	
13 Comoros	1'000	0.13	26.8	1'000	100.0	...	
14 Congo	1'000	0.03	77.8	
15 Cote d'Ivoire	12'213	0.07	9.1	11'740	96.1	...	
16 D.P.R.Korea	...	-	
17 D.R. Congo	6'000	0.01	...	2'050	34.2	...	
18 Equatorial Guinea	1'000	0.20	30.5	
19 Eritrea	3'500	0.08	18.1	3'500	100.0	...	
20 Ethiopia	11'418	0.02	66.8	11'361	99.5	57	
21 Gambia	...	-	
22 Georgia	4'110	0.08	...	2'700	65.7	1'410	
23 Ghana	...	-	
24 Guinea	11'000	0.13	97.3	
25 Guinea-Bissau	221	0.01	
26 Haiti	75'000	0.89	80.9	
27 India	5'450'000	0.50	16.4	5'215'000	95.7	235'000	
28 Indonesia	865'706	0.39	31.1	827'406	...	38'300	
29 Kenya	60'000	0.19	14.5	60'000	100.0	-	
30 Kyrgyzstan	6'459	0.12	34.1	
31 Lao P.D.R.	5'000	0.09	34.4	4'450	89.0	550	
32 Lesotho	2'046	0.11	...	2'046	100.0	...	
33 Liberia	...	-	
34 Madagascar	23'000	0.13	31.6	23'000	100.0	...	
35 Malawi	16'182	0.13	30.4	16'044	99.1	138	
36 Mali	15'000	0.11	36.9	
37 Mauritania	1'981	0.07	27.3	1'981	100.0	...	
38 Moldova	21'081	0.49	13.5	18'697	88.7	2'384	
39 Mongolia	46'000	1.75	79.2	45'500	98.9	500	
40 Mozambique	...	-	
41 Myanmar	31'844	0.06	88.0	24'844	78.0	7'000	
42 Nepal	35'000	0.14	30.7	35'000	100.0	...	
43 Nicaragua	21'745	0.39	10.1	16'844	77.5	4'901	
44 Niger	3'117	0.03	14.1	3'040	97.5	77	
45 Nigeria	53'240	0.04	54.3	31'282	58.8	...	
46 Pakistan	900'000	0.57	17.7	687'000	
47 Papua New Guinea	...	-	
48 Rwanda	2'497	0.03	25.1	
49 S.Tomé & Principe	1'113	0.68	43.3	1'113	100.0	...	
50 Senegal	19'361	0.19	37.1	2'100	
51 Sierra Leone	...	-	
52 Solomon Islands	1'000	0.20	-4.6	795	...	205	
53 Somalia	9'000	0.09	96.8	
54 Sudan	100'000	0.29	140.3	30'000	30.0	1'400	
55 Tajikistan	452	0.01	87.1	442	97.8	10	
56 Tanzania	50'000	0.13	71.0	
57 Togo	12'500	0.25	27.7	12'500	100.0	...	
58 Uganda	8'000	0.03	9.3	
59 Uzbekistan	37'420	0.14	112.8	1'690	
60 Vietnam	1'895'475	2.30	107.6	1'895'475	100.0	8'295	
61 Yemen	75'563	0.36	85.5	75'563	100.0	...	
62 Zambia	12'000	0.11	40.5	11'599	96.7	91	
63 Zimbabwe	83'722	0.65	40.8	79'104	94.5	...	
Low income	10'186'188	0.22	45.2	8'597'621	90.6	991'945	

5. Internet subscribers

		Internet subscribers		CAGR % 2000-2004	Dial-up		Broadband subscribers 2004
		Total	per 100 inhabitants		Total	As % of total subscribers	
		2004	2004		2004	2004	
64	Albania	20'000	0.63
65	Algeria	60'000	0.19	25'000
66	Armenia	90'000	2.95	64.3	89'000	98.9	1'000
67	Belarus	22'714	0.23	69.3	6'605	29.1	123
68	Bolivia	51'780	0.58	9.0
69	Bosnia	37'641	0.90	...	37'641	100.0	...
70	Brazil	7'900'000	4.37	87.4	5'644'000	71.4	2'256'000
71	Bulgaria	7'942	0.10	...	6'651	83.7	1'291
72	Cape Verde	5'371	1.14	21.6	5'088	94.7	283
73	China	71'713'000	5.46	67.9	45'928'000	64.0	25'785'000
74	Colombia	818'853	1.82	35.9	727'561	88.9	91'284
75	Cuba	12'193	0.11	-
76	Djibouti	3'885	0.55	56.5	3'885	100.0	...
77	Dominican Rep.	106'296	1.20	19.1	70'191	66.0	35'623
78	Ecuador	119'768	0.91	19.8	108'148	90.3	11'620
79	Egypt	3'700'000	5.04	...	3'670'693	99.2	29'307
80	El Salvador	117'495	1.78	...	21'698	18.5	95'797
81	Fiji	9'000	1.06	37.0	7'520	83.6	...
82	Guatemala	...	-
83	Guyana	26'000	3.39	18.9
84	Honduras	75'000	1.06	62.5	22'227	29.6	...
85	Iran (I.R.)	816'171	1.17	80.7	800'000	98.0	18'703
86	Iraq	14'887	0.06
87	Jamaica	95'000	3.55
88	Jordan	108'000	1.92	35.6	97'576	90.3	10'424
89	Kazakhstan	151'997	0.99	...	150'000	98.7	1997
90	Kiribati	758	0.89	23.1	758	100.0	...
91	Maldives	1'260	0.38	4.4	543	...	717
92	Marshall Islands	695	1.22	19.3	695	100.0	-
93	Micronesia	2'073	1.87	8.8	-
94	Morocco	102'610	0.33	29.0	37'950	37.0	64'660
95	Namibia	19'000	0.94	17.4
96	Palestine	53'000	1.44	65.8
97	Paraguay	45'500	0.76	11.9	45'000	...	500
98	Peru	643'602	2.33	43.9	505'325	78.5	138'277
99	Philippines	1'200'000	1.47	24.5	1'145'000	95.4	55'000
100	Romania	980'364	4.40	...	888'830	90.7	91'534
101	Russia	1'890'500	1.33	96.0	675'000
102	Samoa	1'913	1.06	109.8	1'913	100.0	...
103	Serbia and Montenegro	600'000	5.70
104	South Africa	1'000'000	2.21	18.6	940'000	94.0	60'000
105	Sri Lanka	93'444	0.49	23.2	90'027	96.3	3'417
106	St. Vincent	4'044	3.40	11.1	2'721	67.3	1'323
107	Suriname	6'545	1.49	13.8	6'000	91.7	565
108	Swaziland	19'000	1.75	56.0
109	Syria	160'000	0.88	100.0	159'400	99.6	600
110	TFYR Macedonia	...	-
111	Thailand	2'403'660	3.79	58.8	2'358'660	98.1	45'000
112	Tonga	1'881	1.81	25.5	1'870	99.4	11
113	Tunisia	121'000	1.22	36.4	118'161	97.7	2'839
114	Turkey	1'508'526	2.09	0.1	1'018'724	67.5	489'802
115	Turkmenistan	...	-
116	Ukraine	...	-
117	Vanuatu	1'600	0.74	3.4	1'577	98.6	23
Lower Middle Income		96'943'968	1.58	39.1	64'719'638	83.3	29'992'720

5. Internet subscribers

		Internet subscribers		CAGR % 2000-2004	Dial-up		Broadband subscribers
		Total	per 100 inhabitants		Total	As % of total subscribers	2004
		2004	2004		2004	2004	2004
118	Argentina	1'968'655	5.06	12.8	755'000	38.4	497'513
119	Belize	6'300	2.41	10.1	4'155	66.0	3'156
120	Botswana	...	-
121	Chile	1'353'739	8.78	11.7	440'567	32.5	913'172
122	Costa Rica	125'000	2.94	36.9	27'931
123	Croatia	600'000	13.59	47.5	12'000
124	Czech Republic	2'276'125	22.26	52.7	2'200'443	96.7	75'682
125	Dominica	6'021	8.48	21.6	2'768	46.0	3'253
126	Estonia	171'544	13.11	20.1	59'844	34.9	111'700
127	Gabon	7'850	0.58	11.9	7'145	91.0	705
128	Grenada	1'900	1.84	-9.0	1'291	67.9	609
129	Guadeloupe	25'000	5.74	33.6
130	Hungary	741'770	7.55	35.4	369'998	49.9	371'772
131	Latvia	90'000	3.94	28.0	40'853	45.4	49'147
132	Lebanon	170'000	4.58	...	90'000	52.9	80'000
133	Libya	...	-
134	Lithuania	512'238	14.97	76.1	429'325	83.8	82'913
135	Malaysia	3'545'239	14.25	18.7	3'292'738	92.9	252'501
136	Mauritius	62'708	5.09	28.7	60'000	95.7	2'708
137	Mayotte
138	Mexico	3'164'783	3.02	29.3	2'324'636	73.5	840'147
139	Northern Marianas	...	-
140	Oman	51'769	1.76	29.4	51'769	100.0	...
141	Panama	76'988	2.43	16.3	58'710	76.3	18'278
142	Poland	2'511'186	6.51	28.2	1'699'390	67.7	811'796
143	Saudi Arabia	928'719	3.73	46.8	909'019	97.9	19'700
144	Seychelles	3'300	4.07	26.6	3'201	97.0	99
145	Slovak Republic	397'777	7.36	44.2	348'589	87.6	49'188
146	St. Kitts and Nevis	4'600	9.79	...	4'100	89.1	500
147	St. Lucia	...	-
148	Trinidad & Tobago	44'765	3.43	14.0	40'195	89.8	4'570
149	Uruguay	680'000	20.98	...	653'000	96.0	27'000
150	Venezuela	458'675	1.75	13.7	248'961	54.3	209'714
Upper Middle Income		19'986'651	6.25	27.4	14'095'697	72.9	4'465'754

5. Internet subscribers

		Internet subscribers		CAGR % 2000-2004	Dial-up		Broadband subscribers
		Total 2004	per 100 inhabitants 2004		Total 2004	As % of total subscribers 2004	2004
							2004
151	Andorra	6'308	9.41	6'282
152	Antigua & Barbuda	...	-
153	Aruba	...	-
154	Australia	5'741'000	28.83	10.0	4'441'000	77.4	1'548'300
155	Austria	1'340'000	16.50	6.3	669'000	49.9	827'675
156	Bahamas	31'023	9.79	38.8	18'220	58.7	12'803
157	Bahrain	50'907	6.89	23.5	35'002	68.8	15'905
158	Barbados	27'319	10.08	27'319
159	Belgium	2'032'766	19.66	15.3	415'581	20.4	1'617'185
160	Bermuda	...	-
161	Brunei Darussalam	23'000	6.28
162	Canada	8'131'714	25.62	17.2	2'500'000	30.7	5'631'714
163	Cyprus	67'328	8.34	6.7	53'960	80.1	13'368
164	Denmark	2'768'011	51.50	12.7	1'754'511	63.4	1'013'500
165	Faroe Islands	9'161	17.11	12.6	8'767	95.7	-
166	Finland	1'400'000	26.84	22.8	600'000	42.9	800'000
167	France	11'936'519	19.75	21.7	5'182'484	43.4	6'754'035
168	French Guiana	12'000	6.86	22.5
169	French Polynesia	13'046	5.26	22.9	12'100	92.7	946
170	Germany	23'000'000	27.87	35.2	16'094'841	70.0	6'905'159
171	Greece	638'000	5.81	23.8	589'565	92.4	48'435
172	Greenland
173	Guam	...	-
174	Guernsey	760	1.36
175	Hong Kong, China	2'507'277	35.24	3.5	997'654	39.8	1'513'103
176	Iceland	54'000	18.56	53'264
177	Ireland	1'200'000	30.01	29.7	1'065'152	88.8	134'848
178	Israel	1'155'000	17.61	9.4	85'000	7.4	1'070'000
179	Italy	19'900'000	34.70	36.1	15'198'748	76.4	4'701'252
180	Japan	33'883'855	26.51	23.2	18'966'690	56.0	19'097'172
181	Jersey
182	Korea (Rep.)	12'028'520	25.09	23.8	107'081	0.9	11'921'439
183	Kuwait	250'000	9.63	...	230'000	92.0	20'000
184	Luxembourg	107'601	23.44	63.8	63'456	59.0	44'145
185	Macao, China	77'153	16.52	29.4	31'935	41.4	45'218
186	Malta	76'814	19.40	30.7	54'079	70.4	22'735
187	Martinique	40'000	10.27	38.7	34'000	85.0	6'000
188	Neth. Antilles	...	-
189	Netherlands	7'000'000	43.14	4.3	3'794'000	54.2	3'206'000
190	New Caledonia	17'296	7.46	-1.0	12'150	70.2	5'146
191	New Zealand	782'000	20.03	16.1	590'305	75.5	19'1695
192	Norway	1'568'713	34.46	3.0	888'713	56.7	680'000
193	Portugal	7'566'507	75.12	50.6	6'708'089	88.7	858'418
194	Puerto Rico	256'000	6.57	22'732
195	Qatar	92'736	14.98	36.5	28'062	30.3	64'674
196	Réunion	47'720	6.22	56'536
197	Singapore	2'226'700	51.60	37.2	1'714'300	77.0	512'400
198	Slovenia	240'500	12.14	19.8	182'508	75.9	57'992
199	Spain	5'709'222	13.88	15.4	1'851'708	32.4	3'441'630
200	Sweden	3'211'000	36.14	12.1	1'908'139	59.4	1'302'861
201	Switzerland	3'100'000	43.28	16.8	1'818'000	58.6	1'282'000
202	Taiwan, China	13'394'639	58.85	30.4	9'643'425	72.0	3'751'214
203	United Arab Emirates	363'646	11.92	14.8	317'814	87.4	45'832
204	United Kingdom	15'800'000	26.59	12.4	9'544'500	60.4	6'255'500
205	United States	63'703'000	21.45	-1.5	25'812'354	40.5	37'890'646
206	Virgin Islands (US)	...	-
High income		253'588'761	19.53	21.2	134'022'893	61.1	123'477'078
WORLD		380'705'568	5.95	34.5	221'435'849	58.2	158'927'497
Africa		5'705'496	0.66	37.7	5'170'366	90.6	246'218
Americas		90'236'303	10.27	25.2	40'067'672	44.4	48'772'947
Asia/Pacific		157'071'720	4.11	44.8	95'556'495	60.8	65'311'390
Europe		121'122'618	15.17	29.2	75'571'391	62.4	42'850'616
Oceania		6'569'431	20.5	23.8	5'069'925	77.2	1'746'326

Note: For data comparability and coverage, see the technical notes.
 Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

6. Information technology

	Internet				PCs	
	Hosts Total 2004	Hosts per 10'000 inhab. 2004	Users (000s) 2004	Users per 10'000 inhab. 2004	Total (000s) 2004	per 100 inhabitants 2004
					2004	2004
1	Afghanistan	4	-	20.0	9.97	...
2	Angola	420	0.30	172.0	122.18	27
3	Azerbaijan	355	0.42	408.0	483.01	149
4	Bangladesh	13	-	300.0	20.04	1'650
5	Benin	899	1.30	100.0	144.55	30
6	Bhutan	1'347	5.79	20.0	86.02	11
7	Burkina Faso	436	0.33	53.2	39.72	29
8	Burundi	155	0.22	25.0	35.37	34
9	Cambodia	827	0.57	41.0	28.31	38
10	Cameroon	461	0.28	167.0	102.48	160
11	Central African Rep.	12	0.03	9.0	23.01	11
12	Chad	6	0.01	60.0	67.77	15
13	Comoros	9	0.11	8.0	101.27	5
14	Congo	46	0.12	36.0	94.29	17
15	Cote d'Ivoire	3'801	2.25	300.0	177.55	262
16	D.P.R.Korea
17	D.R. Congo	163	0.03	50.0	9.50	...
18	Equatorial Guinea	16	0.32	5.0	98.62	7
19	Eritrea	1'037	2.41	50.0	116.39	15
20	Ethiopia	38	0.01	113.0	15.60	225
21	Gambia	784	5.36	49.0	335.16	23
22	Georgia	6'303	12.42	175.6	346.08	192
23	Ghana	373	0.17	368.0	172.15	112
24	Guinea	385	4.81	46.0	575.00	44
25	Guinea-Bissau	2	0.02	26.0	198.78	...
26	Haiti	-	-	500.0	592.63	...
27	India	143'654	1.33	35'000.0	323.71	13'030
28	Indonesia	111'630	5.01	14'508.0	651.72	3'022
29	Kenya	10'016	3.09	1'500.0	462.68	441
30	Kyrgyzstan	5'601	10.75	263.0	504.99	87
31	Lao P.D.R.	1'470	2.54	20.9	36.12	22
32	Lesotho	152	0.84	43.0	238.89	...
33	Liberia	14	0.04	1.0	3.22	...
34	Madagascar	883	0.49	90.0	50.28	91
35	Malawi	65	0.05	46.1	37.40	20
36	Mali	364	0.33	50.0	45.04	42
37	Mauritania	27	0.09	14.0	46.98	42
38	Moldova	13'306	31.21	406.0	952.38	112
39	Mongolia	161	0.61	200.0	760.46	312
40	Mozambique	7'167	3.78	138.0	72.78	112
41	Myanmar	4	-	63.7	11.79	325
42	Nepal	2'846	1.11	175.0	68.03	118
43	Nicaragua	10'094	18.04	125.0	223.37	200
44	Niger	145	0.12	24.0	19.33	9
45	Nigeria	966	0.08	1'769.7	139.22	867
46	Pakistan	25'096	1.60	2'000.0	127.13	...
47	Papua New Guinea	713	1.22	170.0	291.30	367
48	Rwanda	1'744	2.06	38.0	44.81	...
49	S.Tomé & Principe	1'025	62.50	20.0	1'219.51	...
50	Senegal	685	0.66	482.0	466.20	242
51	Sierra Leone	277	0.54	10.0	19.35	...
52	Solomon Islands	760	15.48	3.0	61.10	20
53	Somalia	4	-	89.0	90.29	...
54	Sudan	-	-	1'140.0	330.32	606
55	Tajikistan	154	0.24	5.0	7.94	...
56	Tanzania	5'908	1.57	333.0	88.40	278
57	Togo	81	0.16	221.0	440.50	171
58	Uganda	2'678	1.00	200.0	74.91	121
59	Uzbekistan	2'935	1.11	880.0	332.34	...
60	Vietnam	391	0.05	5'870.0	711.68	1'044
61	Yemen	162	0.08	180.0	86.82	300
62	Zambia	2'342	2.14	231.0	211.46	113
63	Zimbabwe	8'055	6.23	820.0	634.09	1'000
Low income		379'467	1.46	70'231.2	269.97	26'170
						1.01

6. Information technology

		Internet				PCs	
		Hosts	Hosts per	Users	Users per	Total	per 100
		Total	10'000 inhab.	(000s)	10'000 inhab.	(000s)	inhabitants
2004	2004	2004	2004	2004	2004	2004	2004
64	Albania	527	1.65	75.0	234.89	36	1.17
65	Algeria	944	0.29	845.0	261.29	290	0.90
66	Armenia	1'897	6.22	150.0	491.48	200	6.55
67	Belarus	6'905	7.01	1'600.0	1'624.20
68	Bolivia	8'346	9.30	350.0	390.06	190	2.28
69	Bosnia	8'393	20.05	225.0	537.51
70	Brazil	3'485'773	192.25	22'000.0	1'217.79	19'350	10.71
71	Bulgaria	65'759	83.99	2'200.0	2'810.07	461	5.89
72	Cape Verde	228	4.83	25.0	529.66	48	10.17
73	China	162'821	1.24	94'000.0	715.75	52'990	4.03
74	Colombia	192'761	42.92	3'585.7	798.35	2'996	6.67
75	Cuba	1'712	1.51	150.0	132.42	300	2.65
76	Djibouti	772	11.35	9.0	132.35	21	3.09
77	Dominican Rep.	65'949	75.02	800.0	910.00
78	Ecuador	8'800	6.67	624.6	473.42	724	5.49
79	Egypt	3'499	0.50	3'900.0	557.17	2'300	3.29
80	El Salvador	4'387	6.63	587.5	888.23	297	4.49
81	Fiji	1'124	13.27	61.0	720.19	44	5.19
82	Guatemala	23'743	18.75	756.0	597.11	231	1.82
83	Guyana	642	8.37	145.0	1'890.48	27	3.52
84	Honduras	3'968	5.67	222.3	317.53	110	1.57
85	Iran (I.R.)	6'616	0.95	550.0	78.81	7'347	10.53
86	Iraq	1	-	25.0	10.31	200	0.83
87	Jamaica	1'456	5.44	1'067.0	3'987.29	166	6.20
88	Jordan	2'966	5.28	600.0	1'068.95	300	5.34
89	Kazakhstan	22'625	14.69	400.0	259.69
90	Kiribati	17	1.91	2.0	228.42	1	1.14
91	Maldives	534	16.28	19.0	579.27	36	10.98
92	Marshall Islands	6	1.05	2.0	350.88	5	8.77
93	Micronesia	686	63.58	10.0	926.78
94	Morocco	4'118	1.38	3'500.0	1'170.57	620	2.07
95	Namibia	3'359	16.70	75.0	372.95	220	10.94
96	Palestine	160.0	434.19	169	4.59
97	Paraguay	8'418	13.99	150.0	249.25	356	5.92
98	Peru	110'118	39.95	3'220.0	1'168.06	2'689	9.75
99	Philippines	65'390	7.91	4'400.0	532.35	3'684	4.46
100	Romania	49'077	22.03	4'500.0	2'019.75	2'450	11.00
101	Russia	854'310	59.24	16'000.0	1'109.57	19'010	13.18
102	Samoa	10'305	572.50	6.0	333.33	1	0.67
103	Serbia and Montenegro	27'578	26.22	1'200.0	1'140.79	389	3.70
104	South Africa	350'501	77.52	3'566.0	788.69	3'740	8.27
105	Sri Lanka	2'061	1.07	280.0	145.30	530	2.75
106	St. Vincent	15	1.24	8.0	661.16	16	13.22
107	Suriname	130	2.96	30.0	683.37
108	Swaziland	2'642	24.40	36.0	332.41	36	3.32
109	Syria	11	0.01	800.0	439.01	600	3.29
110	TFYR Macedonia	3'595	17.40	159.0	769.60	140	6.78
111	Thailand	360'255	56.76	6'970.0	1'098.24	3'716	5.86
112	Tonga	19'090	1'835.58	3.0	288.46	5	4.81
113	Tunisia	373	0.38	835.0	840.29	472	4.75
114	Turkey	474'129	65.56	10'220.0	1'413.16	3'703	5.12
115	Turkmenistan	598	1.21	36.0	72.87
116	Ukraine	130'144	27.03	3'750.0	778.80	1'327	2.76
117	Vanuatu	534	24.61	7.5	345.62	3	1.38
Lower Middle Income		6'560'608	26.49	194'897.6	786.89	132'546	5.35

6. Information technology

		Internet				PCs	
		Hosts Total 2004	Hosts per 10'000 inhab. 2004	Users (000s) 2004	Users per 10'000 inhab. 2004	Total (000s) 2004	per 100 inhabitants 2004
118	Argentina	926'667	238.40	5'120.0	1'317.18	3'000	8.00
119	Belize	3'696	141.61	35.0	1'341.00	35	12.70
120	Botswana	2'097	11.68	60.0	334.26	80	4.46
121	Chile	219'250	142.27	4'300.0	2'790.21	2'138	13.87
122	Costa Rica	11'194	26.35	1'000.0	2'354.05	1'014	23.87
123	Croatia	34'695	78.57	1'303.0	2'950.63	842	19.07
124	Czech Republic	384'633	376.13	4'800.0	4'693.92	2'450	23.96
125	Dominica	686	96.62	18.5	2'605.63	9	12.68
126	Estonia	63'609	486.31	670.0	5'122.32	1'242	94.95
127	Gabon	194	1.43	40.0	295.86	40	2.96
128	Grenada	19	1.84	8.0	776.70	16	15.53
129	Guadeloupe	434	9.87	50.0	1'148.6	111	25.50
130	Hungary	483'814	492.13	2'700.0	2'746.41	1'476	15.01
131	Latvia	59'136	258.69	810.0	3'543.31	501	21.92
132	Lebanon	6'875	19.37	600.0	1'690.14	400	11.27
133	Libya	67	0.12	205.0	362.25	130	2.34
134	Lithuania	94'503	274.25	968.0	2'809.14	533	15.47
135	Malaysia	135'082	54.30	9'878.2	3'970.98	4'900	19.70
136	Mauritius	4'243	34.41	180.0	1'459.85	344	27.90
137	Mayotte
138	Mexico	1'523'277	145.17	14'036.5	1'337.69	11'210	10.68
139	Northern Marianas	17	2.21
140	Oman	1'506	5.13	245.0	834.75	118	4.02
141	Panama	6'945	21.89	300.0	945.67	130	4.10
142	Poland	271'767	70.50	9'000.0	2'334.57	7'362	19.10
143	Saudi Arabia	16'665	6.69	1'586.0	636.46	8'476	34.01
144	Seychelles	266	32.84	20.0	2'469.14	15	18.52
145	Slovak Republic	122'377	226.33	2'276.0	4'209.36	1'593	29.46
146	St. Kitts and Nevis	55	11.96	40.0	8'695.65	11	23.91
147	St. Lucia	41	2.73	55.0	3'666.67	26	17.33
148	Trinidad & Tobago	12'207	93.40	160.0	1'224.18	137	10.48
149	Uruguay	108'188	333.81	680.0	2'098.12	430	13.27
150	Venezuela	38'025	14.53	2'312.7	883.54	2'145	8.19
Upper Middle Income		4'532'230	133.10	63'456.9	1'863.60	50'914	14.95

6. Information technology

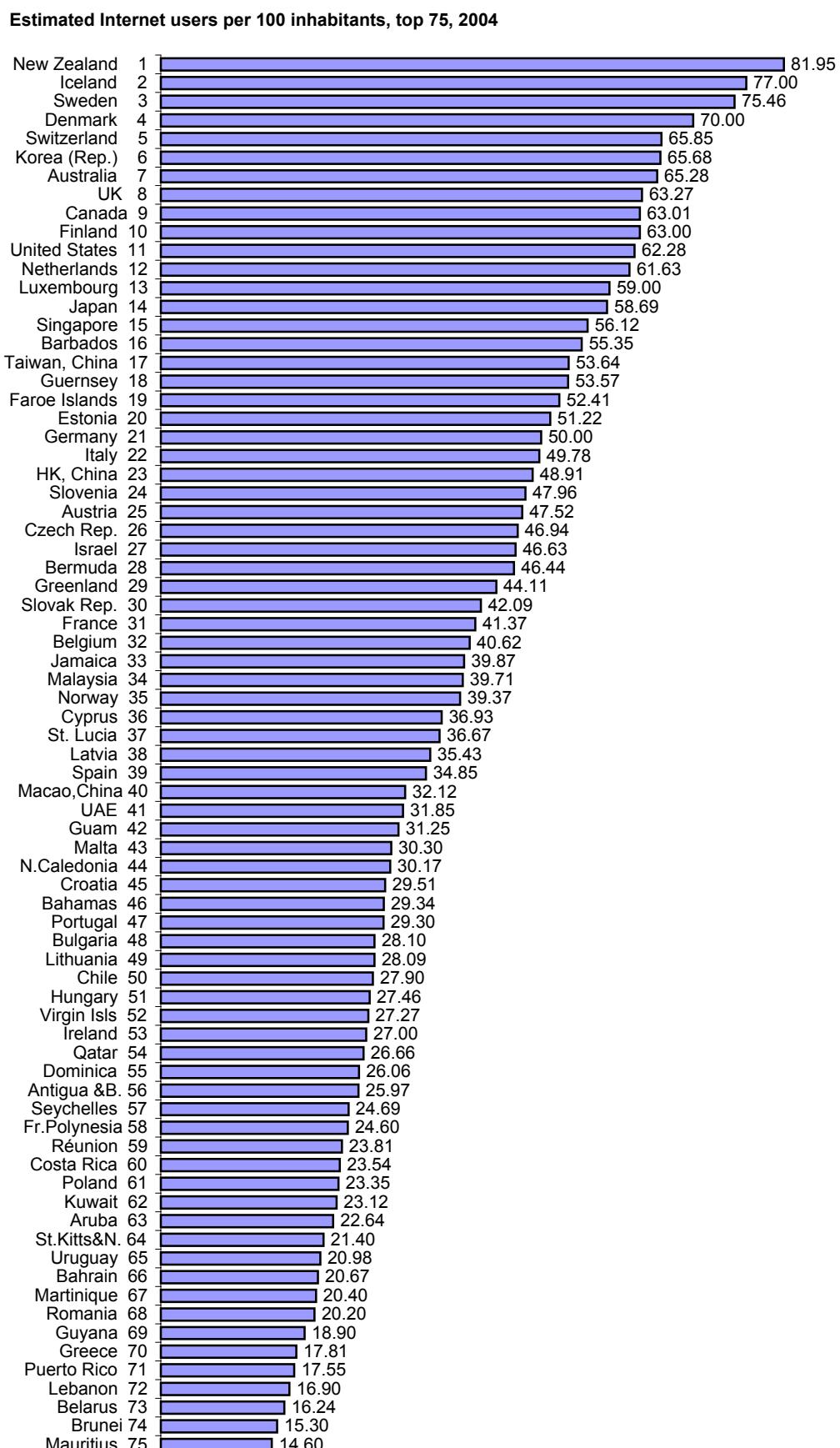
		Internet				PCs	
		Hosts Total 2004	Hosts per 10'000 inhab. 2004	Users (000s) 2004	Users per 10'000 inhab. 2004	Total (000s) 2004	per 100 inhabitants 2004
151	Andorra	4'138	491.45	10.0	1'193.47
152	Antigua & Barbuda	2'113	274.42	20.0	2'597.40
153	Aruba	3'630	317.86	24.0	2'264.15
154	Australia	3'939'321	1'978.27	13'000.0	6'528.40	13'720	68.90
155	Austria	1'284'933	1'565.75	3'900.0	4'752.33	3'420	41.67
156	Bahamas	322	10.16	93.0	2'933.75
157	Bahrain	1'850	25.03	152.7	2'066.59	121	16.37
158	Barbados	211	7.79	150.0	5'535.06	34	12.55
159	Belgium	242'861	234.90	4'200.0	4'062.29	3'627	35.08
160	Bermuda	8'808	1'346.79	30.0	4'643.96	34	52.31
161	Brunei Darussalam	6'180	168.85	56.0	1'530.05	31	8.47
162	Canada	3'562'482	1'122.29	20'000.0	6'300.60	22'390	70.54
163	Cyprus	7'624	94.47	298.0	3'692.69	249	30.86
164	Denmark	1'451'200	2'699.91	3'762.5	7'000.00	3'543	65.92
165	Faroe Islands	2'584	511.68	25.0	5'240.65
166	Finland	1'155'427	2'215.16	3'286.0	6'299.85	2'515	48.22
167	France	2'335'625	386.48	25'000.0	4'136.74	29'410	48.66
168	French Guiana	1	0.06	25.0	1'430.12	29	16.59
169	French Polynesia	5'143	207.38	61.0	2'459.68	78	31.45
170	Germany	3'021'130	366.08	41'263.0	5'000.00	46'300	56.10
171	Greece	275'091	250.61	1'955.0	1'781.00	986	8.98
172	Greenland	2'616	456.54	25.0	4'411.04
173	Guam	93	5.74	50.0	3'125.00
174	Guernsey	1'734	310.75	30.0	5'357.14
175	Hong Kong, China	783'371	1'101.01	3'479.7	4'890.65	4'187	58.85
176	Iceland	139'427	4'758.60	225.6	7'700.00	138	47.10
177	Ireland	170'191	425.58	1'079.7	2'700.00	2'011	50.29
178	Israel	541'794	789.56	3'200.0	4'663.36	5'037	73.40
179	Italy	1'635'799	282.03	28'870.0	4'977.59	18'150	31.29
180	Japan	16'445'223	1'286.80	75'000.0	5'868.59	69'200	54.15
181	Jersey	1'672	190.00
182	Korea (Rep.)	5'433'591	1'130.06	31'580.0	6'567.92	26'201	54.49
183	Kuwait	2'791	10.76	600.0	2'312.14	450	17.34
184	Luxembourg	51'649	1'125.25	270.8	5'900.00	296	64.49
185	Macao, China	81	1.73	150.0	3'211.99	130	27.84
186	Malta	6'669	168.41	120.0	3'030.30	126	31.82
187	Martinique	318	8.11	80.0	2'039.67	80	20.40
188	Neth. Antilles	124	5.57
189	Netherlands	5'410'760	3'334.42	10'000.0	6'162.57	11'110	68.47
190	New Caledonia	5'920	255.17	70.0	3'017.24
191	New Zealand	587'678	1'504.94	3'200.0	8'194.62	1'924	49.27
192	Norway	873'272	1'918.44	1'792.0	3'936.73	2'630	57.78
193	Portugal	581'583	577.43	2'951.0	2'929.90	1'402	13.92
194	Puerto Rico	85	0.22	677.0	1'754.57
195	Qatar	315	5.09	165.0	2'665.59	133	21.49
196	Réunion	20	0.26	180.0	2'380.95	53	7.13
197	Singapore	503'099	1'165.93	2'421.8	5'612.47	3'939	91.29
198	Slovenia	53'421	269.67	950.0	4'795.56	704	35.54
199	Spain	939'376	228.40	14'332.8	3'484.93	10'957	26.64
200	Sweden	1'321'676	1'466.67	6'800.0	7'546.00	6'861	76.14
201	Switzerland	761'283	1'062.80	4'717.0	6'585.23	6'105	85.23
202	Taiwan, China	3'153'004	1'385.21	12'210.0	5'364.20	11'924	52.39
203	United Arab Emirates	26'570	61.11	1'384.8	3'185.00	450	11.99
204	United Kingdom	2'130'786	358.55	37'600.0	6'326.98	35'890	60.39
205	United States	195'138'696	6'569.38	185'000.0	6'228.05	220'000	74.06
206	Virgin Islands (US)	3'783	341.73	30.0	2'727.27
High income		254'019'144	2'592.68	546'553.4	5'578.47	566'575	57.83
WORLD		265'491'449	414.92	875'139.1	1'367.72	776'205	12.13
Africa		424'964	4.89	22'373.0	257.50	13'580	1.56
Americas		205'497'569	2'338.51	268'565.8	3'056.21	290'631	33.07
Asia/Pacific		27'987'521	73.26	311'291.4	814.78	225'770	5.91
Europe		27'010'784	338.36	256'506.4	3'213.19	230'057	28.82
Oceania		4'570'611	1'423.56	16'583.5	5'166.04	16'167	50.35

Note: For data comparability and coverage, see the technical notes.

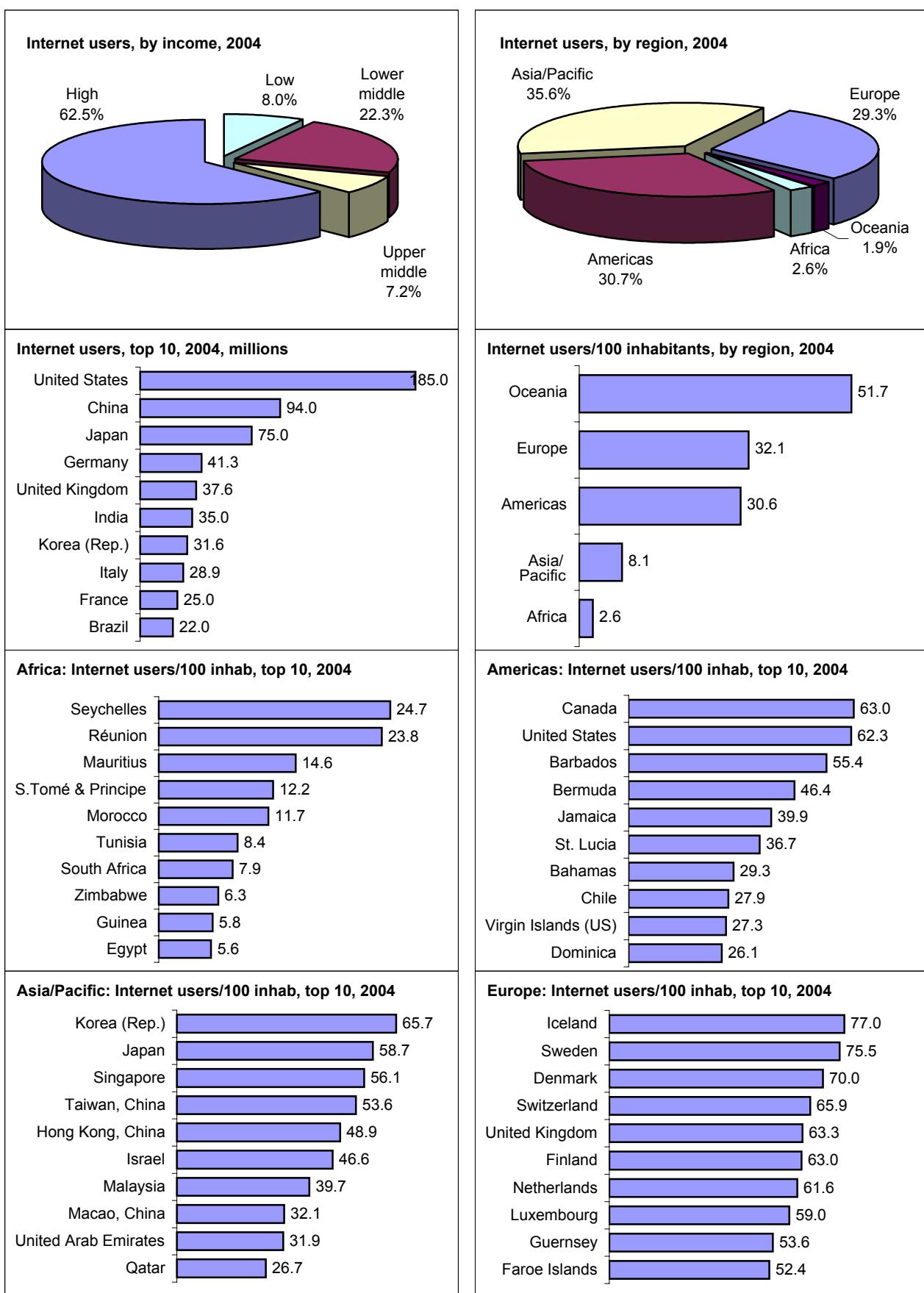
Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

6. Information technology: Internet users



6. Information technology: Internet users



* Penetration = subscribers per 100 inhabitants

7. Broadband subscribers

	DSL	Cable modem	Other	Total broadband subscribers	
				Total	Per 100 inhabitants
	2004	2004	2004	2004	2004
1	Afghanistan	-	200	...	200
2	Angola
3	Azerbaijan
4	Bangladesh	-	-	-	...
5	Benin	47	17	...	64
6	Bhutan	-	-
7	Burkina Faso	80	74	-	154
8	Burundi
9	Cambodia	350	...	69	419
10	Cameroon
11	Central African Rep.
12	Chad
13	Comoros
14	Congo
15	Cote d'Ivoire
16	D.P.R.Korea
17	D.R. Congo
18	Equatorial Guinea
19	Eritrea
20	Ethiopia	57	57
21	Gambia
22	Georgia	400	1'010	...	1'410
23	Ghana
24	Guinea
25	Guinea-Bissau
26	Haiti
27	India	105'000	130'000	...	235'000
28	Indonesia	31'300	7'000	...	38'300
29	Kenya	-	-
30	Kyrgyzstan
31	Lao P.D.R.	550	550
32	Lesotho
33	Liberia
34	Madagascar	-	-
35	Malawi	-	138	...	138
36	Mali	-	-
37	Mauritania	-
38	Moldova	1'415	969	...	2'384
39	Mongolia	370	50	80	500
40	Mozambique
41	Myanmar	7'000	-	-	7'000
42	Nepal
43	Nicaragua	96	4'805	...	4'901
44	Niger	...	77	...	77
45	Nigeria
46	Pakistan	687'000	687'000
47	Papua New Guinea
48	Rwanda
49	S.Tomé & Principe
50	Senegal	2'100	2'100
51	Sierra Leone
52	Solomon Islands	205	205
53	Somalia
54	Sudan	1'400	-	-	1'400
55	Tajikistan	...	10	...	10
56	Tanzania
57	Togo
58	Uganda
59	Uzbekistan	1'690	1'690
60	Vietnam	7'228	1'067	...	8'295
61	Yemen	...	-
62	Zambia	91	91
63	Zimbabwe	-
Low income		846'379	145'417	149	991'945
					0.0

7. Broadband subscribers

		DSL	Cable modem	Other	Total broadband subscribers	
					Total	Per 100 inhabitants
		2004	2004	2004	2004	2004
64	Albania
65	Algeria	...	25'000	-	25'000	0.1
66	Armenia	1'000	1'000	0.0
67	Belarus	123	123	0.0
68	Bolivia
69	Bosnia
70	Brazil	1'883'000	161'000	212'000	2'256'000	1.2
71	Bulgaria	1'291	1'291	0.0
72	Cape Verde	283	...	-	283	...
73	China	16'935'000	8'850'000	...	25'785'000	2.0
74	Colombia	18'403	66'881	6'000	91'284	0.2
75	Cuba	-	-	...
76	Djibouti	-
77	Dominican Rep.	33'505	2'118	...	35'623	0.4
78	Ecuador	2'079	9'541	...	11'620	0.1
79	Egypt	-	29'307	-	29'307	0.0
80	El Salvador	7'623	88'174	...	95'797	1.4
81	Fiji
82	Guatemala
83	Guyana
84	Honduras
85	Iran (I.R.)	17'703	...	1'000	18'703	0.0
86	Iraq	-	-	-
87	Jamaica
88	Jordan	10'424	-	-	10'424	0.2
89	Kazakhstan	1'997	1'997	0.0
90	Kiribati
91	Maldives	717	-	...	717	0.2
92	Marshall Islands	-	...
93	Micronesia	-	-	...	-	...
94	Morocco	62'960	-	1'700	64'660	0.2
95	Namibia	-	-
96	Palestine	-	-	-
97	Paraguay	-	500	...	500	0.0
98	Peru	111'681	26'596	...	138'277	0.5
99	Philippines	30'000	20'000	5'000	55'000	0.1
100	Romania	4'161	87'373	...	91'534	0.4
101	Russia	125'000	...	550'000	675'000	0.5
102	Samoa
103	Serbia and Montenegro
104	South Africa	60'000	60'000	0.1
105	Sri Lanka	2'929	395	93	3'417	0.0
106	St. Vincent	770	546	7	1'323	1.1
107	Suriname	409	...	156	565	0.1
108	Swaziland
109	Syria	600	-	-	600	0.0
110	TFYR Macedonia
111	Thailand	35'000	10'000	...	45'000	0.1
112	Tonga	11	11	0.0
113	Tunisia	2'839	-	-	2'839	0.0
114	Turkey	452'398	37'404	...	489'802	0.7
115	Turkmenistan
116	Ukraine
117	Vanuatu	...	23	...	23	0.0
Lower Middle Income		19'801'906	9'414'858	775'956	29'992'720	1.2

7. Broadband subscribers

		DSL 2004	Cable modem 2004	Other 2004	Total broadband subscribers	
					Total 2004	Per 100 inhabitants 2004
118	Argentina	352'133	145'380	...	497'513	1.3
119	Belize	2'486	670	...	3'156	1.2
120	Botswana
121	Chile	212'916	227'110	473'146	913'172	5.9
122	Costa Rica	5'484	22'447	...	27'931	0.7
123	Croatia	12'000	12'000	0.3
124	Czech Republic	29'373	46'309	-	75'682	0.7
125	Dominica	1'095	2'158	...	3'253	4.6
126	Estonia	68'458	43'242	...	111'700	8.5
127	Gabon	585	-	120	705	0.1
128	Grenada	609	609	0.6
129	Guadeloupe
130	Hungary	235'969	135'803	-	371'772	3.8
131	Latvia	39'299	9'848	...	49'147	2.1
132	Lebanon	-	80'000	-	80'000	2.2
133	Libya	-	-	-
134	Lithuania	50'686	32'227	...	82'913	2.4
135	Malaysia	252'501	-	...	252'501	1.0
136	Mauritius	2'708	2'708	0.2
137	Mayotte
138	Mexico	560'293	235'000	44'854	840'147	0.8
139	Northern Marianas
140	Oman	...	-	-
141	Panama	9'670	7'076	1'532	18'278	0.6
142	Poland	670'000	141'796	-	811'796	2.1
143	Saudi Arabia	19'700	-	-	19'700	0.1
144	Seychelles	-	...	99	99	0.1
145	Slovak Republic	38'334	10'854	-	49'188	0.9
146	St. Kitts and Nevis	500	500	1.1
147	St. Lucia
148	Trinidad & Tobago	4'570	4'570	0.3
149	Uruguay	27'000	27'000	0.8
150	Venezuela	150'000	59'714	...	209'714	0.8
Upper Middle Income		2'746'369	1'199'634	519'751	4'465'754	1.3

7. Broadband subscribers

		DSL	Cable modem	Other	Total broadband subscribers	
					Total	Per 100 inhabitants
		2004	2004	2004	2004	2004
151	Andorra	6'282	6'282	9.4
152	Antigua & Barbuda
153	Aruba
154	Australia	1'130'200	404'300	13'800	1'548'300	7.8
155	Austria	442'075	380'000	5'600	827'675	10.2
156	Bahamas	12'803	12'803	4.0
157	Bahrain	15'905	-	-	15'905	2.2
158	Barbados	10'000	17'319	...	27'319	10.1
159	Belgium	995'408	621'777	...	1'617'185	15.6
160	Bermuda
161	Brunei Darussalam
162	Canada	2'643'000	2'946'000	42'714	5'631'714	17.7
163	Cyprus	13'368	-	...	13'368	1.7
164	Denmark	633'459	295'041	85'000	1'013'500	18.9
165	Faroe Islands	-	...
166	Finland	684'800	115'200	-	800'000	15.3
167	France	6'300'000	454'035	...	6'754'035	11.2
168	French Guiana
169	French Polynesia	900	...	46	946	0.4
170	Germany	6'709'683	145'000	50'476	6'905'159	8.4
171	Greece	46'547	-	1'888	48'435	0.4
172	Greenland
173	Guam
174	Guernsey
175	Hong Kong, China	762'091	291'000	460'012	1'513'103	21.3
176	Iceland	50'612	670	1'982	53'264	18.3
177	Ireland	115'583	8'045	11'220	134'848	3.4
178	Israel	720'000	350'000	...	1'070'000	16.3
179	Italy	4'402'585	20	298'647	4'701'252	8.2
180	Japan	13'325'408	2'873'076	2'898'688	19'097'172	14.9
181	Jersey
182	Korea (Rep.)	6'777'398	4'079'204	1'064'837	11'921'439	24.9
183	Kuwait	20'000	-	-	20'000	0.8
184	Luxembourg	40'000	4'081	64	44'145	9.6
185	Macao, China	45'218	45'218	9.7
186	Malta	13'000	9'735	...	22'735	5.7
187	Martinique	6'000	6'000	1.5
188	Neth. Antilles
189	Netherlands	1'876'000	1'330'000	-	3'206'000	19.8
190	New Caledonia	5'146	5'146	2.2
191	New Zealand	168'272	10'123	13'300	191'695	4.9
192	Norway	562'000	93'000	25'000	680'000	14.9
193	Portugal	420'631	434'958	2'829	858'418	8.5
194	Puerto Rico	21'661	1'071	...	22'732	0.6
195	Qatar	10'652	-	191	10'843	1.8
196	Réunion	56'536	56'536	7.4
197	Singapore	288'300	218'500	5'600	512'400	11.9
198	Slovenia	36'838	21'154	...	57'992	2.9
199	Spain	2'604'067	817'737	19'826	3'441'630	8.4
200	Sweden	849'661	229'000	224'200	1'302'861	14.7
201	Switzerland	802'000	480'000	-	1'282'000	17.9
202	Taiwan, China	3'169'202	526'209	55'803	3'751'214	16.5
203	United Arab Emirates	45'832	-	-	45'832	1.5
204	United Kingdom	4'220'000	2'027'000	8'500	6'255'500	10.5
205	United States	13'817'280	21'357'400	2'715'966	37'890'646	12.8
206	Virgin Islands (US)
High income		74'876'403	40'540'655	8'006'189	123'423'247	12.6
WORLD		98'271'057	51'300'564	9'302'045	158'873'666	2.5
<i>Africa</i>		<i>189'686</i>	<i>54'613</i>	<i>1'919</i>	<i>246'218</i>	<i>0.0</i>
<i>Americas</i>		<i>19'895'066</i>	<i>25'381'506</i>	<i>3'496'375</i>	<i>48'772'947</i>	<i>5.6</i>
<i>Asia/Pacific</i>		<i>43'328'465</i>	<i>17'437'721</i>	<i>4'491'373</i>	<i>65'257'559</i>	<i>1.7</i>
<i>Europe</i>		<i>33'553'106</i>	<i>8'012'278</i>	<i>1'285'232</i>	<i>42'850'616</i>	<i>5.4</i>
<i>Oceania</i>		<i>1'304'734</i>	<i>414'446</i>	<i>27'146</i>	<i>1'746'326</i>	<i>5.4</i>

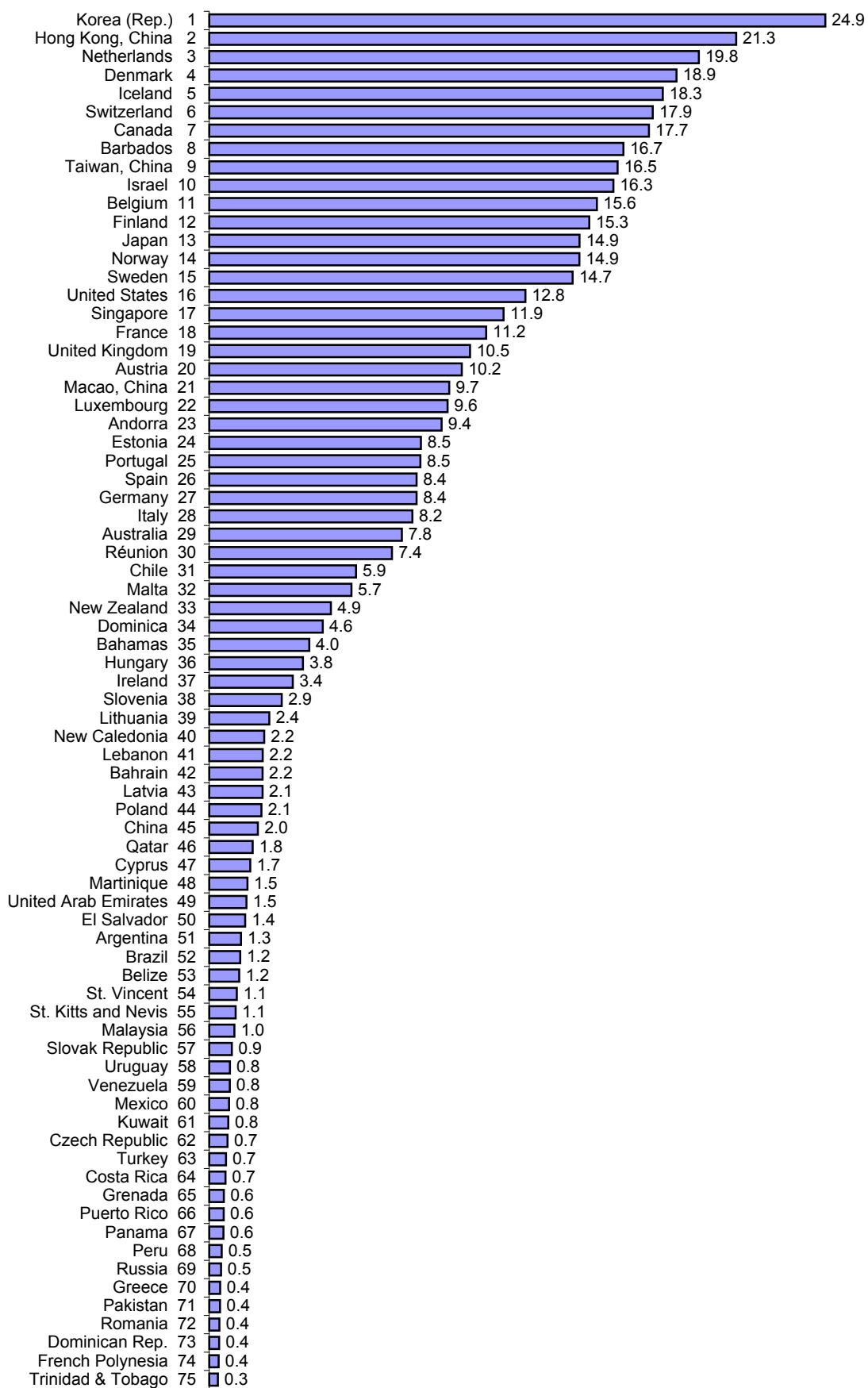
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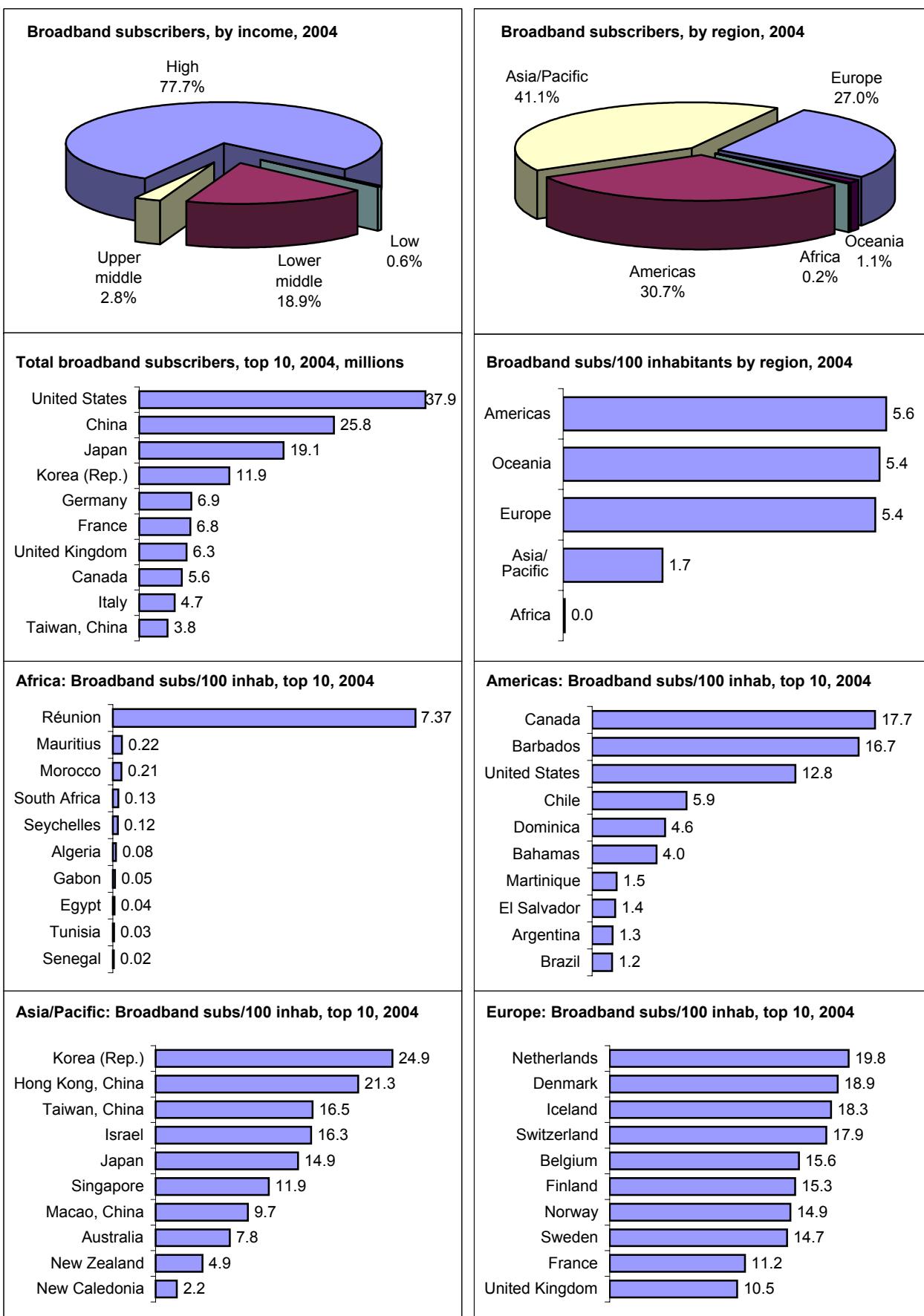
Source: ITU.

7. Broadband subscribers

Broadband penetration per 100 inhabitants, top 75, 2004



7. Broadband Subscribers



8. Broadband prices

	Lower speed		Higher speed		Lowest sampled cost		
	Monthly charge US\$	Speed Down (kbit/s)	Monthly charge US\$	Speed Down (kbit/s)	US\$ per 100 kbit/s	as a % of monthly income (GNI)	ISP
1 Afghanistan
2 Angola	871.00	256	340.23	396.39	Nexus L
3 Azerbaijan
4 Bangladesh
5 Benin	573.24	512	1'910.80	2'048	93.30	211.25	OPT L
6 Bhutan	2'173.99	512	7'848.20	2'048	383.21	605.07	DrukNet L
7 Burkina Faso	1'528.64	2'048	1'528.64	2'048	74.64	248.80	ONATEL L
8 Burundi	1'620.00	256	632.81	8437.50	CBINET L
9 Cambodia	199.00	256	1'199.00	1'024	77.73	291.50	OnlineCom L
10 Cameroon	4'469.06	512	8'469.25	1'024	827.08	1240.61	Camnet L
11 Central African Rep.
12 Chad
13 Comoros
14 Congo
15 Côte d'Ivoire	66.88	256	26.12	40.71	Aviso
16 D.P.R. Korea
17 D.R. Congo
18 Equatorial Guinea
19 Eritrea
20 Ethiopia
21 Gambia
22 Georgia	66.00	1'024	108.00	2'048	5.27	6.08	Georgia Online
23 Ghana
24 Guinea
25 Guinea-Bissau
26 Haiti
27 India	45.51	256	18.78	512	3.67	7.10	Tata Indicom
28 Indonesia	19.35	384	33.86	512	5.04	5.30	CBN
29 Kenya
30 Kyrgyzstan	100.00	256	120.00	512	23.44	70.31	EICat L
31 Lao P.D.R.	320.00	256	580.00	512	113.28	348.56	Lao Telecom L
32 Lesotho
33 Liberia
34 Madagascar
35 Malawi
36 Mali
37 Mauritania	2'058.70	256	7'431.91	1'024	725.77	2'073.64	Mauritel L
38 Moldova	80.00	768	10.42	17.61	Transtelecom
39 Mongolia	149.00	256	299.00	1'024	29.20	59.39	Micom L
40 Mozambique	1'320.00	256	2'488.00	512	485.94	2'332.50	TDM L
41 Myanmar	4'471.06	256	6'387.23	512	1'247.50	...	Bagan Net L
42 Nepal	1'374.14	256	536.77	2477.41	NTCnet L
43 Nicaragua	39.99	256	74.99	512	14.65	22.25	Terra ADSL
44 Niger
45 Nigeria
46 Pakistan	803.68	768	1'105.06	1'024	104.65	209.29	Multinet Broadband
47 Papua New Guinea
48 Rwanda
49 S. Tomé & Principe
50 Senegal	43.95	512	103.18	1'024	8.58	15.37	Sentoo
51 Sierra Leone
52 Solomon Islands
53 Somalia
54 Sudan	267.61	512	403.47	1'024	39.40	89.21	Sudatel
55 Tajikistan
56 Tanzania
57 Togo
58 Uganda	3'480.00	256	5'760.00	512	1'125.00	5000.00	Uganda Telecom L
59 Uzbekistan	292.05	256	535.42	512	104.57	272.80	Sarkor Telecom
60 Viet Nam	75.55	2'048	3.69	8.05	FPT Communications
61 Yemen	1'300.00	512	2'000.00	2'048	97.66	205.59	Yemen Net L
62 Zambia
63 Zimbabwe
Low Income	1'029.94	517	2'304.99	1'048	264.43	949.70	

8. Broadband prices

	Lower speed		Higher speed		Lowest sampled cost			ISP
	Monthly charge	Speed (kbit/s)	Monthly charge	Speed (kbit/s)	US\$ per 100 kbit/s	as a % of monthly income (GNI)		
	US\$	Down	US\$	Down				
64 Albania	37.60	256	43.87	512	8.57	4.94	Albania Online	
65 Algeria	484.65	512	888.53	1'024	86.77	45.67	Wanadoo	L
66 Armenia	463.68	256	3'338.49	2'048	163.01	174.66	Arminco	L
67 Belarus
68 Bolivia	100.00	256	200.00	512	39.06	48.83	Acelerate	
69 Bosnia	43.21	1'024	67.90	1'024	4.22	2.48	Bihnet	
70 Brazil	23.58	256	255.15	2'000	9.21	3.58	Speedy	
71 Bulgaria	38.12	256	95.30	1'024	9.31	4.08	Telecom Bulgaria	
72 Cape Verde
73 China	9.87	512	1.93	1.79	E-NET	
74 Colombia	50.52	256	19.74	11.84	ETB	
75 Cuba	85.71	256	33.48	...	Citmatel	
76 Djibouti
77 Dominican Rep.	49.83	384	12.98	7.49	Verizon	
78 Ecuador	360.00	256	880.00	512	140.63	77.41	IT Net	L
79 Egypt
80 El Salvador	59.00	512	11.52	5.88	Navegante	
81 Fiji
82 Guatemala	299.00	512	379.00	1'024	37.01	20.85	Turbonet	L
83 Guyana	21.05	640	26.25	2'048	1.28	1.55	GH&T	
84 Honduras	50.00	384	13.02	15.17	Globalnet	
85 Iran (I.R.)	75.95	256	569.56	1'024	29.67	15.48	Pars Online	
86 Iraq
87 Jamaica	50.00	512	70.00	1'024	6.84	2.83	Cable & Wireless	
88 Jordan	15.52	512	16.93	1'024	1.65	0.93	Jordan Telecom	
89 Kazakhstan	13.13	512	2.56	1.36	Almatytelecom	
90 Kiribati
91 Maldives	45.91	256	75.88	256	17.94	8.57	Dhirragu	
92 Marshall Islands
93 Micronesia
94 Morocco	44.95	512	56.21	1'024	5.49	4.33	Menara	
95 Namibia
96 Palestine
97 Paraguay	60.00	1'536	3.91	4.01	Parnet	
98 Peru	31.92	400	39.83	600	6.64	3.38	Terra ADSL	
99 Philippines	44.51	512	53.41	768	6.95	7.13	My DSL	
100 Romania	110.00	256	42.97	17.66	Astral	L
101 Russia	228.00	512	288.00	1'024	28.13	9.90	WebPlus	L
102 Samoa
103 Serbia and Montenegro
104 South Africa	98.65	384	127.47	1'024	12.45	4.11	Telkom	
105 Sri Lanka	22.18	512	66.55	2'048	3.25	3.86	Sri Lanka Telecom	
106 St. Vincent	92.22	256	370.00	1'544	23.96	7.88	Cable & Wireless	
107 Suriname	83.92	256	165.84	512	32.39	17.28	TeleSur	
108 Swaziland
109 Syria
110 TFYR Macedonia
111 Thailand	17.04	512	24.35	1'024	2.38	1.12	Internet East	
112 Tonga	2'028.81	256	792.50	519.67	Tonga	L
113 Tunisia	42.23	256	153.56	384	16.50	7.53	Hexabyte Internet	
114 Turkey	60.76	512	156.54	2'048	7.64	2.45	Superonline	
115 Turkmenistan
116 Ukraine	26.60	512	105.52	2'048	5.15	4.91	Ukrtelecom	
117 Vanuatu
Lower Middle Income	149.12	438	327.47	1'119	45.58	30.59		

8. Broadband prices

	Lower speed		Higher speed		Lowest sampled cost		
	Monthly charge US\$	Speed (kbit/s) Down	Monthly charge US\$	Speed (kbit/s) Down	US\$ per 100 kbit/s	as a % of monthly income (GNI)	ISP
118 Argentina	69.69	512	109.17	1'024	10.66	3.44	Millicom
119 Belize
120 Botswana	234.06	6'144	278.05	9'216	3.02	0.83	Mweb L
121 Chile	48.41	256	18.91	4.62	Entel Internet
122 Costa Rica	46.32	256	98.31	1'024	9.60	2.47	Grupoice
123 Croatia	33.48	768	62.08	1'536	4.04	0.74	Tcom
124 Czech Republic	40.90	1'024	189.43	4'096	3.99	0.52	Contactel
125 Dominica
126 Estonia	27.63	512	39.64	1'000	3.96	0.68	Elion
127 Gabon
128 Grenada	140.37	768	258.89	1'544	16.77	5.35	Xnet
129 Guadeloupe	25.07	512	37.60	2'048	1.84	...	France Telecom
130 Hungary	66.24	512	86.77	768	11.30	1.64	Online Aruhaz
131 Latvia	231.02	512	311.55	2'048	15.21	3.34	Vernet L
132 Lebanon
133 Libya
134 Lithuania	14.16	256	5.53	1.16	Lietuvos Telekomas
135 Malaysia	20.45	512	26.30	1'024	2.57	0.66	TMNET
136 Mauritius	53.27	512	217.76	1'024	10.40	2.69	Telecom Plus
137 Mayotte
138 Mexico	93.50	512	430.42	2'000	18.26	3.24	Prodigy
139 Northern Marianas
140 Oman	46.75	256	101.30	384	18.26	2.78	Omantel
141 Panama	50.00	256	80.00	512	15.63	4.21	Inter.net
142 Poland	78.83	1'024	43.85	1'024	4.28	0.84	TP
143 Saudi Arabia	79.72	256	31.14	3.58	Sahara DSL
144 Seychelles	443.46	256	620.84	512	121.26	17.99	Atlas
145 Slovak Republic	22.76	1'024	28.98	1'024	2.22	0.41	Slovak Telecom
146 St. Kitts and Nevis	73.70	256	295.93	1'544	19.17	3.03	Cable & Wireless
147 St. Lucia	73.70	512	221.85	1'544	14.37	4.00	Cable & Wireless
148 Trinidad & Tobago	487.00	512	73.38	256	28.66	4.01	TSTT L
Uruguay	20.26	256	80.38	384	7.91	2.40	Netgate
150 Venezuela	46.47	384	163.21	1'536	10.63	3.17	Cantv
Upper Middle Income	98.74	714	167.64	1'612	15.75	3.11	

8. Broadband prices

	Lower speed		Higher speed		Lowest sampled cost		
	Monthly charge	Speed (kbit/s)	Monthly charge	Speed (kbit/s)	US\$ per 100 kbit/s	as a % of monthly income (GNI)	ISP
	US\$	Down	US\$	Down			
151 Andorra	51.39	512	175.48	2'048	8.57	...	Asta ADSL
152 Antigua & Barbuda	92.22	256	370.00	1'024	36.02	4.32	Cable & Wireless
153 Aruba	55.93	384	89.83	640	14.04	...	Setar
154 Australia	22.91	256	53.55	1'500	3.57	0.16	Bigpond
155 Austria	50.01	768	6.51	0.24	AON kundenbereich
156 Bahamas	34.83	384	54.73	1'024	5.34	0.43	Batelnet
157 Bahrain	119.35	256	132.61	512	25.90	2.50	Batelco
158 Barbados	68.64	512	162.47	1'024	13.41	1.74	CaribSurf
159 Belgium	37.60	512	50.14	4'096	1.22	0.05	Belgaocom
160 Bermuda	99.00	1'536	89.00	1'536	5.79	...	BTC
161 Brunei Darussalam	98.87	256	140.07	384	36.48	...	E Speed
162 Canada	37.85	3'000	42.05	4'000	1.05	0.04	Bell
163 Cyprus	32.83	1'024	98.49	1'536	3.21	0.22	I - choice
164 Denmark	57.15	1'024	67.06	2'048	3.27	0.10	Tele2
165 Faroe Islands	47.06	256	100.01	512	18.38	...	Tele.fo
166 Finland	55.15	2'048	60.16	8'192	0.73	0.03	Sonera
167 France	37.60	1'024	37.60	1'024	3.67	0.15	Free
168 French Guiana	50.14	1'024	50.14	2'048	2.45	...	Wanadoo
169 French Polynesia	136.44	256	293.70	512	53.30	...	Manal L
170 Germany	25.07	2'048	31.33	6'016	0.52	0.02	Freenet.de
171 Greece	73.95	512	110.30	1'024	10.77	0.78	Forthnet.ADSL
172 Greenland	75.64	512	14.77	...	TelePost
173 Guam	800.00	256	1'600.00	512	312.50	...	Kuentos L
174 Guernsey	54.55	500	10.91	...	Cable & Wireless
175 Hong Kong, China	25.49	640	51.24	6'144	0.83	0.04	Netvigator
176 Iceland	11.51	2'048	12.21	6'144	0.20	0.01	Vodafone
177 Ireland	37.60	1'024	3.67	0.13	Eircosm
178 Israel	23.62	256	64.91	2'000	3.25	0.22	Actcom
179 Italy	25.01	640	46.31	4'000	1.16	0.05	Libero
180 Japan	32.89	12'288	36.53	51'200	0.07	0.00	Yahoo BB
181 Jersey	92.13	1'024	156.61	2'048	7.65	...	Jersey Telecom
182 Korea (Rep.)	35.95	13'000	40.68	50'000	0.08	0.01	Hanaro
183 Kuwait	109.57	512	325.28	1'536	21.18	1.41	Qualitynet
184 Luxembourg	47.38	1'024	89.12	3'072	2.90	0.06	Cegecom
185 Macao, China	23.76	2'048	57.59	3'072	1.16	...	CyberCTM
186 Malta	50.98	256	58.12	512	11.35	1.11	Malta Online
187 Martinique	50.14	512	9.79	...	OOL
188 Neth. Antilles
189 Netherlands	31.33	2'048	30.08	4'096	0.73	0.03	Internet Access
190 New Caledonia	157.68	500	384.73	1'000	31.54	...	Can'L
191 New Zealand	35.30	256	49.42	2'048	2.41	0.14	Fast ADSL
192 Norway	48.07	704	64.15	1'024	6.26	0.14	Tele2
193 Portugal	44.60	2'048	76.46	8'128	0.94	0.08	Sapo ADSL
194 Puerto Rico	40.00	256	15.63	...	Coqui.Net
195 Qatar	82.39	1'024	109.86	2'048	5.36	...	barQ ADSL
196 Réunion	75.20	512	14.69	...	Agence France
197 Singapore	89.65	512	47.82	3'000	1.59	0.08	StarHub
198 Slovenia	30.85	1'024	68.97	4'096	1.68	0.14	AMIS
199 Spain	45.12	512	8.81	0.50	Terra
200 Sweden	39.05	8'192	60.68	24'000	0.25	0.01	Bredbandsbolaget
201 Switzerland	56.11	1'200	80.51	2'400	3.35	0.08	Bluewin
202 Taiwan, China	13.50	2'048	22.40	12'288	0.18	0.02	Chunghwa
203 United Arab Emirates	122.51	1'024	176.96	2'048	8.64	...	EIM
204 United Kingdom	27.64	2'048	42.38	2'048	1.35	0.05	Pipex
205 United States	43.00	1'536	20.00	4'096	0.49	0.01	Comcast
206 Virgin Islands (US)
High Income	69.67	1'478	130.04	5'288	14.07	0.42	
WORLD	276.27	896	575.49	2'857	69.58	211.93	
Africa	935.55	775	2'029.18	1'562	244.71	1'120.51	
Americas	86.13	561	176.37	1'348	17.80	9.51	
Asia/Pacific	342.67	1'211	779.19	4'731	82.15	145.23	
Europe	55.35	1'054	89.28	3'154	7.14	2.09	
Oceania	530.19	297	476.28	1'114	199.30	173.33	

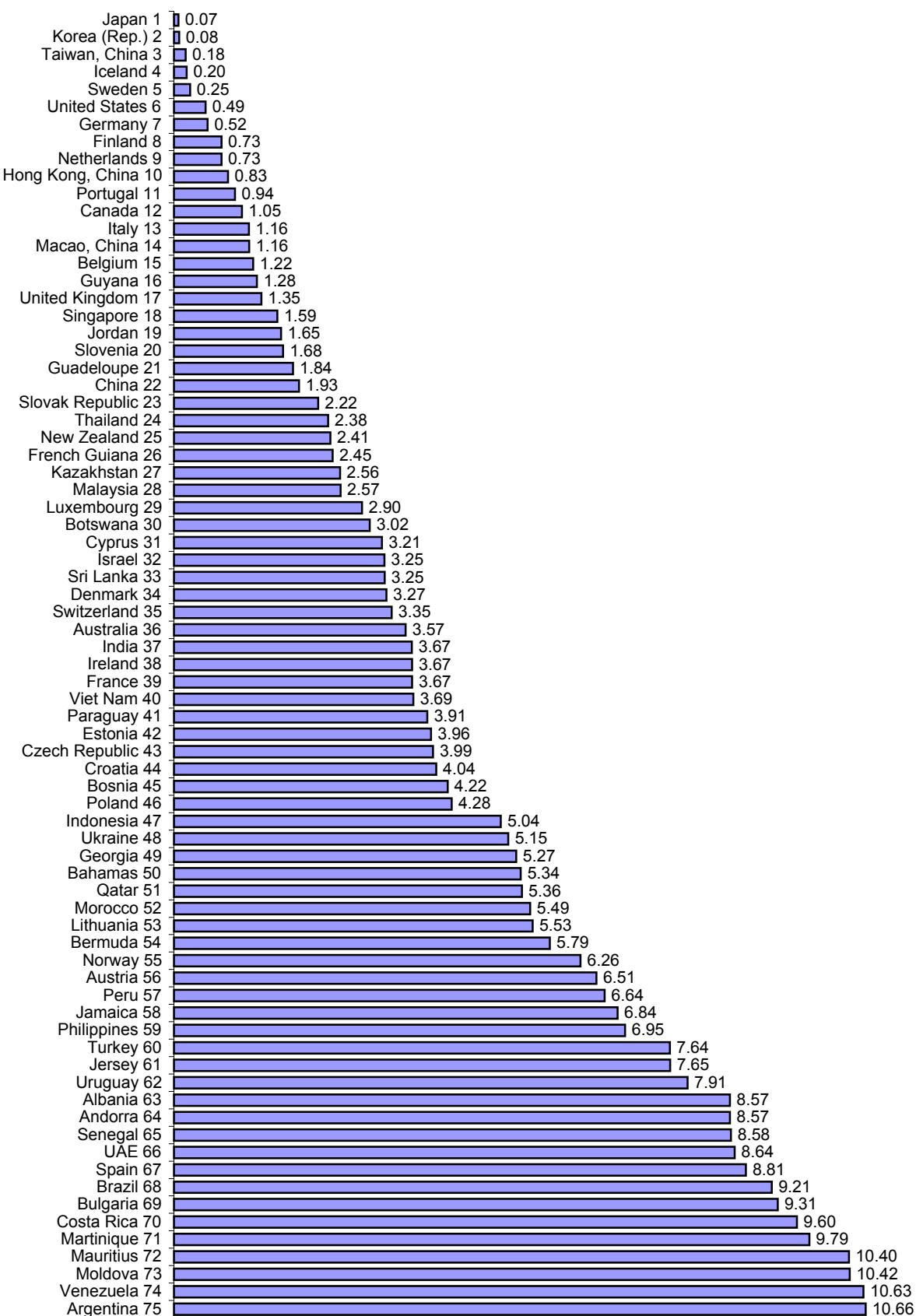
Note: Exchange rates valid 5 September 2005.

L denotes connectivity through leased lines. See technical notes for more details.

Source: ITU.

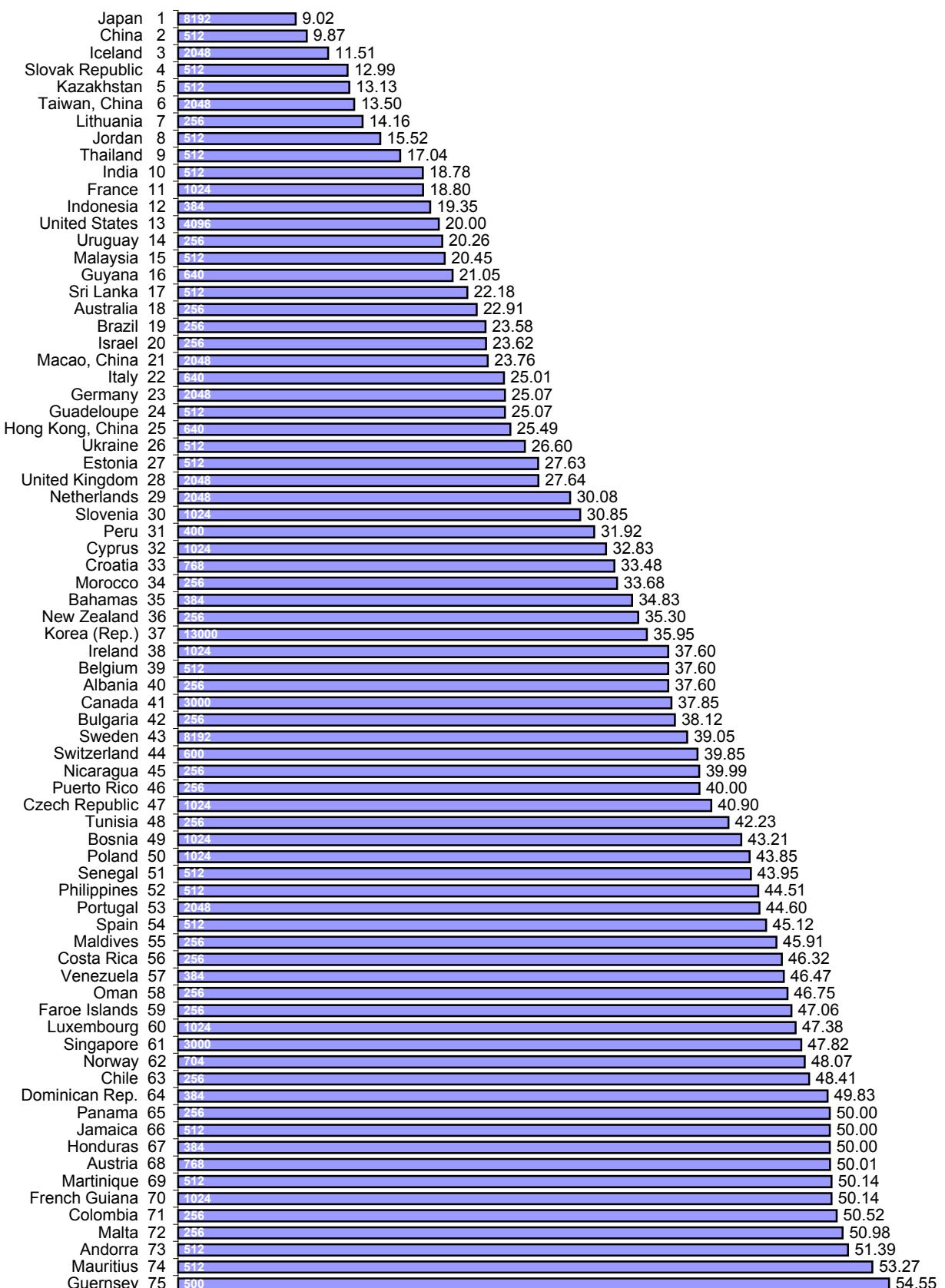
8. Broadband Prices

Broadband prices per 100 kbit/s, top 75, 2005



8. Broadband prices

Broadband subscription price, cheapest plan sampled, monthly, US\$, top 75, 2005



9. International internet bandwidth

	Total (Mbit/s)	Bits per inhabitant		Bits per Internet user		Simultaneous intl. 256 kbit/s links		
		2004	Rank	2004	Rank	2004	Rank	
1	Afghanistan	30.0	1.26	155	1'572.9	46	120.0	119
2	Angola	7.0	0.52	172	42.7	172	28.0	151
3	Azerbaijan	2.1	0.26	183	5.3	189	8.2	167
4	Bangladesh	134.0	0.94	166	468.4	95	536.0	94
5	Benin	47.0	7.12	121	492.8	92	188.0	106
6	Bhutan	9.3	4.19	132	486.5	93	37.1	146
7	Burkina Faso	8.0	0.63	169	157.7	145	32.0	149
8	Burundi	4.0	0.59	171	167.8	140	16.0	160
9	Cambodia	18.0	1.30	150	460.4	97	72.0	128
10	Cameroon	50.0	3.22	138	313.9	117	200.0	103
11	Central African Rep.	0.5	0.12	187	52.4	168	1.8	187
12	Chad	3.5	0.41	174	61.2	163	14.0	162
13	Comoros	0.3	0.35	177	34.1	178	1.0	188
14	Congo	1.0	0.27	182	29.1	181	4.0	181
15	Cote d'Ivoire	40.5	2.51	143	141.5	146	161.9	110
16	D.P.R.Korea
17	D.R. Congo	10.2	0.20	186	214.7	131	41.0	143
18	Equatorial Guinea	1.0	2.07	146	209.7	132	4.0	181
19	Eritrea	8.0	1.95	148	167.8	140	32.0	149
20	Ethiopia	20.0	0.29	181	185.6	136	80.0	125
21	Gambia	4.0	2.87	140	85.6	157	16.0	160
22	Georgia	30.0	6.20	124	179.1	137	120.0	119
23	Ghana	25.0	1.23	156	71.2	162	100.0	122
24	Guinea	2.0	0.24	184	45.6	171	8.0	169
25	Guinea-Bissau	0.1	0.04	190	2.6	190	0.3	190
26	Haiti	35.0	4.35	131	73.4	161	140.0	115
27	India	3'910.0	3.79	135	117.1	150	15'640.0	40
28	Indonesia	2'244.0	10.57	118	162.2	144	8'976.0	47
29	Kenya	34.0	1.10	161	23.8	185	136.0	116
30	Kyrgyzstan	19.3	3.89	134	76.9	160	77.2	126
31	Lao P.D.R.	6.5	1.18	157	326.1	113	26.0	152
32	Lesotho	1.0	0.59	170	24.9	184	4.1	179
33	Liberia	0.3	0.08	189	272.6	122	1.0	188
34	Madagascar	34.0	1.99	147	396.1	104	136.0	116
35	Malawi	4.6	0.39	175	104.6	155	18.4	157
36	Mali	18.0	1.41	149	377.5	107	72.0	128
37	Mauritania	9.5	3.34	136	711.5	77	38.0	145
38	Moldova	180.0	44.27	83	464.9	96	720.0	86
39	Mongolia	22.0	8.77	119	115.3	151	88.0	124
40	Mozambique	18.5	1.01	164	140.6	147	74.0	127
41	Myanmar	61.0	1.28	152	1'004.1	65	244.0	100
42	Nepal	18.0	0.73	168	107.9	153	72.0	128
43	Nicaragua	1'000.0	187.38	55	8'388.6	17	4'000.0	55
44	Niger	4.4	0.37	176	192.2	135	17.6	159
45	Nigeria	155.0	1.28	151	91.8	156	620.0	90
46	Pakistan	800.0	5.33	126	419.4	99	3'200.0	60
47	Papua New Guinea	6.0	1.08	163	37.0	175	24.0	153
48	Rwanda	10.3	1.27	153	283.4	121	41.1	142
49	S.Tomé & Principe	2.0	12.79	114	104.9	154	8.0	169
50	Senegal	310.0	31.44	92	674.4	80	1'240.0	77
51	Sierra Leone	0.5	0.10	188	53.5	167	2.0	184
52	Solomon Islands	0.5	1.09	162	178.3	138	2.0	184
53	Somalia	3.0	0.31	179	35.3	176	12.0	163
54	Sudan	215.0	6.57	122	197.8	134	860.0	83
55	Tajikistan	2.0	0.33	178	419.4	99	8.0	169
56	Tanzania	16.0	0.45	173	50.4	170	64.0	132
57	Togo	12.0	2.51	144	56.9	164	48.0	137
58	Uganda	60.5	2.38	145	317.4	114	242.1	101
59	Uzbekistan	32.0	1.27	154	38.1	174	128.0	118
60	Vietnam	1'892.0	24.05	100	338.0	111	7'568.0	49
61	Yemen	6.0	0.30	180	35.0	177	24.0	153
62	Zambia	12.0	1.15	159	54.5	166	48.0	137
63	Zimbabwe	14.5	1.17	158	18.5	187	57.8	136
Low income		11'624.7	7	357		46'498.7		

9. International internet bandwidth

	Total (Mbit/s)	Bits per inhabitant		Bits per Internet user		Simultaneous intl. 256 kbit/s links		
		2004	Rank	2004	Rank	2004	Rank	
64	Albania	12.0	3.94	133	167.8	140	48.0	137
65	Algeria	136.0	4.41	130	168.8	139	544.0	93
66	Armenia	36.0	12.37	115	251.7	125	144.0	114
67	Belarus	355.0	37.79	89	232.7	127	1'420.0	75
68	Bolivia	398.0	46.51	80	1'192.4	53	1'592.0	74
69	Bosnia	300.0	75.15	71	1'398.1	49	1'200.0	80
70	Brazil	27'448.5	159.32	58	1'308.3	51	109'794.0	20
71	Bulgaria	620.0	83.04	69	295.5	119	2'480.0	66
72	Cape Verde	10.0	22.22	103	419.4	99	40.0	144
73	China	74'429.0	59.43	74	830.3	71	297'716.0	13
74	Colombia	5'560.0	129.81	62	1'625.9	45	22'240.0	36
75	Cuba	87.0	8.05	120	608.2	82	348.0	96
76	Djibouti	2.1	3.02	139	238.8	126	8.2	168
77	Dominican Rep.	171.0	20.21	105	224.1	130	684.0	89
78	Ecuador	489.0	38.87	88	820.9	72	1'956.0	69
79	Egypt	1'412.0	20.17	106	379.6	106	5'648.0	52
80	El Salvador	422.0	66.90	73	753.2	75	1'688.0	72
81	Fiji	12.0	14.86	112	206.3	133	48.0	137
82	Guatemala	706.0	58.47	75	979.2	66	2'824.0	63
83	Guyana
84	Honduras	18.0	2.66	142	84.9	158	72.0	128
85	Iran (I.R.)	1'000.0	15.02	111	1'906.5	40	4'000.0	55
86	Iraq
87	Jamaica	115.5	45.26	82	113.5	152	462.0	95
88	Jordan	310.0	57.91	76	541.8	85	1'240.0	77
89	Kazakhstan	48.0	3.27	137	125.8	148	192.0	105
90	Kiribati	0.5	6.29	123	267.4	123	2.0	184
91	Maldives	9.0	28.77	93	496.7	90	36.0	147
92	Marshall Islands	1.5	28.33	95	807.4	73	6.2	178
93	Micronesia	4.5	42.51	85	471.9	94	18.0	158
94	Morocco	775.0	26.16	98	232.2	128	3'100.0	61
95	Namibia	9.0	4.69	129	125.8	148	36.0	147
96	Palestine	80.0	22.76	102	524.3	86	320.0	97
97	Paraguay	155.0	27.01	96	1'083.5	59	620.0	90
98	Peru	5'644.0	214.68	51	1'837.9	42	22'576.0	35
99	Philippines	3'214.5	41.40	87	766.1	74	12'858.0	41
100	Romania	4'033.0	189.81	54	939.8	68	16'132.0	39
101	Russia	14'365.0	105.78	66	941.4	67	57'460.0	27
102	Samoa	3.0	17.48	110	524.3	86	12.0	163
103	Serbia and Montenegro	706.0	70.38	72	616.9	81	2'824.0	63
104	South Africa	881.5	20.44	104	259.2	124	3'526.0	58
105	Sri Lanka	324.0	17.68	109	1'213.4	52	1'296.0	76
106	St. Vincent	3.0	26.43	97	393.2	105	12.0	163
107	Suriname	12.0	28.66	94	419.4	99	48.0	137
108	Swaziland	1.0	0.99	165	29.7	180	4.1	179
109	Syria	16.0	0.92	167	21.0	186	64.0	132
110	TFYR Macedonia	50.0	25.38	99	329.7	112	200.0	103
111	Thailand	3'006.0	49.67	79	452.2	98	12'024.0	44
112	Tonga	2.0	20.16	107	699.1	78	8.0	169
113	Tunisia	437.0	46.11	81	548.8	84	1'748.0	71
114	Turkey	2'890.0	41.90	86	296.5	118	11'560.0	45
115	Turkmenistan	1.0	0.21	185	29.1	181	4.0	181
116	Ukraine	814.0	17.73	108	227.6	129	3'256.0	59
117	Vanuatu	2.5	12.08	116	349.5	108	10.0	166
Lower Middle Income		151'537.1	41	573		606'148.5		

9. International internet bandwidth

		Total (Mbit/s)	Bits per inhabitant		Bits per Internet user		Simultaneous intl. 256 kbit/s links	
			2004	Rank	2004	Rank	2004	Rank
118	Argentina	12'248.0	330.40	48	2'508.4	35	48'992.0	30
119	Belize	46.0	184.81	56	1'378.1	50	184.0	107
120	Botswana	40.0	23.37	101	699.1	78	160.0	111
121	Chile	12'704.0	864.39	34	3'097.9	31	50'816.0	28
122	Costa Rica	500.0	123.36	63	524.3	86	2'000.0	68
123	Croatia	1'410.0	334.80	47	1'134.7	57	5'640.0	53
124	Czech Republic	25'000.0	2'563.50	22	5'461.3	26	100'000.0	21
125	Dominica	40.0	590.75	38	2'267.2	39	160.0	111
126	Estonia	4'600.0	3'687.65	16	7'199.2	19	18'400.0	37
127	Gabon	45.0	34.90	90	1'179.6	54	180.0	108
128	Grenada	45.0	458.12	44	5'898.2	22	180.0	108
129	Guadeloupe	2.0	4.82	128	41.9	173	8.0	169
130	Hungary	10'000.0	1'066.60	31	3'883.6	27	40'000.0	32
131	Latvia	2'248.0	1'031.15	32	2'910.1	33	8'992.0	46
132	Lebanon	200.0	56.56	77	349.5	108	800.0	84
133	Libya	6.0	1.11	160	30.7	179	24.0	153
134	Lithuania	666.0	204.08	52	721.4	76	2'664.0	65
135	Malaysia	3'193.0	134.59	61	338.9	110	12'772.0	43
136	Mauritius	180.0	153.08	59	1'048.6	63	720.0	86
137	Mayotte
138	Mexico	11'238.0	112.30	65	839.5	70	44'952.0	31
139	Northern Marianas
140	Oman	38.0	13.58	113	162.6	143	152.0	113
141	Panama	16.0	5.29	127	55.9	165	64.0	132
142	Poland	21'380.0	581.53	39	2'491.0	36	85'520.0	26
143	Saudi Arabia	750.0	31.56	91	495.9	91	3'000.0	62
144	Seychelles	6.0	77.67	70	314.6	116	24.0	153
145	Slovak Republic	12'355.0	2'396.00	23	5'692.1	24	49'420.0	29
146	St. Kitts and Nevis	2.0	44.17	84	51.9	169	7.9	177
147	St. Lucia	15.0	104.86	67	286.0	120	60.0	135
148	Trinidad & Tobago	180.0	144.41	60	1'179.6	54	720.0	86
149	Uruguay	600.0	194.12	53	925.2	69	2'400.0	67
150	Venezuela	1'337.0	53.56	78	606.2	83	5'348.0	54
Upper Middle Income		121'090.0	503		1'735		484'359.9	

9. International internet bandwidth

	Total (Mbit/s)	Bits per inhabitant		Bits per Internet user		Simultaneous intl. 256 kbit/s links		
		2004	Rank	2004	Rank	2004	Rank	
151	Andorra	188.0	2'942.3	21	19'713.2	9	752.0	85
152	Antigua & Barbuda	28.0	376.4	46	1'468.0	48	112.0	121
153	Aruba
154	Australia	22'055.6	1'161.4	28	1'779.0	43	88'222.3	25
155	Austria	54'616.0	7'052.8	11	14'684.4	11	218'464.0	17
156	Bahamas	145.0	479.6	43	1'634.9	44	580.0	92
157	Bahrain	409.0	580.3	40	2'808.6	34	1'636.0	73
158	Barbados
159	Belgium	117'535.0	11'920.3	5	29'343.9	3	470'140.0	11
160	Bermuda
161	Brunei Darussalam	60.0	171.9	57	1'123.5	58	240.0	102
162	Canada	217'521.0	7'185.4	10	11'404.4	13	870'084.0	6
163	Cyprus	300.0	389.8	45	1'055.6	61	1'200.0	80
164	Denmark	188'455.0	36'764.5	1	52'520.8	1	753'820.0	7
165	Faroe Islands
166	Finland	22'617.0	4'546.7	15	7'217.2	18	90'468.0	24
167	France	505'924.3	8'778.2	8	21'220.0	8	2'023'697.0	4
168	French Guiana	2.0	12.0	117	83.9	159	8.0	169
169	French Polynesia	24.0	101.5	68	412.6	103	96.0	123
170	Germany	566'056.0	7'192.3	9	14'384.6	12	2'264'224.0	3
171	Greece	6'513.0	622.2	37	3'493.3	28	26'052.0	34
172	Greenland
173	Guam
174	Guernsey
175	Hong Kong, China	32'987.1	4'861.5	14	9'940.4	15	131'948.5	19
176	Iceland	68.0	245.0	50	316.1	115	272.0	98
177	Ireland	24'587.0	6'446.9	12	23'878.2	6	98'348.0	23
178	Israel	3'203.8	512.1	42	1'049.8	62	12'815.0	42
179	Italy	90'506.6	1'654.9	25	3'287.3	29	362'026.2	12
180	Japan	132'608.4	1'088.0	30	1'854.0	41	530'433.6	9
181	Jersey
182	Korea (Rep.)	71'380.0	1'560.9	26	2'370.1	38	285'520.0	15
183	Kuwait	287.0	116.0	64	501.6	89	1'148.0	82
184	Luxembourg	1'487.0	3'397.0	18	5'757.9	23	5'948.0	51
185	Macao, China	886.0	1'989.4	24	6'193.6	20	3'544.0	57
186	Malta	310.0	820.9	35	1'079.9	60	1'240.0	77
187	Martinique	2.0	5.4	125	26.2	183	8.0	169
188	Neth. Antilles
189	Netherlands	334'578.0	21'620.2	2	35'083.0	2	1'338'312.0	5
190	New Caledonia	68.0	307.3	49	1'018.6	64	272.0	98
191	New Zealand	4'575.0	1'228.5	27	1'499.1	47	18'300.0	38
192	Norway	43'019.0	9'909.6	7	25'172.3	4	172'076.0	18
193	Portugal	8'746.0	910.5	33	3'107.7	30	34'984.0	33
194	Puerto Rico
195	Qatar	465.0	787.7	36	2'955.1	32	1'860.0	70
196	Réunion	2.0	2.7	141	11.7	188	8.0	169
197	Singapore	24'704.0	6'003.2	13	10'696.2	14	98'816.0	22
198	Slovenia	2'167.0	1'147.0	29	2'391.9	37	8'668.0	48
199	Spain	120'461.0	3'071.2	20	8'812.8	16	481'844.0	10
200	Sweden	157'636.0	18'601.5	3	24'307.8	5	630'544.0	8
201	Switzerland	71'464.0	10'461.5	6	15'886.2	10	285'856.0	14
202	Taiwan, China	71'333.0	3'286.1	19	6'126.0	21	285'332.0	16
203	United Arab Emirates	1'517.0	521.4	41	1'148.7	56	6'068.0	50
204	United Kingdom	781'553.5	13'790.1	4	21'795.7	7	3'126'214.0	2
205	United States	970'953.0	3'427.5	17	5'503.3	25	3'883'812.0	1
206	Virgin Islands (US)
	High income	4'654'003.2	4'623.4		9'024.9		18'616'012.7	
	WORLD	4'938'255.0	1'293.6		2'922.3		19'753'019.9	
	Africa	5'109.6	10.0		228.6		20'438.4	
	Americas	1'269'888.0	446.3		1'746.4		5'083'191.9	
	Asia/Pacific	435'735.9	507.4		1'393.0		1'798'128.6	
	Europe	3'200'771.3	4'508.4		9'022.3		12'803'085.3	
	Oceania	26'750.1	263.1		682.8		107'000.5	

Note: For data comparability and coverage, see the technical notes.

Figures in italics are estimates or refer to years other than those specified.

Source: ITU.

10. Fixed telephone lines

	Fixed telephone lines			Fixed telephone lines per 100 inhabitants		
	(k)	CAGR		2000	2004	CAGR
		(%)	2000-04			
1	Afghanistan	29.0	36.7	8.2	0.13	0.18
2	Angola	69.7	96.3	11.4	0.53	0.67
3	Azerbaijan	801.2	983.6	5.3	10.22	11.64
4	Bangladesh	491.3	827.0	13.9	0.38	0.55
5	Benin	51.6	72.8	9.0	0.81	1.05
6	Bhutan	14.1	29.6	20.3	2.15	1.27
7	Burkina Faso	53.2	81.4	11.2	0.47	0.61
8	Burundi	20.0	23.9	6.1	0.30	0.34
9	Cambodia	30.9	36.4	5.6	0.24	0.26
10	Cameroon	95.0	95.2	0.1	0.63	0.59
11	Central African Rep.	9.5	10.0	1.4	0.26	-0.6
12	Chad	10.3	12.4	6.7	0.14	0.15
13	Comoros	6.8	13.2	25.1	0.98	1.66
14	Congo	22.0	7.0	-31.7	0.75	0.20
15	Cote d'Ivoire	263.7	238.0	-3.4	1.78	1.43
16	D.P.R.Korea	500.0	980.0	25.1	2.15	4.10
17	D.R. Congo	9.8	10.0	1.0	0.02	0.02
18	Equatorial Guinea	6.1	9.6	16.3	1.35	1.77
19	Eritrea	30.6	39.3	6.5	0.84	0.91
20	Ethiopia	231.9	435.0	23.3	0.37	0.63
21	Gambia	33.3	38.4	7.3	2.65	2.89
22	Georgia	508.8	683.2	7.7	10.14	13.47
23	Ghana	212.5	313.3	10.2	1.08	1.47
24	Guinea	24.3	26.2	2.5	0.32	0.34
25	Guinea-Bissau	11.1	10.6	-1.7	0.93	0.82
26	Haiti	72.5	140.0	17.9	0.89	1.66
27	India	32'436.1	43'960.0	7.9	3.20	4.07
28	Indonesia	6'662.6	9'990.0	10.7	3.23	4.49
29	Kenya	291.7	299.3	0.6	0.95	0.92
30	Kyrgyzstan	376.1	396.2	1.7	7.71	7.87
31	Lao P.D.R.	40.9	75.0	16.4	0.78	1.30
32	Lesotho	22.2	37.2	13.8	1.03	2.07
33	Liberia	6.7	6.9	1.5	0.21	0.21
34	Madagascar	55.0	59.6	2.7	0.36	0.36
35	Malawi	46.4	93.0	19.0	0.45	0.75
36	Mali	39.2	74.9	17.6	0.38	0.68
37	Mauritania	19.0	38.2	26.3	0.74	1.39
38	Moldova	583.8	863.4	10.3	16.04	20.25
39	Mongolia	117.5	138.1	5.5	4.95	5.62
40	Mozambique	85.7	77.6	-3.3	0.50	0.42
41	Myanmar	271.4	424.9	11.9	0.54	0.79
42	Nepal	266.9	400.2	10.7	1.20	1.56
43	Nicaragua	164.5	214.5	6.9	3.24	3.83
44	Niger	20.0	24.1	4.8	0.19	0.19
45	Nigeria	553.4	1'027.5	16.7	0.49	0.81
46	Pakistan	3'053.5	4'880.0	12.4	2.20	3.10
47	Papua New Guinea	64.8	62.0	-2.2	1.26	1.13
48	Rwanda	17.6	23.2	14.9	0.23	0.28
49	S.Tomé & Principe	4.6	7.0	14.7	3.10	4.59
50	Senegal	205.9	228.8	3.6	2.16	2.21
51	Sierra Leone	19.0	24.0	12.4	0.39	0.48
52	Solomon Islands	7.7	6.2	-6.7	1.83	1.31
53	Somalia	35.0	100.0	69.0	0.36	1.01
54	Sudan	386.8	1'028.9	27.7	1.24	2.98
55	Tajikistan	218.5	245.2	3.9	3.57	3.75
56	Tanzania	173.6	149.1	-4.9	0.53	0.42
57	Togo	42.8	60.6	12.3	0.92	1.21
58	Uganda	61.7	71.6	3.8	0.27	0.27
59	Uzbekistan	1'655.0	1'717.1	1.2	6.71	6.70
60	Vietnam	2'542.7	10'124.9	41.3	3.19	12.28
61	Yemen	346.7	798.1	23.2	1.89	3.85
62	Zambia	83.3	88.4	2.0	0.81	0.79
63	Zimbabwe	249.4	317.0	6.2	2.19	2.45
Low income		54'836.9	83'381.8	9.9	1.90	2.47
						7.0

10. Fixed telephone lines

		Fixed telephone lines			Fixed telephone lines per 100 inhabitants		
		(k)		CAGR			CAGR
		2000	2004	(%)	2000	2004	(%)
64	Albania	152.7	255.0	18.6	4.93	8.30	18.9
65	Algeria	1'761.3	2'199.6	7.7	5.80	6.93	6.1
66	Armenia	533.4	582.5	2.2	14.03	19.09	8.0
67	Belarus	2'751.9	3'071.3	3.7	27.55	31.11	4.1
68	Bolivia	510.8	625.4	5.2	6.22	6.97	2.9
69	Bosnia	780.0	938.0	6.3	20.63	24.48	5.9
70	Brazil	30'926.3	42'382.2	8.2	18.21	23.46	6.5
71	Bulgaria	2'881.8	2'770.2	-1.0	35.36	35.38	-
72	Cape Verde	54.6	73.4	7.7	12.57	15.56	5.5
73	China	144'829.0	312'443.0	21.2	11.18	23.79	20.8
74	Colombia	7'192.8	8'768.1	5.1	17.00	19.52	3.5
75	Cuba	488.6	768.2	12.0	4.36	6.78	11.7
76	Djibouti	9.7	11.1	3.4	1.54	1.63	1.5
77	Dominican Rep.	894.2	936.2	1.2	11.19	10.65	-1.2
78	Ecuador	1'224.4	1'612.3	7.1	9.68	12.22	6.0
79	Egypt	5'483.6	9'464.1	14.6	8.64	13.52	11.8
80	El Salvador	625.3	887.8	9.2	9.96	13.42	7.7
81	Fiji	86.4	102.0	5.7	10.66	12.35	5.0
82	Guatemala	676.6	1'132.1	13.7	5.94	8.94	10.8
83	Guyana	68.4	102.7	10.7	7.94	13.39	13.9
84	Honduras	298.7	371.4	5.6	4.76	5.31	2.7
85	Iran (I.R.)	9'486.3	14'571.1	15.4	14.90	21.97	13.8
86	Iraq	675.0	675.0	0.0	2.94	2.78	-2.7
87	Jamaica	507.1	500.0	-0.4	19.53	18.68	-1.1
88	Jordan	620.0	617.3	-0.1	12.30	11.00	-2.8
89	Kazakhstan	1'834.2	2'500.0	8.0	11.31	16.23	9.5
90	Kiribati	3.4	4.5	15.5	3.96	5.11	13.6
91	Maldives	24.4	31.5	6.6	9.05	9.60	1.5
92	Marshall Islands	4.0	4.5	3.7	7.75	8.27	2.2
93	Micronesia	9.6	11.1	7.3	8.41	10.33	10.8
94	Morocco	1'425.0	1'308.6	-2.1	4.96	4.38	-3.1
95	Namibia	110.2	127.9	3.8	6.19	6.36	0.7
96	Palestine	272.2	357.3	7.0	8.64	9.70	2.9
97	Paraguay	282.9	280.0	-0.3	5.15	4.73	-2.7
98	Peru	1'717.1	2'049.8	4.5	6.69	7.44	2.7
99	Philippines	3'061.4	3'437.5	2.9	4.00	4.16	1.0
100	Romania	3'899.2	4'389.1	3.0	17.38	19.70	3.2
101	Russia	32'070.0	36'993.0	4.9	21.83	25.27	5.0
102	Samoa	8.5	13.3	16.0	4.82	7.29	14.8
103	Serbia and Montenegro	2'406.2	2'685.4	2.8	22.61	25.53	3.1
104	South Africa	4'961.7	4'821.0	-1.0	11.36	10.40	-2.9
105	Sri Lanka	767.4	991.2	6.6	4.16	5.14	5.5
106	St. Vincent	24.9	19.0	-6.5	21.96	15.72	-8.0
107	Suriname	75.3	81.3	1.9	17.35	18.52	1.6
108	Swaziland	31.9	46.2	13.2	3.16	4.43	11.9
109	Syria	1'675.2	2'660.0	12.3	10.35	14.60	9.0
110	TFYR Macedonia	507.3	525.0	1.1	25.07	25.19	0.2
111	Thailand	5'591.1	6'724.0	4.7	9.23	10.59	3.5
112	Tonga	9.7	11.2	7.5	9.84	11.29	7.1
113	Tunisia	955.1	1'203.5	5.9	9.99	12.11	4.9
114	Turkey	18'395.2	19'125.2	1.0	28.17	26.45	-1.6
115	Turkmenistan	364.4	376.1	1.1	8.17	7.73	-1.8
116	Ukraine	10'417.0	12'142.0	3.9	21.04	25.22	4.6
117	Vanuatu	6.6	6.8	0.4	3.46	3.11	-2.6
Lower Middle Income		304'430.0	508'786.0	5.9	11.55	13.37	4.7

10. Fixed telephone lines

		Fixed telephone lines			Fixed telephone lines per 100 inhabitants		
		(k)		CAGR			CAGR
		2000	2004	(%)	2000	2004	(%)
118	Argentina	7'894.2	8'700.0	2.5	21.46	22.38	1.1
119	Belize	35.8	33.8	-1.4	14.88	12.94	-3.4
120	Botswana	135.9	136.5	0.1	8.27	7.60	-2.1
121	Chile	3'302.5	3'318.3	0.1	21.71	21.53	-0.2
122	Costa Rica	898.7	1'343.2	10.6	23.50	31.62	7.7
123	Croatia	1'721.1	1'700.0	-0.4	38.48	38.87	0.3
124	Czech Republic	3'871.7	3'450.0	-2.8	37.69	33.74	-2.7
125	Dominica	22.7	21.0	-2.0	29.43	29.53	0.1
126	Estonia	522.8	444.0	-4.0	36.33	33.95	-1.7
127	Gabon	39.0	38.7	-0.2	3.18	2.86	-2.6
128	Grenada	31.4	32.7	1.1	33.20	31.75	-1.1
129	Guadeloupe	204.9	210.0	2.5	48.02	48.73	1.5
130	Hungary	3'798.3	3'577.3	-1.5	37.25	36.39	-0.6
131	Latvia	734.7	631.0	-3.7	30.31	27.60	-2.3
132	Lebanon	576.0	630.0	2.3	17.53	17.75	0.3
133	Libya	605.0	750.0	7.4	10.79	13.56	7.9
134	Lithuania	1'187.7	820.0	-8.8	32.16	23.80	-7.3
135	Malaysia	4'634.3	4'446.3	-1.0	19.92	17.87	-2.7
136	Mauritius	280.9	353.8	5.9	23.53	28.69	5.1
137	Mayotte	10.0	10.0	-	6.75	6.24	-3.9
138	Mexico	12'331.7	18'073.2	10.0	12.47	17.22	8.4
139	Northern Marianas	21.0	21.0	-	30.87	30.87	-
140	Oman	221.8	240.3	2.0	9.23	8.19	-3.0
141	Panama	429.1	376.1	-3.2	15.11	11.85	-5.9
142	Poland	10'945.6	12'292.5	3.9	28.32	31.85	4.0
143	Saudi Arabia	2'964.7	3'695.1	5.7	14.22	14.83	1.1
144	Seychelles	20.6	21.2	0.7	25.42	26.16	0.7
145	Slovak Republic	1'698.0	1'250.4	-7.4	31.43	23.13	-7.4
146	St. Kitts and Nevis	21.9	23.5	3.6	48.58	50.00	1.5
147	St. Lucia	48.9	51.1	2.2	31.53	31.95	0.7
148	Trinidad & Tobago	316.8	321.3	0.4	24.47	24.58	0.1
149	Uruguay	929.1	1'000.0	1.9	29.02	30.85	1.5
150	Venezuela	2'536.0	3'346.5	7.2	10.49	12.78	5.1
Upper Middle Income		62'992.8	71'358.8	1.0	24.41	24.29	0.0

10. Fixed telephone lines

		Fixed telephone lines			Fixed telephone lines per 100 inhabitants		
		(k)	CAGR		2000	CAGR	
			(%)	(%)		2004	2000-04
		2000	2004	2000-04	2000	2004	2000-04
151	Andorra	34.2	45.1	9.6	43.87	53.52	6.9
152	Antigua & Barbuda	38.3	38.0	-0.2	49.95	49.35	-0.3
153	Aruba	38.1	37.1	-2.5	37.16	35.03	-5.7
154	Australia	10'350.0	10'872.0	1.2	54.04	54.60	0.3
155	Austria	3'995.0	3'763.0	-1.5	49.87	46.34	-1.8
156	Bahamas	114.3	139.9	5.2	37.50	44.14	4.2
157	Bahrain	171.0	191.6	2.9	26.94	25.92	-1.0
158	Barbados	123.8	134.0	2.7	46.29	49.68	2.4
159	Belgium	5'036.4	4'756.6	-1.4	49.07	46.01	-1.6
160	Bermuda	56.1	56.0	-0.1	86.98	86.15	-0.5
161	Brunei Darussalam	80.5	90.0	5.7	24.25	25.57	2.7
162	Canada	20'347.0	20'068.0	-0.5	66.09	63.21	-1.5
163	Cyprus	440.1	418.4	-1.3	64.81	51.84	-5.4
164	Denmark	3'835.0	3'475.0	-2.4	71.95	64.65	-2.6
165	Faroe Islands	25.0	23.0	-4.0	55.45	48.24	-6.7
166	Finland	2'848.8	2'368.0	-4.5	55.04	45.40	-4.7
167	France	33'987.1	33'870.2	-0.1	57.71	56.04	-0.7
168	French Guiana	50.0	51.0	2.0	30.70	30.22	-1.5
169	French Polynesia	53.7	53.5	-0.1	22.70	21.41	-1.9
170	Germany	50'220.0	54'550.0	2.1	61.05	66.10	2.0
171	Greece	5'659.3	5'157.5	-2.3	53.57	46.98	-3.2
172	Greenland	26.2	25.3	-1.6	46.75	44.69	-2.2
173	Guam	74.4	80.0	7.6	48.04	50.89	5.9
174	Guernsey	53.1	55.0	3.5	84.65	97.74	15.5
175	Hong Kong, China	3'925.8	3'779.7	-0.9	58.90	53.12	-2.5
176	Iceland	196.3	190.5	-0.8	69.87	65.01	-1.8
177	Ireland	1'832.0	2'019.1	2.5	48.38	50.49	1.1
178	Israel	2'974.0	3'000.0	0.2	47.44	43.72	-2.0
179	Italy	27'153.0	25'957.0	-1.1	47.39	45.26	-1.1
180	Japan	61'957.1	58'788.0	-1.3	48.82	46.00	-1.5
181	Jersey	73.0	73.9	1.3	84.11	84.79	0.8
182	Korea (Rep.)	25'863.0	26'058.1	0.2	56.24	54.19	-0.9
183	Kuwait	467.1	497.0	1.6	21.33	19.15	-2.7
184	Luxembourg	331.0	360.1	2.8	75.48	79.75	1.8
185	Macao, China	176.8	173.9	-0.4	40.93	37.24	-2.3
186	Malta	204.2	208.3	0.7	52.36	52.07	-0.2
187	Martinique	171.6	172.0	0.2	44.68	44.47	-0.5
188	Neth. Antilles	80.0	81.0	1.3	37.16	37.23	0.2
189	Netherlands	9'889.0	7'861.0	-5.6	61.86	48.44	-5.9
190	New Caledonia	51.0	53.3	1.1	23.77	22.98	-0.8
191	New Zealand	1'831.0	1'800.5	-0.4	47.46	46.11	-0.7
192	Norway	2'401.0	2'228.0	-2.5	53.31	48.64	-3.0
193	Portugal	4'226.0	4'237.7	0.1	42.16	42.07	-0.1
194	Puerto Rico	1'299.3	1'276.5	-0.9	34.11	33.08	-1.5
195	Qatar	160.2	190.9	4.5	26.38	30.84	4.0
196	Réunion	280.0	300.0	7.1	40.06	41.04	2.5
197	Singapore	1'946.5	1'864.0	-1.1	48.45	43.20	-2.8
198	Slovenia	785.4	812.3	1.1	39.47	40.68	1.0
199	Spain	17'104.0	17'752.0	0.9	42.63	43.16	0.3
200	Sweden	6'728.0	6'873.0	0.7	75.76	76.57	0.4
201	Switzerland	5'235.7	5'250.0	0.1	72.63	73.29	0.2
202	Taiwan, China	12'642.2	13'529.9	1.7	56.75	59.44	1.2
203	United Arab Emirates	1'020.1	1'187.7	3.9	31.42	27.32	-3.4
204	United Kingdom	35'228.0	33'700.0	-1.1	58.94	56.71	-1.0
205	United States	192'513.0	177'947.0	-1.9	68.41	59.91	-3.3
206	Virgin Islands (US)	68.3	69.8	1.6	62.87	63.49	1.0
High income		556'470.8	538'610.4	0.6	50.78	49.52	-0.4
WORLD		978'730.5	1'202'137.0	4.9	21.32	21.61	3.2
Africa		19'744.9	26'235.1	7.9	3.89	4.40	5.5
Americas		289'653.8	297'792.0	3.4	26.41	27.09	2.0
Asia/Pacific		339'965.7	541'150.8	7.4	15.57	16.35	4.9
Europe		316'871.7	323'952.8	0.6	45.13	44.24	0.4
Oceania		12'494.4	13'006.3	2.2	18.21	18.39	0.6

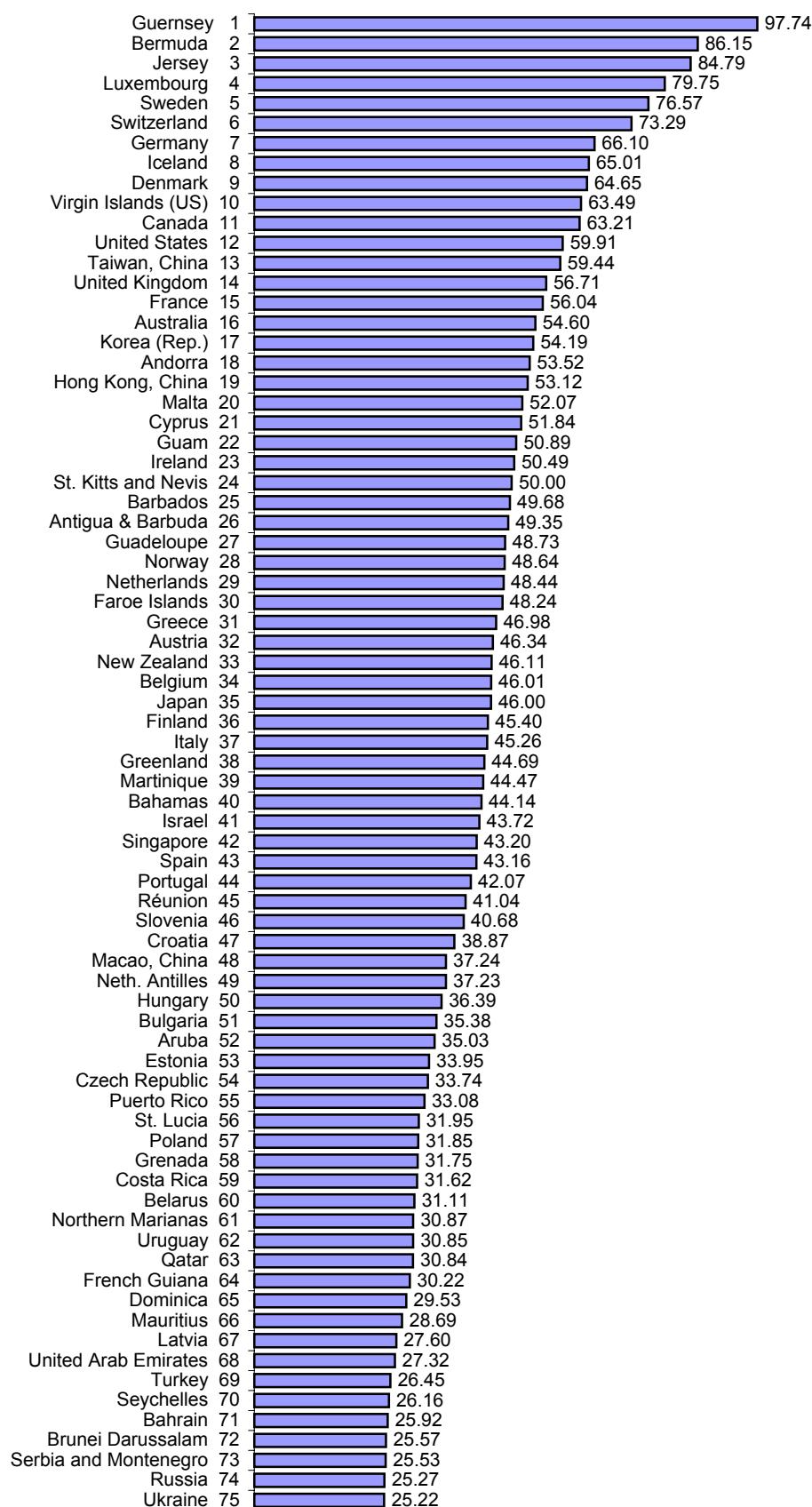
Note: For data comparability and coverage, see the technical notes.

Figures in italics are estimates or refer to years other than those specified.

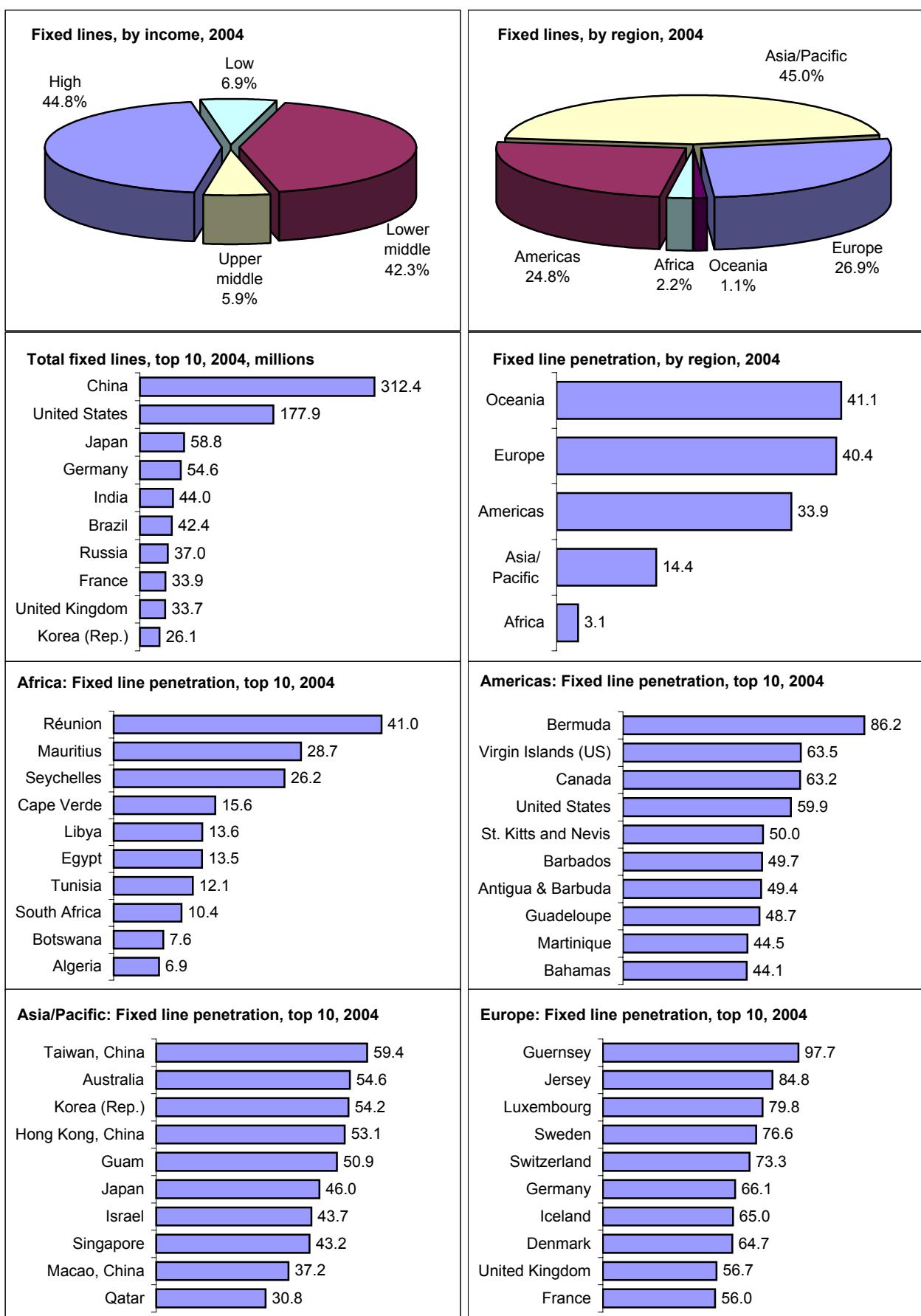
Source: ITU.

10. Fixed telephone lines

Fixed lines per 100 inhabitants, top 75, 2004



10. Fixed telephone lines



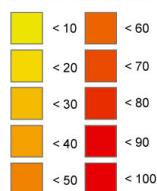
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Effective teledensity (fixed or mobile), 2004

Per 100 inhabitants



Fixed Lines, 2004
in thousands



Fixed vs Mobile, 2004



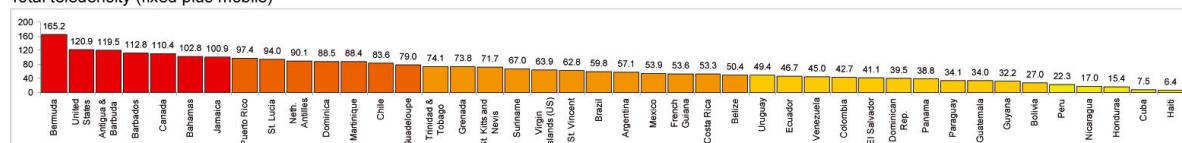
Total Americas 671.4 million

Mobile users, 2004
in thousands

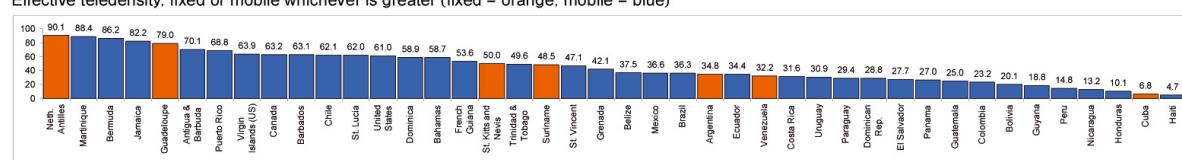
10	St. Kitts & Nevis
42	Dominica
43	Grenada
54	Antigua & Barbuda
57	St. Vincent
76	Cuba
93	St. Lucia
98	Belize
98	French Guiana
144	Guyana
171	Barbados
186	Bahamas
213	Suriname
400	Haiti
600	Uruguay
648	Trinidad & Tobago
707	Honduras
739	Nicaragua
856	Panama
923	Costa Rica
1,768	Paraguay
1,801	Bolivia
1,833	El Salvador
2,200	Jamaica
2,534	Dominican Rep.
3,168	Guatemala
4,093	Peru
4,544	Ecuador
8,421	Venezuela
9,567	Chile
10,401	Colombia
13,512	Argentina
14,984	Canada
20,068	Mexico
42,382	Brazil
65,605	United States
38,451	

Denominations and classifications employed in these maps do not imply any opinion on the part of the ITU concerning the legal or other status of any territory or any endorsement or acceptance of any boundary.

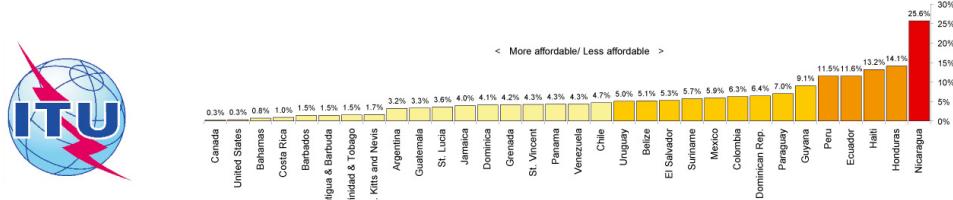
Total teledensity (fixed plus mobile)



Effective teledensity, fixed or mobile whichever is greater (fixed = orange, mobile = blue)



Mobile prices: OECD low user basket as a proportion of average monthly income (August, 2005)



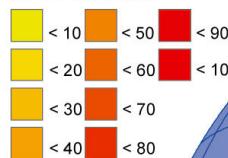
ITU Telecom Americas 2005

www.itu.int/AMERICAS2005/



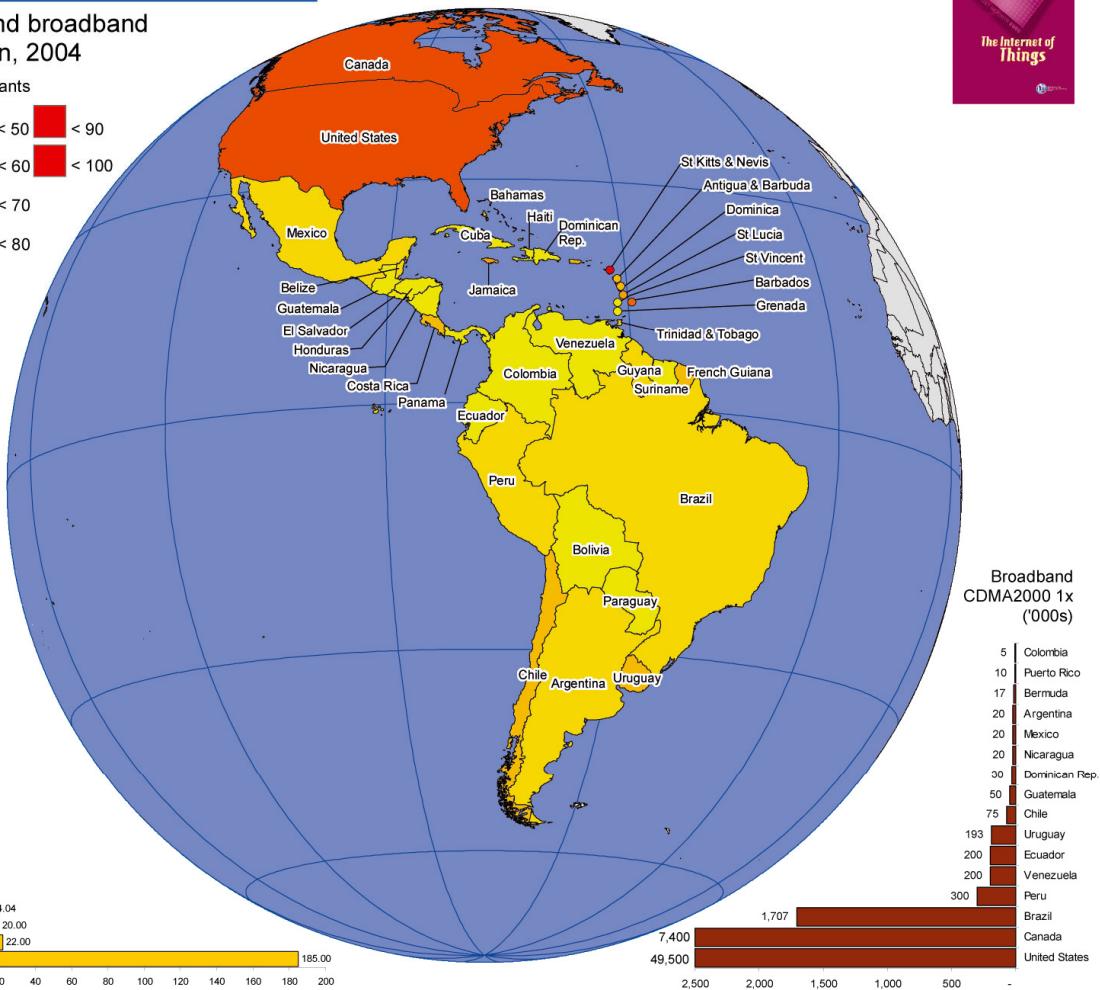
Internet and broadband penetration, 2004

Per 100 inhabitants



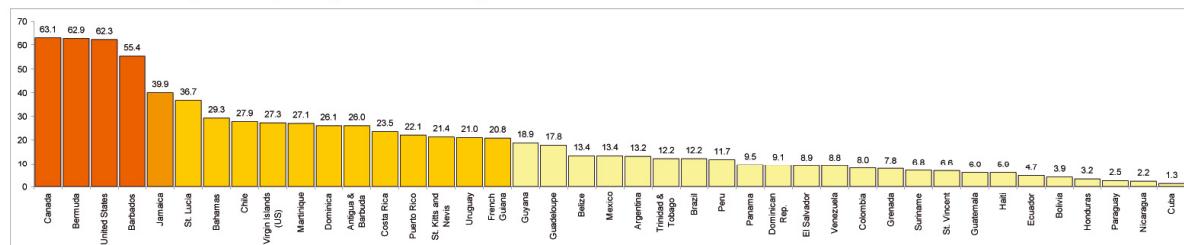
Est. Internet users, 2004 (millions)

Grenada	0.01
St. Vincent	0.01
St. Kitts and Nevis	0.01
Dominica	0.02
Antigua & Barbuda	0.02
Suriname	0.03
Belize	0.04
French Guiana	0.04
St. Lucia	0.06
Bahamas	0.09
Nicaragua	0.13
Guyana	0.15
Barbados	0.15
Cuba	0.15
Paraguay	0.15
Trinidad & Tobago	0.16
Honduras	0.22
Panama	0.30
Bolivia	0.35
Haiti	0.50
El Salvador	0.59
Ecuador	0.62
Uruguay	0.68
Guatemala	0.76
Dominican Rep.	0.80
Costa Rica	1.00
Jamaica	1.07
Venezuela	2.31
Peru	3.22
Colombia	3.59
Chile	4.30
Argentina	5.12
Mexico	14.04
Canada	20.00
Brazil	22.00
United States	63.1

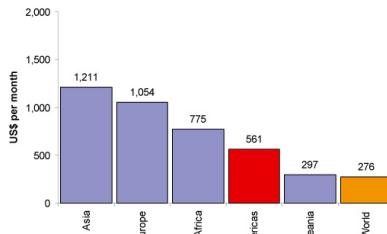


Denominations and classifications employed in these maps do not imply any opinion on the part of the ITU concerning the legal or other status of any territory or any endorsement or acceptance of any boundary.

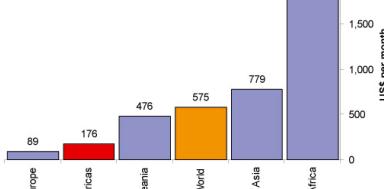
Estimated Internet user penetration, 2004 (per 100 inhabitants)



Broadband Prices Lower speed



Higher speed



TECHNICAL NOTES

General methodology

The compound annual growth rate (CAGR) is computed by the formula:

$$[(P_v / P_0)^{(1/n)}]-1$$

where P_v = Present value
 P_0 = Beginning value
n = Number of periods

The result is multiplied by 100 to obtain a percentage.

United States dollar figures are reached by applying the average annual exchange rate (from the International Monetary Fund, IMF) to the figure reported in national currency, unless otherwise noted. For economies where the IMF rate is unavailable or where the exchange rate typically applied to foreign exchange transactions differs markedly from the official IMF rate, a World Bank conversion rate is used. For the few economies where neither the IMF nor World Bank rates are available, a United Nations end-of-period rate is used.

Group figures are either *totals* or weighted *averages* depending on the indicator. For example, for main telephone lines, the total number of *main telephone lines* for each grouping is shown, while for *main lines per 100 inhabitants*, the weighted average is shown. Group figures are shown in bold in the tables. In cases of significant missing data and country rankings, group totals are not shown. Group growth rates generally refer to economies for which data is available for both years. Data was collected and updated on an ongoing basis up to the date of publication; different collection times and dates may account for slight discrepancies between individual entries.

1. Basic indicators

The data for *Population* are mid-year estimates from the United Nations (UN). National statistics have been used for some countries. *Population Density* is based on land area data from the UN: the land area does not include any overseas dependencies, but does include inland waters. The data for *gross domestic product* (GDP) are generally from the IMF, the Organisation for Economic Co-operation and Development (OECD) or the World Bank. They are current price data in national currency converted to United States dollars by the method identified above. Readers are advised to consult the publications of the international organisations listed in *Sources* for precise definitions of the demographic and macro-economic data. *Total telephone subscribers* refer to the sum of main telephone lines and cellular mobile subscribers. *Total telephone subscribers per 100 inhabitants* is calculated by dividing the total number of telephone subscribers by the population and multiplying by 100.

2. Mobile subscribers

Cellular mobile telephone subscribers refer to users of portable telephones subscribing to an automatic public mobile telephone service using cellular technology that provides access to the PSTN. *Per 100 inhabitants* is obtained by dividing the number of cellular subscribers by the population and multiplying by 100. *% digital* is the number of mobile cellular subscribers who use a second- or third-generation digital cellular service (e.g. GSM, CDMA, CDMA 1x, DAMPS, PCS, PHS, W-CDMA) by the total number of mobile subscribers. *As a % of total telephone subscribers* is obtained by dividing the number of cellular subscribers by the total number of telephone subscribers (sum of the main telephone lines and the cellular subscribers) and multiplying by 100.

3. Mobile prices

The table shows the costs associated with cellular mobile telephone service. Where possible, the prices of the incumbent and/or major operator were taken, from operators' websites or by correspondence: this may not necessarily be the most cost-effective connection, but rather a representative package on offer to consumers in August 2005. *Connection charge* refers to connection charges for basic telephone service in USD, using exchange rates as at 5 September 2005. Offers of free local calls on connection were not taken into account. *Per minute local call* refers to the average cost of a one-minute mobile call to within the same network, off-net and to a fixed line during *Peak* and *Off-peak* hours. Any taxes involved in these charges are included to improve comparability. *Cost of a local SMS* is the charge to the consumer of sending a single short messaging service (SMS) text within the local exchange area. *OECD low-user basket* gives the price of a standard basket of mobile usage monthly usage in USD determined by the OECD for 25 outgoing calls per month (on and off the network and to fixed line) in predetermined ratios and 30 SMS messages. For more details on the OECD Teligen methodology, see www.oecd.org. *As a percentage (%) of monthly income* is the price of the OECD low-user mobile basket divided by per capita monthly income (World Bank, Atlas method, no PPP).

4. IMT-2000 (3G) subscribers and networks

This table presents data for IMT-2000 (3G) subscribers for 68 economies as at 31 December 2004, as well as information on network deployment. As defined by the ITU, IMT-2000 includes five main radio interfaces, of which only three were commercially deployed by December 2004: CDMA 2000 1x, CDMA 2000 1x EVDO and W-CDMA. This table excludes economies that have deployed 3G networks for the purposes of limited mobility services (i.e. Wireless Local Loop or WLL) only. Subscribers to data services are also included, on the basis that they are accessing a 3G network,

irrespective of the device used. *3G as a % of all mobile subscribers* is obtained by dividing the number of IMT-2000 (3G) subscribers by the total number of cellular mobile telephone subscribers and multiplying by 100. *Rank* shows the relative position of each economy in terms of the proportion of 3G mobile subscribers and 3G-enabled mobile handsets on a scale of 1 to 58, where 1 represents the highest rate of 3G penetration as a proportion of total mobile subscribers. Where possible, data has been sourced directly from operators and national regulators. In the case of CDMA 2000 1x, the number of mobile subscribers may be equivalent to the number of 3G-enabled handsets, according to the operators' information, although users with such handsets may or may not be official subscribers to a 3G service. For each economy, known *operators* that have launched commercial networks are listed, along with the *launch date*. IMT-2000 (3G) subscriber data originate from various sources, including: ITU research, operators, national regulators, Informa Telecoms Group, TMG, industry press and other sources.

5. Internet subscribers

Internet subscribers refers to the sum of dial-up, leased lines and broadband subscribers. *Internet subscribers per 100 inhabitants* is calculated by dividing Internet subscribers by population and multiplying by 100. *Dial-up subscribers* refer to those who use the public switched telephone network to access the Internet. *As % of total subscribers* is calculated by dividing dial-up subscribers by total Internet subscribers and multiplying by 100. Where this statistic is low, it can be assumed that broadband subscriptions are high. *Broadband subscribers* is the total number of broadband subscribers and includes DSL, cable modem and other access technologies.

6. Information technology

Internet hosts refers to the number of computers in the economy that are directly linked to the worldwide Internet network. Note that Internet host computers are identified by a two digit country code or a three digit generic top-level domain generally reflecting the nature of the organization using the Internet computer. The numbers of hosts are assigned to countries based on the country code although this does not necessarily indicate that the host is actually physically in the country. In addition, all other hosts for which there is no country code identification (e.g. generic top-level domains such as .edu or .com) are assigned to the United States. Therefore, the number of Internet hosts shown for each country can only be considered an approximation. Data on Internet host computers come from Internet Software Consortium (<http://www.isc.org>) and RIPE (<http://www.ripe.net>). *Users* is based on reported estimates, derivations based on reported Internet access provider subscriber counts, or calculated by multiplying the number of hosts by an estimated multiplier. *Estimated PCs* shows the number of personal computers (PCs) in use, both in absolute numbers and in terms of PC ownership per 100 inhabitants. These numbers are derived from the annual questionnaire, supplemented by other sources.

7. Broadband subscribers

Although various definitions of *broadband* exist, the statistics here exclude services offering a combined throughput of less than 256 kbit/s in both directions. *DSL* refers to the total number of digital subscriber lines. *Cable modem Internet subscribers* refers to Internet subscribers via a cable TV network. *Other* refers to other broadband access technologies that are not related to DSL or cable modem. Examples may include fibre-optic, fixed wireless, apartment LANs or satellite connections. *Broadband subscribers* refer to the sum of DSL, cable modem and other broadband subscribers. *Broadband subscribers per 100 inhabitants* is calculated by dividing the total number of broadband subscribers by the population and multiplying by 100. *Total broadband subscribers* sums the last known values for DSL, cable modem, and other technologies. As a result, the *Total broadband subscribers* figure may combine data from different years. *Broadband subscriber* data originate from various sources, including: ITU research, OECD, the Arab Advisors Group and other sources.

8. Broadband prices

The prices gathered for the Broadband prices table are meant only as a broad representation of typical broadband offers available in an economy. Broadband is considered any dedicated connection to the Internet of 256 kbit/s or faster. They do not necessarily represent the least expensive, fastest or most cost-effective connections. Rather, they give a small sample of the offers available to consumers. All prices were gathered during July-September 2005, with exchange rates valid as of 5 September 2005. Broadband offers are usually residential offerings unless only business connections are available from the ISP. Since ADSL technologies are increasingly used to replace leased lines in businesses, the costs shown in the table may be very high in some developing economies and markets since they represent replacements for leased lines (indicated by the abbreviation LL), rather than residential broadband offers. In general, ISP choices do not necessarily reflect the dominant ISP in the market. Some ISPs place download limits on broadband connections and where applicable, the service offering closest to 1 Gigabyte of data per month is used. Other ISPs may put time restrictions on broadband usage. The service offering closest to 100 hours per month is selected. The prices included are those advertised and may or may not include ISP charges. Where ISP charges are known to be separate, they are included. Taxes may or may not be included in the advertised prices. All prices are gathered in local currency and converted to nominal US\$ at the exchange rate on 5 September, 2005. Most prices in the table are for DSL services. Cable modem prices are given if they are found to be lower or more prevalent. The prices shown do not include installation charges or telephone line rentals that are often required for DSL service. In most cases, two prices are gathered for each economy. *Lower speed monthly charge* refers to a lower-speed connection, typically between 256 - 1'024 kbit/s download speed and is meant to show an example of a typical "entry-level"

broadband offer in the economy. The monthly charge reflects the ISP charge for one month of service. It does not include installation fees or modem rental charges if they are charged separately. *Speed (kbit/s) down* represents the advertised maximum theoretical download speed and not speeds guaranteed to users. *Higher speed monthly charge* refers to a faster and typically more expensive offer available in the economy. It is not necessarily from the same provider as the *Lower speed* offering. Again, charges do not include installation fees or modem rentals. Download speeds are theoretical maximums. *Lowest sampled cost US\$ per 100 kbit/s* gives the most cost-effective subscription based on criteria of least cost per 100 kbit/s. This is calculated by dividing the monthly subscription charge in US\$ by the theoretical download speed, and then multiplying by 100. This figure is calculated for each recorded sample and the lowest cost per 100 kbit/s is given. *Lowest sampled cost as a % of monthly income (GNI)* is *Lowest sampled cost US\$ per 100 kbit/s* divided by per capita monthly income (World Bank, Atlas method, no PPP). The figure is then reported as a percentage (multiplied by 100). *ISP* lists the name of the Internet service provider whose sampled price was the lowest per 100 kbit/s over all the country samples.

9. International Internet bandwidth

Bandwidth refers to the width of the range of frequencies that an electronic signal occupies on a given transmission medium. It is a measure of how fast data flows on a given transmission path, and determines the quantity and the speed of information transmitted. *Rank* shows the relative

position of each economy in terms of each respective indicator of bit capacity, on a scale of 1 to 207, where 1 represents the highest bit capacity (although the total number of country rankings is fewer, due to omissions of countries where data are unavailable). *Total international Internet bandwidth* shows the total capacity of Internet bandwidth expressed in Megabits per second (Mbit/s). *Bits per inhabitant* divides *Total international Internet bandwidth* by the population. *Bits per Internet user* divides *Total international Internet bandwidth* by *estimated Internet users*. *Simultaneous international 256 kbit/s links* examines how many international 256 kbit/s connections (the lowest speed defined as broadband) can be accommodated using the total international Internet bandwidth of the economy. This number is calculated first by multiplying *Total international Internet bandwidth* by 1000 to convert it to kbit/s. Next, *Total international Internet bandwidth* is divided by 256. While it is likely that many broadband connections will access local or national content, the figure should give an idea of the maximum number of simultaneous international, dedicated broadband connections the economy can support. Note that for some countries with a large domestic market (e.g. USA) or a language that is not widely used outside of the country (e.g. the Republic of Korea, Japan) then domestic rather than international might be the dominant form of international internet traffic. International Internet bandwidth data are provided from various sources, including: ITU research, TeleGeography Inc. (<http://www.telegeography.com>), and other sources.

Box 1: Other economies

Population, main telephone lines, cellular subscribers and total telephone density (fixed plus mobile cellular subscribers per 100 inhabitants) for economies not shown in the main tables, 2004.

Economy	Population	Mainlines	Mobile subs	Total teledensity
American Samoa	57'000	14'700	...	24.2
Anguilla	11'600	6'201	1'773	68.7
Ascension	1'300	642	0	49.4
British Virgin Islands	23'400	11'705	8'000	84.2
Cayman Islands	49'300	38'000	17'000	111.6
Cook Islands	18'000	6'170	1'499	39.7
Falkland (Malvinas) Is.	2'500	2'592	0	103.7
Gibraltar	28'500	24'552	12'167	128.8
Liechtenstein	34'294	19'923	11'402	91.3
Monaco	32'000	33'499	15'081	149.0
Montserrat	4'000	2'811	489	82.5
Nauru	10'000	1'850	1'500	28.8
Niue	1'982	1'050	400	73.2
San Marino	27'000	20'689	16'900	139.2
St. Helena	4'186	2'193	0	52.4
St. Pierre & Miquelon	6'600	4'770	...	72.3
Timor Leste	820'000
Tokelau	2'000	300	0	15.0
Turks & Caicos Is.	18'800	5'740	...	30.5
Tuvalu	10'000	650	0	6.8
Wallis and Futuna	14'700	1'890	0	12.9

Note: Figures in italics are estimates or refer to earlier years.

Source: ITU World Telecommunication Indicators Database.

10. Fixed telephone lines

This table shows the number of *Fixed telephone lines* and *Fixed telephone lines per 100 inhabitants* (or teledensity) for the years indicated and corresponding annual growth rates. *Fixed telephone lines* refer to telephone lines connecting a customer's equipment (e.g., telephone set, facsimile machine) to the public switched telephone network (PSTN) and which have a dedicated port on a telephone exchange. It includes ISDN subscribers but not broadband lines, even though these may be used for voice, to avoid double counting. Note that for most countries, main lines also include public payphones. *Fixed telephone lines per 100 inhabitants* is calculated by dividing the number of main lines by the population and multiplying by 100.

11. Special focus: Americas

The two pages of maps and accompanying charts highlight the development of the ICT market in the Americas region. They were specially prepared for ITU TELECOM Americas 2005, in Salvador da Bahia, Brazil, 3-6 October 2005. For more information see <http://www.itu.int/AMERICAS2005/>.

SOURCES

Demographic and economic

In addition to national sources, demographic and economic statistics were obtained from the following:

International Monetary Fund. Various years. *International Financial Statistics*. Washington D.C.

United Nations. Various years. *Monthly Bulletin of Statistics*. New York.

World Bank. Various years. *World Development Indicators*. Washington D.C.

Telecommunications

The telecommunications data are obtained via an annual questionnaire. Depending on the country, the questionnaire is sent to the government ministry responsible for telecommunications, to the telecommunications regulator or to the telecommunication operator. Data is cross-checked and supplemented from reports issued by these organisations as well as regional telecommunication agencies. For pricing data, information is obtained from company websites or by correspondence. In a few cases, data are obtained from mission reports prepared by ITU staff or from other sources (see the Technical Notes). In some instances, estimates, generally based on extrapolation or interpolation techniques, are made by ITU staff.

