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CITS 5506
The Internet of Things
Lecture 02

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Lecture Overview

Challenges for IoT

IoT History, Evolution, Development Issues

IoT forecast, IoT Applications

Network, Internet of Things Communications Models

The Internet of Things

The Internet of Things is an emerging topic of technical, social, and economic significance.

Consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects are being combined with Internet connectivity and powerful data analytic capabilities that promise to transform the way we work, live, and play.

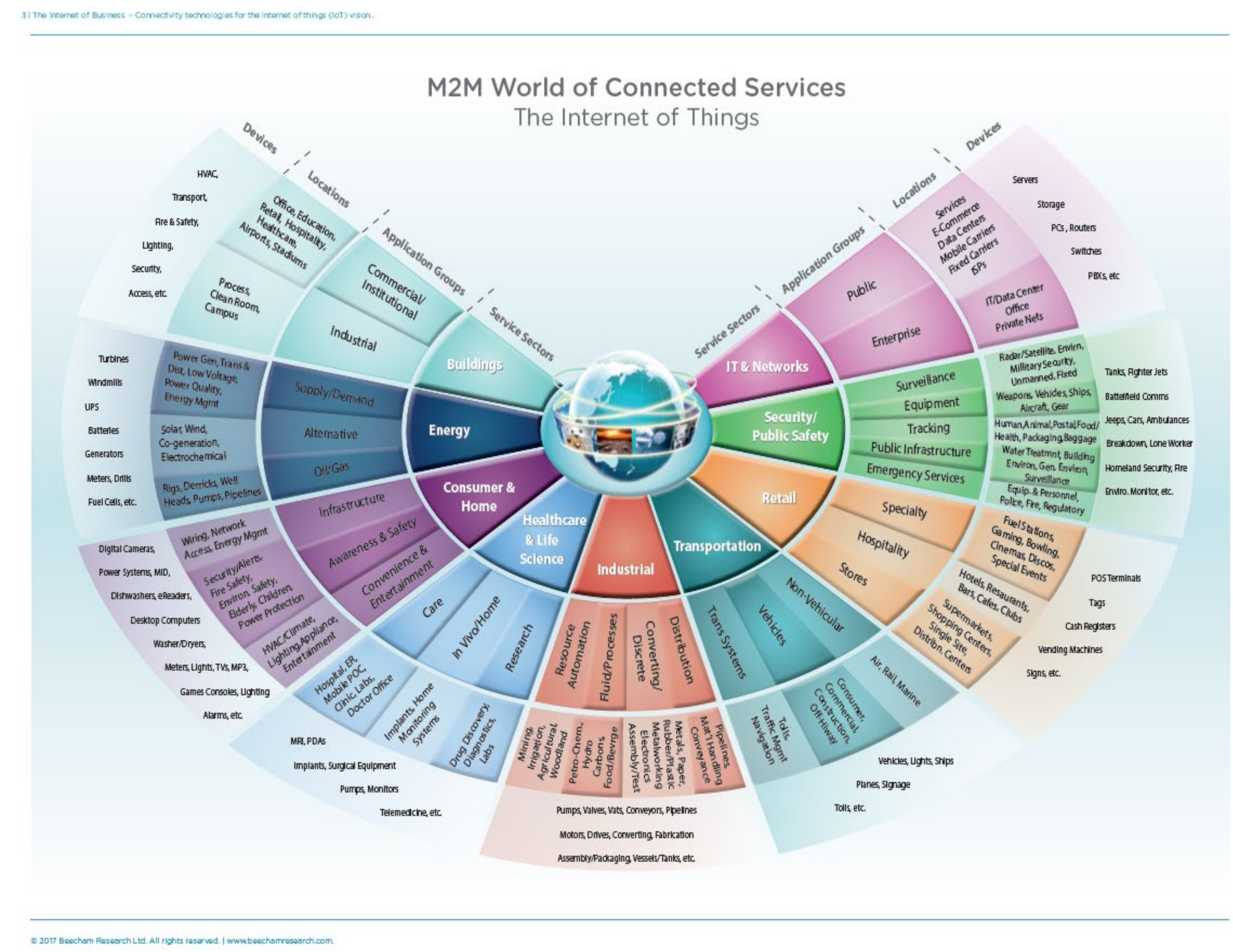
The Internet of Things

Projections for the impact of IoT on the Internet and economy are impressive, with some anticipating as many as 100 billion connected IoT devices by 2025[1]

Estimated global economic impact of more than $11 trillion by 2025[1].

1. The Internet of Things : An Overview , Understanding the Issues and Challenges of a More Connected World Published by the Internet Society

The Internet of Things



It may force a shift in thinking about the implications and issues in a world where the most common interaction with the Internet comes from passive engagement with connected objects rather than active engagement with content.

IoT …………Conflicting Perceptions

IoT a revolutionary fully–interconnected “smart” world of progress, efficiency, and opportunity, with the potential for adding billions in value to industry and the global economy.

Others warn that the IoT represents a darker world of surveillance, privacy and security violations, and consumer lock–in.

Challenges for IoT

However, the Internet of Things raises significant challenges that could stand in the way of realizing its potential benefits.

Societal Challenges

- privacy fears
- surveillance concerns
- Security Concern (hacking of Internet-connected devices)

Example of Societal challenge: Google Glass

- The smart spectacles by Google unveiled in 2012.
- Introduction demo that featured skydivers streaming their jump through the device.

  https://youtu.be/uh-liQDE3cM
- Privacy advocates are concerned that people wearing such eyewear may be able to identify strangers in public using facial recognition, or secretively record and broadcast private conversation.
- Google shelved the product in 2015

Even the future King could not save it

Privacy concern kept it from going mainstream.

Challenges for IoT

Legal Challenges

The use of IoT devices raises many new regulatory and legal questions:

- Issues related to cross border data flows
- Data collected by IoT devices is sometimes susceptible to misuse, potentially causing discriminatory outcomes for some users.

Challenges for IoT

Legal Challenges

- Conflict between law enforcement surveillance and civil rights

- Data retention and destruction policies

- Legal liability for unintended uses

- Security breaches or privacy lapses

IoT History

IoT History

The term “Internet of Things” (IoT) was first used in 1999 by British technology pioneer Kevin Ashton to describe a system in which objects in the physical world could be connected to the Internet by sensors.

Ashton was working on RFID (radio-frequency identification) devices, and the close association of RFID and other sensor networks with the development of the IoT concept is reflected in the name of the RFID device company that Ashton joined later in his career: “ThingMagic.”

http://www.thingmagic.com/ Now https://www.jadaktech.com/

IoT History

- In 1977, work started on commercial automatic meter reading and load management for electrical services which led to the "smart grid" and "smart meter“ over telephone lines[1].
- In the 1990s, advances in wireless technology allowed “machine–to–machine” (M2M) enterprise and industrial solutions for equipment monitoring and operation.
- Many of these early M2M solutions, however, were based on **closed purpose–built networks** and **proprietary or industry–specific standards**, rather than on Internet Protocol (IP) and Internet standards[2].

1. “Machine to Machine.” Wikipedia, https://en.wikipedia.org/wiki/Machine_to_machine
2. Polsonetti, Chantal. “Know the Difference Between IoT and M2M.” Automation World, July 15, 2014

IoT History

- The first Internet "device"—an IP–enabled toaster that could be turned on and off over the Internet—was featured at an Internet conference in 1990[1].
- Over the next several years, other "things" were IP–enabled, including a soda machine[2] at Carnegie Mellon University in the US and a coffee pot[3] in the Trojan Room at the University of Cambridge in the UK (which remained Internet–connected until 2001)

1. "The Internet Toaster." Living Internet, 7 Jan. 2000. Web. 06 Sept. 2015. http://www.livinginternet.com/i/ia_myths_toast.htm
2. "The "Only" Coke Machine on the Internet." Carnegie Mellon University Computer Science Department, n.d. Web. 06 Sept. 2015. https://www.cs.cmu.edu/~coke/history_long.txt
3. Stafford-Fraser, Quentin. "The Trojan Room Coffee Pot." N.p., May 1995. Web. 06 Sept. 2015. http://www.cl.cam.ac.uk/coffee/qsf/coffee.html

Enabling Technologies

- The concept of combining computers, sensors, and networks to monitor and control devices has existed for decades.
- The recent confluence of several technology market trends, however, is bringing the Internet of Things closer to widespread reality.
- These include Ubiquitous Connectivity, Widespread Adoption of IP-based Networking, Computing Economics, Miniaturization, Advances in Data Analytics, and the rise of Cloud Computing.

IoT Evolution

From a broad perspective, the confluence of several technology and market trends is making it possible to interconnect more and smaller devices cheaply and easily.

- Ubiquitous Connectivity—Low cost, high–speed, pervasive network connectivity
- Widespread adoption of IP–based networking— IP has become the dominant global standard for networking.
  - Internet Protocol version 4 (IPv4), 32-bit address space which provides 4,294,967,296 (2^{32}) unique addresses
  - Internet Protocol version 6 (IPv6), 128-bit addresses

IoT Evolution

- Computing Economics — Greater computing power at lower price and lower power consumption

- Miniaturization — Manufacturing advances allow cutting-edge computing and communications technology to be incorporated into very small objects & small and inexpensive sensor devices

- Advances in Data Analytics — New algorithms and rapid increases in computing power, data storage, and cloud services enable the analysis of vast quantities of data

IoT Evolution

- Rise of Cloud Computing– Cloud computing, which leverages remote, networked computing resources to process, manage, and store data, allows small and distributed devices to interact with powerful back-end analytic and control capabilities.

Economy and Development Issues

The Internet of Things holds significant promise for delivering social and economic benefits to emerging and developed economies.

This includes areas such as sustainable agriculture, water quality and use, healthcare, industrialization, and environmental management, among others.

Development Issues

The unique needs and challenges of implementation will need to be addressed, including :

- infrastructure readiness
- market and investment incentives
- technical skill requirements
- policy resources

IoT Forecast

- A number of companies and research organizations have offered a wide range of projections about the potential impact of IoT on the Internet and the economy

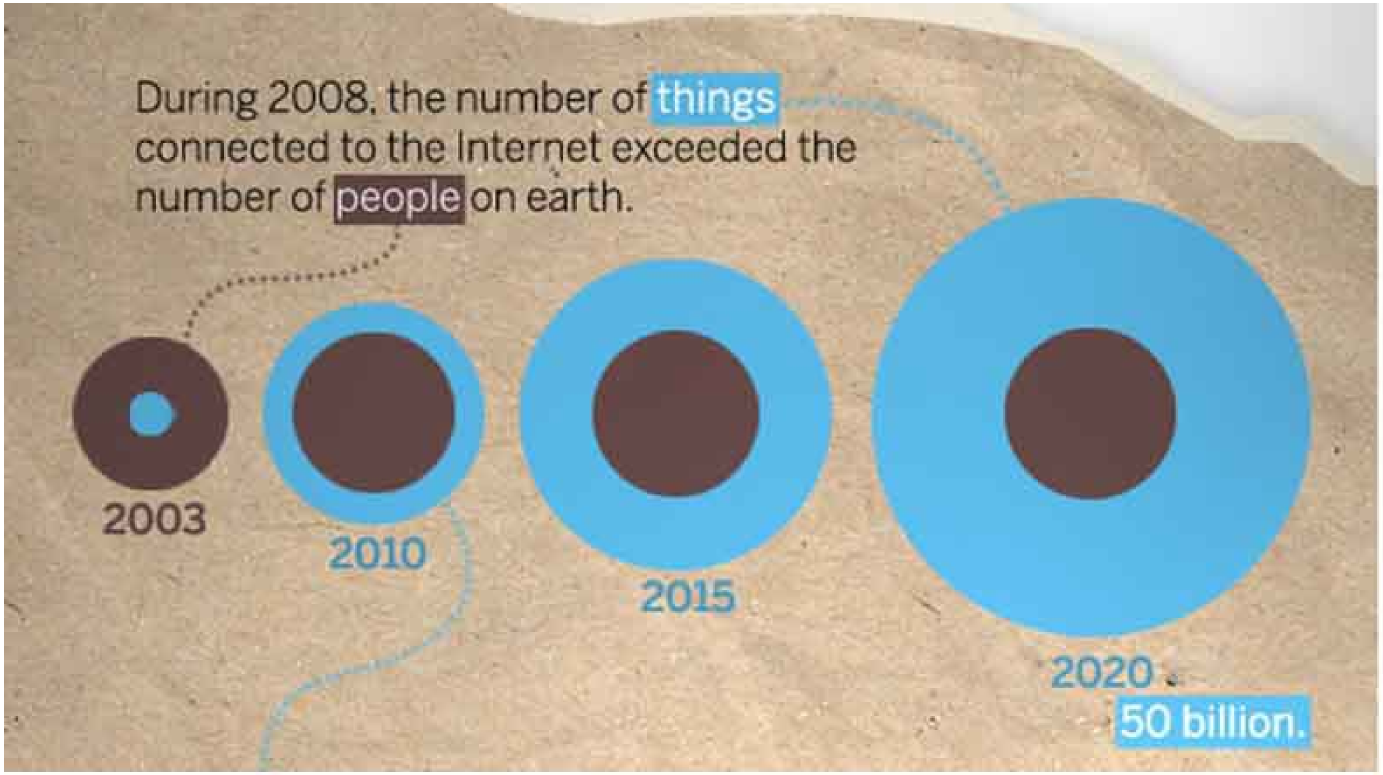
- Morgan Stanley, a global financial services firm in 2013 projected 75 billion networked devices by 2020[1]
  - Cisco says connected devices will be 3 x global population by 2023[2].

1. "Danova, Tony. "Morgan Stanley: 75 Billion Devices Will Be Connected To The Internet Of Things By 2020." Business Insider, October 2, 2013. http://www.businessinsider.com/75-billion-devices-will-be-connected-to-the-internet-by-2020-2013-10
2. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

MacroEconomic Insight IoT

IoT Evolution

Sources: Cisco IBSG, Jim Cicconi, AT&T , Steve Leibson, Computer History Museum, CNN, University of Michigan, Fraunhofer



IoT Forecast

- Huawei forecasts 100 billion IoT connections by 2025[1]

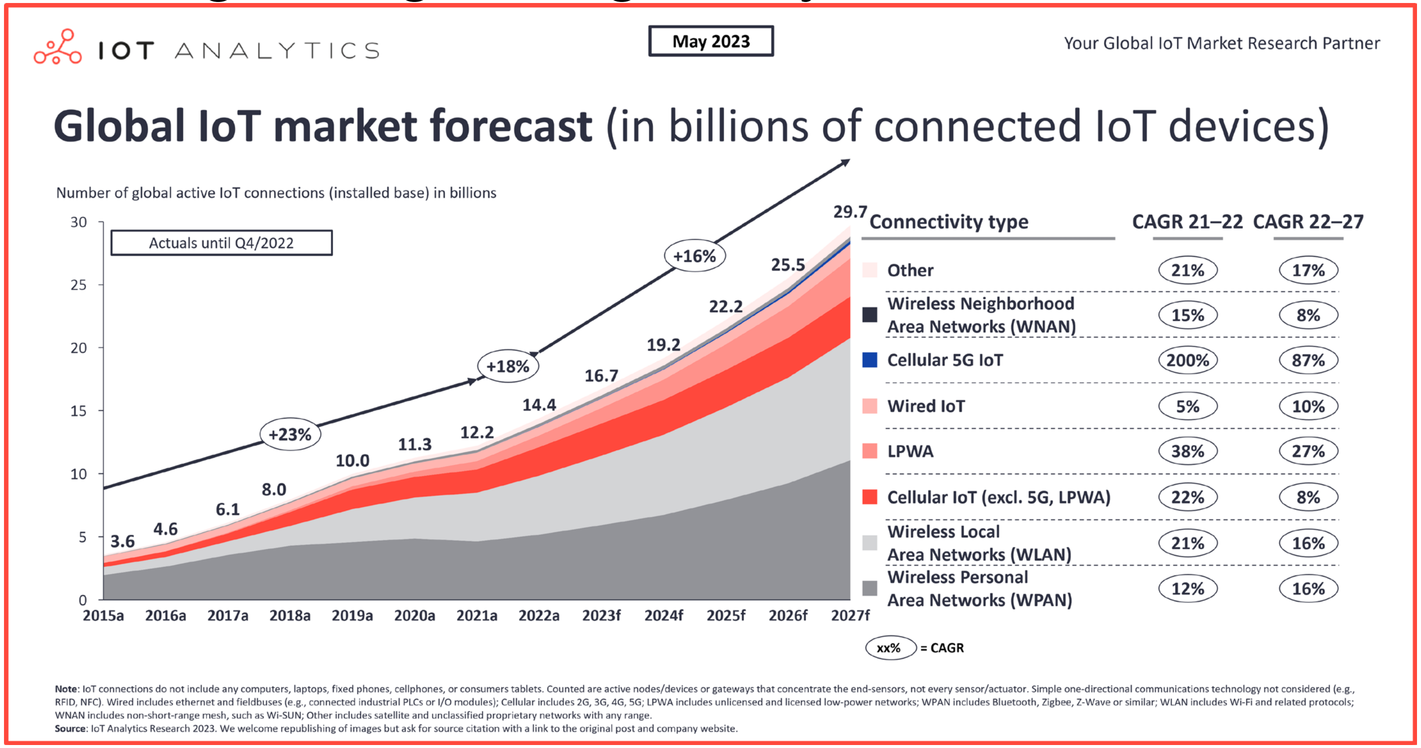
- McKinsey Global Institute suggests that the financial impact of IoT on the global economy may be as much as $3.9 to $11.1 trillion by 2025[2]

While the variability in predictions makes any specific number questionable, collectively they paint a picture of significant growth and influence.

1. "Global Connectivity Index." Huawei Technologies Co., Ltd., 2015. Web. 6 Sept. 2015. http://www.huawei.com/minisite/gci/en/index.html
2 . Manyika, James, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. "The Internet of Things: Mapping the Value Beyond the Hype." McKinsey Global Institute, June 2015.

State of IoT 2022

State of IoT May 2023: Number of connected IoT devices growing 16% globally[1]



1. https://iot-analytics.com/number-connected-iot-devices/

“Settings” for IoT Applications

Setting	Description	Examples
Human	Devices attached or inside the human body	Devices (wearables and ingestible) to monitor and maintain human health and wellness; disease management, increased fitness, higher productivity
Home	Buildings where people live	Home Controllers and Security Systems
Retail Environments	Spaces where consumers engage in commerce	Stores, banks, restaurants, arenas – anywhere consumers consider and buy; self-checkout, in-store offers, inventory optimization

“Settings” for IoT Applications

Setting	Description	Examples
Factories	Standardized production environments	Places with repetitive work routines, including hospitals and farms; operating efficiencies, optimizing equipment use and inventory
Worksites	Custom production environments	Mining, oil and gas, construction; operating efficiencies, predictive maintenance, health and safety
Vehicles	Systems inside moving vehicles	Vehicles including cars, trucks, ships, aircraft, and trains; condition-based maintenance, usage-based design,

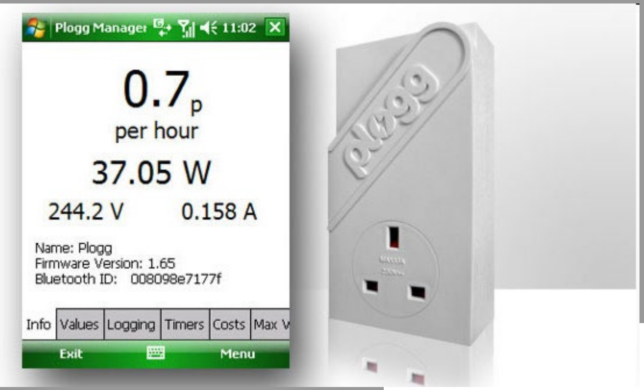
“Settings” for IoT Applications

Setting	Description	Examples
Cities	Urban Environment	Public spaces and infrastructure in urban settings; adaptive traffic control, smart meters, environmental monitoring, resource management
Offices	Spaces where knowledge workers work	Energy management and security in office buildings; improved productivity, including for mobile employees

Manyika, James, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. “The Internet of Things: Mapping the Value Beyond the Hype.” McKinsey Global Institute, June 2015. p.3.
http://www.mckinsey.com/insights/business_technology/the_internet_of_things_the_value_of_digitizing_the_physical_world 25

Sensor Devices are widely available

- Programmable devices
- Off-the-shelf gadgets/tools



Challenges for IoT

Technical challenges

- Sensors
- Power Consumption
- Security & Privacy
- Data Analytics
- Communication Technologies
- Interoperability / Standards
- Development Challenges/ Enabling Technologies

Technical Challenges for IoT

- Sensors
  – applications —edge computing and IoT, smart cities, smart manufacturing, hospitals, industrial, machine learning, and automotive.
  – chips to capture data about what is happening in our analog world, and then digitize the data so it can be processed, stored, combined, mined, correlated, and utilized by both humans and machines.
  – Energy and power efficiency are critical

Sensors

- Some type of always-on circuitry for faster boot-up or to detect motion, gestures, or specific keywords.
- In the past these types of functions typically were built into the central processor
  - wasteful of energy
- Developing a flexible system optimized with dedicated processors, as well as hardware accelerators offloading the host processor, seems to be emerging as a basic requirement
- Sensor data capture, fusion processing, and communication tasks, resulting in more power-efficient use of processing resources

Sensors

- Miniaturization of Sensor
  - “*Nanosensors are chemical or mechanical sensors that can be used to detect the presence of chemical species and nanoparticles, or monitor physical parameters such as temperature, on the nanoscale (10^{-9}). They find use in medical diagnostic applications, food and water quality sensing, and other chemicals*.”

(Nature)

Miniaturization of Sensor

- Objects have characteristics of both particles and waves (wave–particle duality); and there are limits to how accurately the value of a physical quantity can be predicted prior to its measurement, given a complete set of initial conditions (the uncertainty principle).

- Quantum sensor utilizes properties of quantum mechanics, which have optimized precision and beat current limits in sensor technology.

How are the Network changing

Extensions

- More nodes, more connections, IPv6 (128-bit addresses) as compared to IPv4 (32-bit address space)
- Any TIME, Any PLACE + Any THING
- M2M, IoT
  - Billions of interconnected devices,
  - Everybody connected.

Expansions

- Broadband & LPWAN

Enhancements

- Data-centric and content-oriented networking
- Context-aware (autonomous) systems (knowing the surrounding environment through sensors)

Data Centric Networking

A fundamental innovation in the area of wireless sensor networks has been the concept of data-centric networking.

In a nutshell, the idea is this: routing, storage, and querying techniques for sensor networks can all be made more efficient if communication is based directly on application-specific data content instead of the traditional IP-style addressing

Content-oriented networking

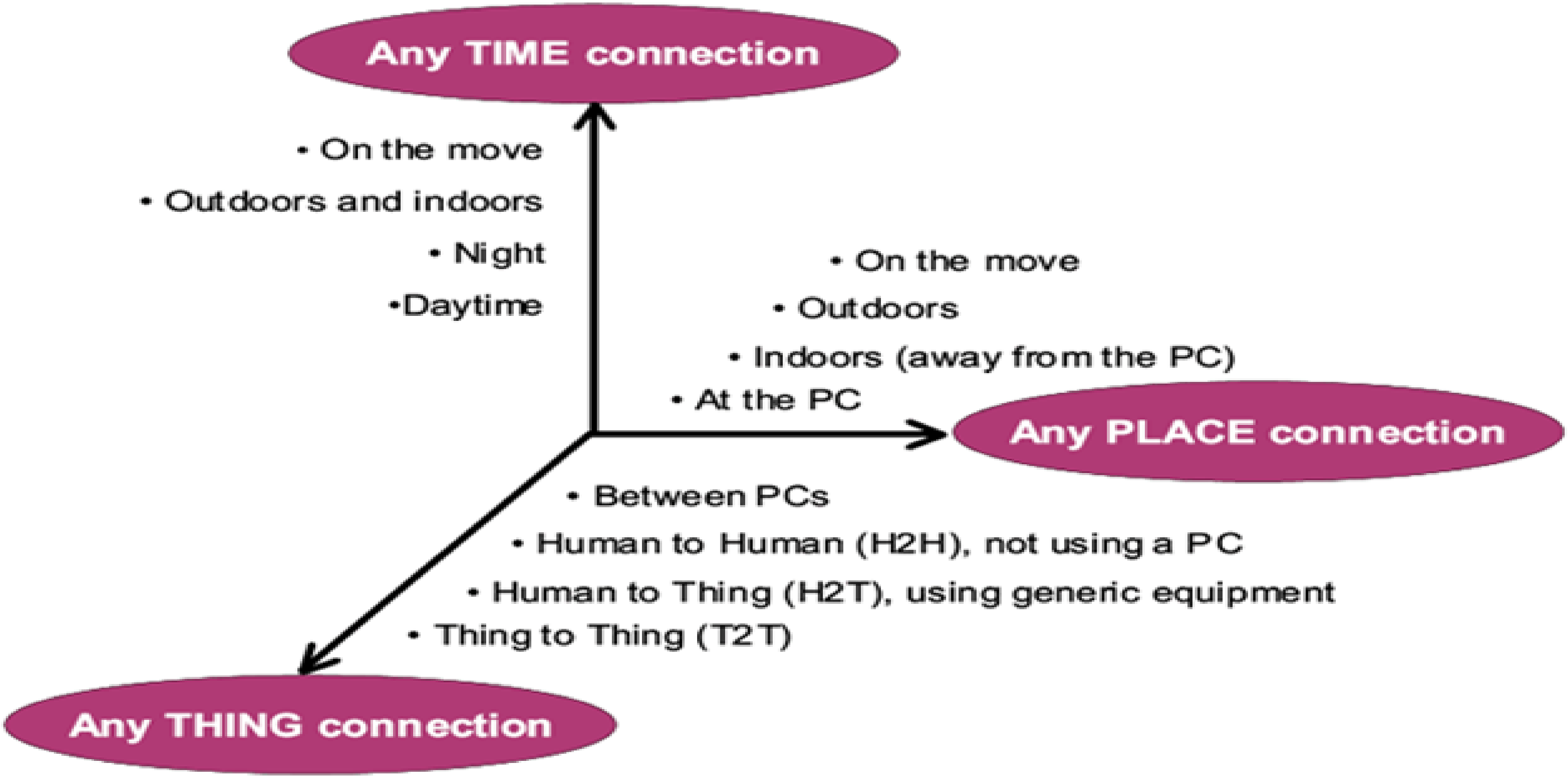
Consumers request content by sending an Interest message with the name of the desired content.

The network routes the interest based on the name using longest prefix match.

When a match is found (when an Interest matches a Content Object) the content is sent back on the reverse path of the Interest.

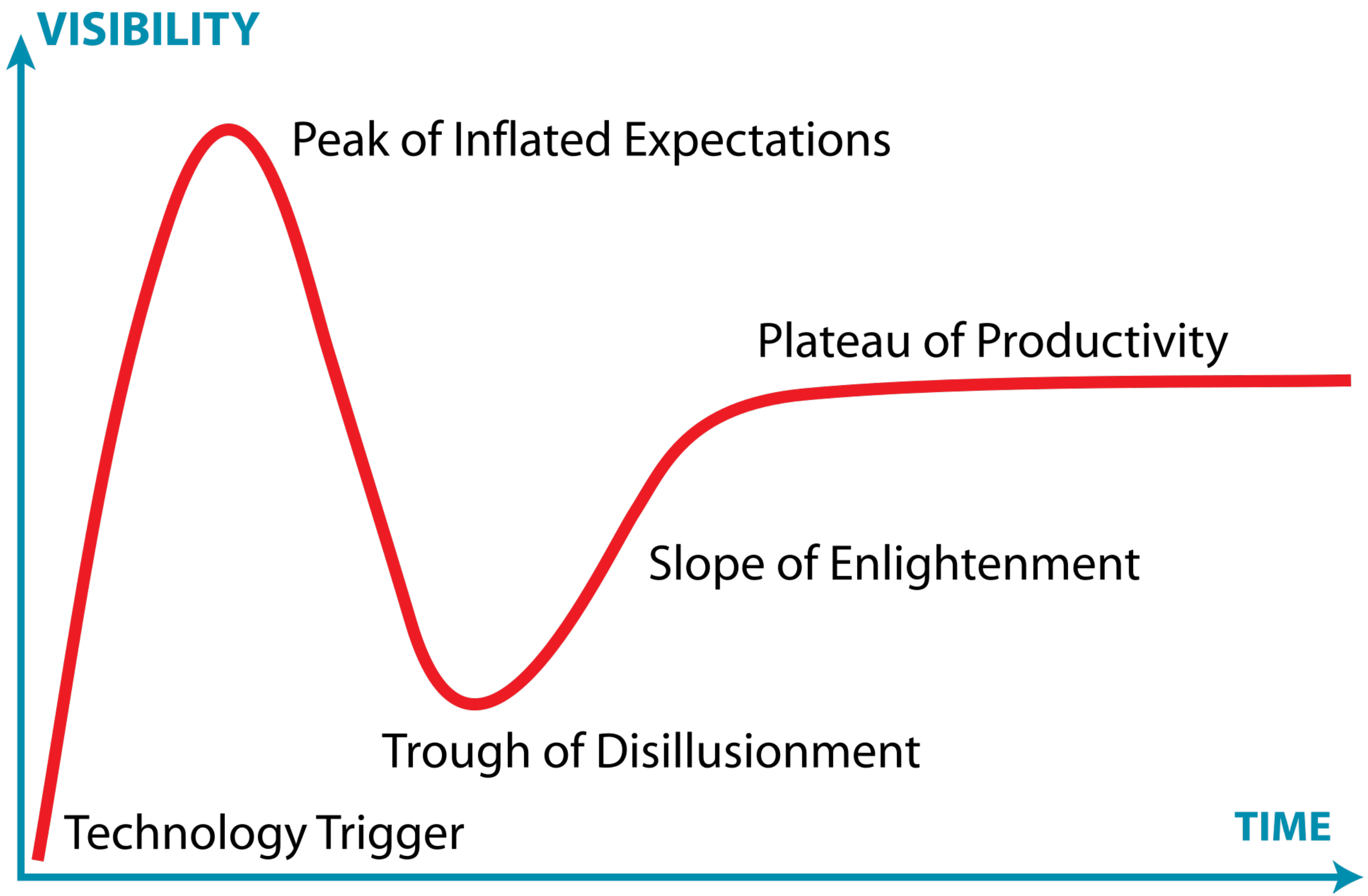
Interest messages may be matched against caches along the way, not only at the publishers.

Future Networks



Source: ITU adapted from Nomura Research Institute

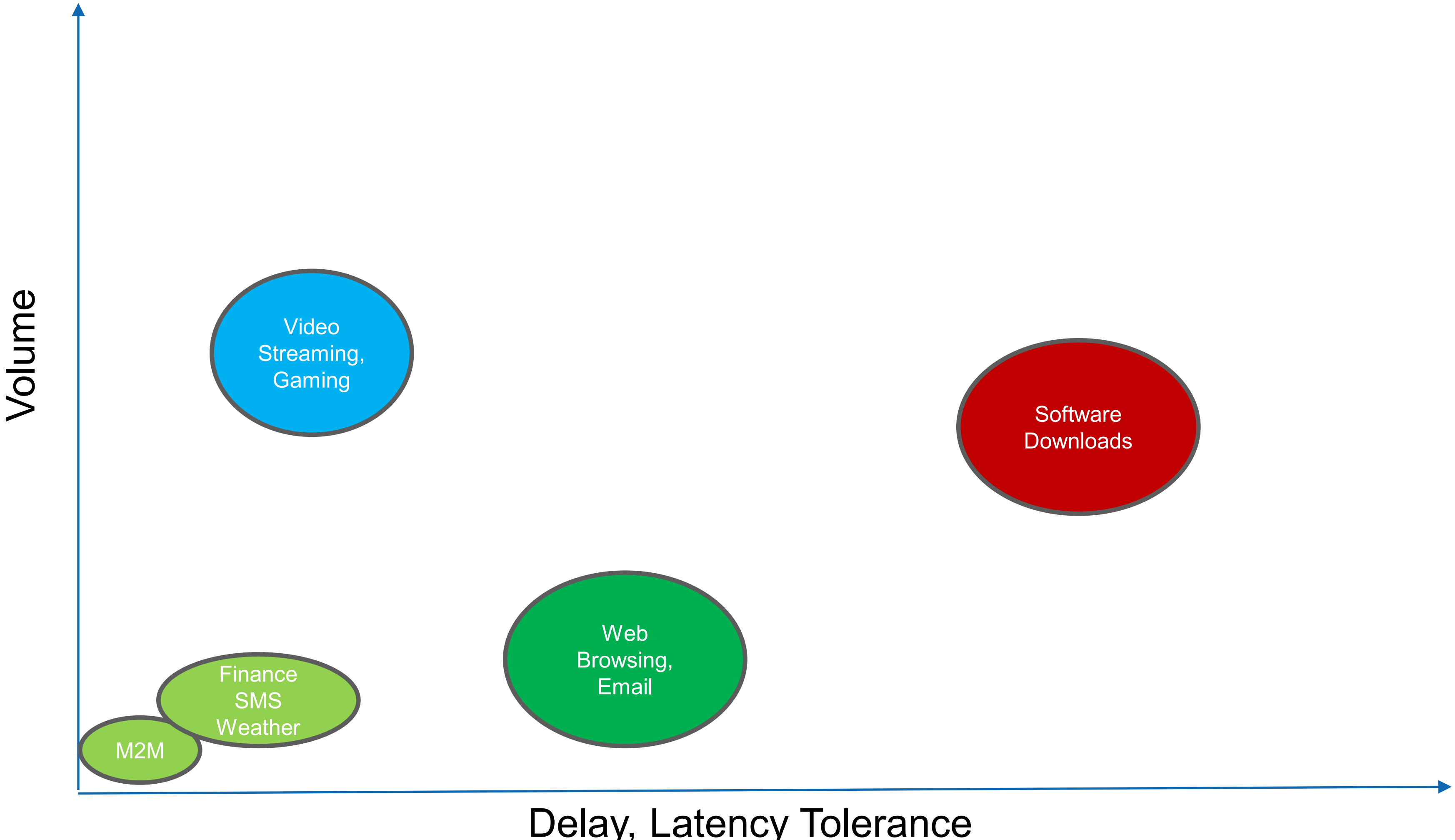
Interpreting technology hype - Gartner Hype Cycle



IoT Requirements for Various Applications

Requirements	Health	Aviation	Home Automation	Smart Cars	Wearables	Industrial Control
Reliability	high	high	high	high	low	high
Latency	long	low	long	low	long	low
Mobility	low	high	no	high	low	low
Security	high	high	high	high	mixed	high
Power	low	low/mix	mix	mix	low	mix
Protocol Message Size	short	mix	short	mix	mix	mix
Frequency of Interactions	low	high	Low	high	low	high

Data Behaviour



Internet of Things Communications Models

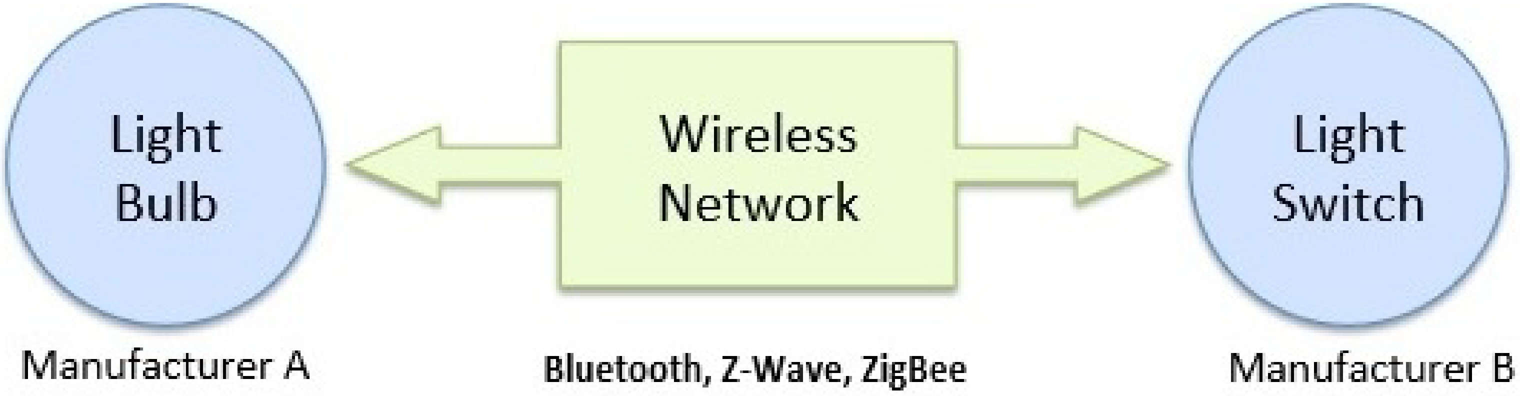
Internet of Things Communications Models

As stated in RFC 7452 Architectural Considerations in Smart Object Networking

- Device-to-Device Communications
- Device-to-Cloud Communications
- Device-to-Gateway Model
- Back-End Data-Sharing Model

Device-to-Device Communications

- The device-to-device communication model represents two or more devices that directly connect and communicate between one another, rather than through an intermediary application server.



Device-to-Device Communications

- These devices communicate over many types of networks, including IP networks or the Internet.

- Often, however these devices use protocols like Bluetooth, Z-Wave or ZigBee to establish direct device-to-device communications

Bluetooth

- Bluetooth transmission power is limited to 2.5 milliwatts, giving it a very short range of up to 10 metres (33 ft).
- It employs UHF radio waves in the ISM bands, from 2.402 GHz to 2.48 GHz.
- Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 35,000 member companies.
- As IEEE 802.11 is wifi standard, similarly the IEEE standardized Bluetooth as IEEE 802.15.1 but no longer maintains the standard.

Z - Wave

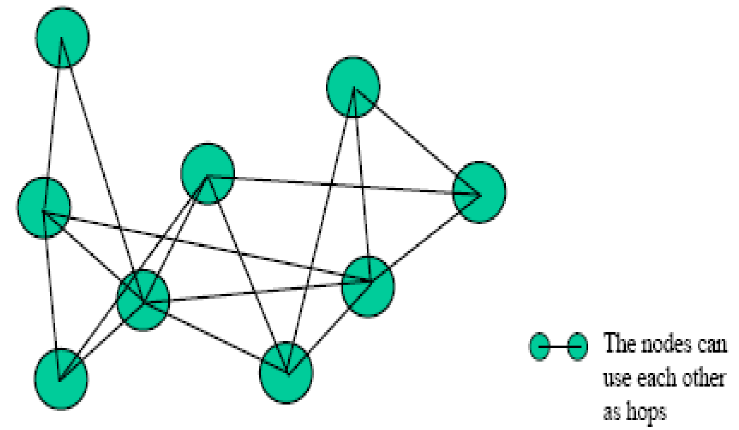
- Z-Wave is a wireless communications protocol used primarily for home automation.

- It uses low-energy radio waves to communicate from appliance to appliance, allowing for wireless control of residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers.

- Z-Wave automation system can be controlled via the Internet.

Z - Wave

- Z-Wave use mesh architecture network.



- 232 nodes can be connected to Z-Wave network. Bridging option can increase the number of nodes.

- Z-Wave uses the unlicensed industrial, scientific, and medical (ISM) band operating on varying frequencies globally Europe it operates at the 868-869 MHz band while in North America the band varies from 908-916 MHz

Zigbee

Zigbee is an IEEE 802.15 based specification for a suite of high-level communication protocols used to create personal area networks

It works with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.

Hence, zigbee is a low-power, low data rate, and close proximity (i.e., personal area) wireless mesh ad hoc network.

Zigbee

- Transmission distances to 10–100 meters (30' to 300') line-of-sight, depending on power output and environmental characteristics.
- Zigbee networks are secured by 128 bit symmetric encryption keys.
- Zigbee has a defined rate of up to 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Zigbee

- Zigbee operates in the industrial, scientific and medical (ISM) radio bands, including 2.4 GHz in most jurisdictions worldwide.

- Some devices also use 784 MHz in China, 868 MHz in Europe and 915 MHz in the US and Australia, even those regions and countries still use 2.4 GHz for most commercial Zigbee devices for home use.

- Data rates vary from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band).

Zigbee

- Zigbee technology is based on IEEE 802.15.4 developed by Zigbee Alliance

- Zigbee is good for short range but it requires large number of nodes to cover larger range, and maintenance cost increases manifold

- While designing the standard, the emphasis was on low power instead of low energy. Low power results in short range, thus increasing number of nodes and maintenance cost.

Zigbee

- Energy = Power x Time , so a better design could have worked on high power for very short amount of time and hibernating for rest.

- An undue emphasis on cost, instead of looking at a bigger model affected the standard. With high number of nodes covering a larger area, the maintenance cost surpasses the Zigbee hardware cost manifold.