IoT and 5G: Opportunities and Challenges

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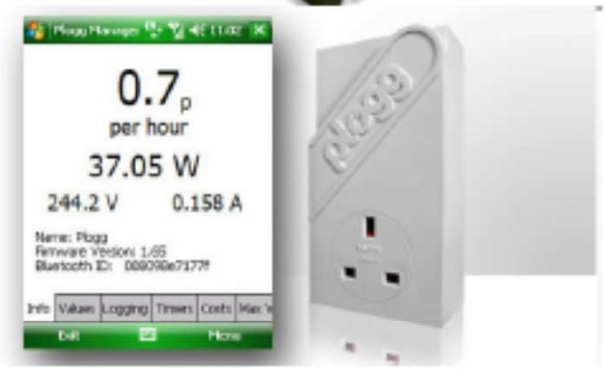
The Internet of Things: many definitions

- a ***dynamic*** global network infrastructure of ***adaptable*** and ***interoperable*** devices integrated in a common information and communication network (*CERP-IoT - IERC*, http://www.rfid-in-action.eu/cerp/)
- a ***collection of technologies*** that make it possible to connect things like sensors and actuators to the Internet, thereby ***allowing the physical world to be accessed through software*** (*Contiki project*, http://www.contiki-os.org)
- a layer of **digital connectivity** on top of **existing infrastructure and things** (*IoT Council*, http://www.theinternetofthings.eu)
- a vision of employing the ***networked devices and applications*** in business, information, and social processes
- The enabler for ***interconnecting ANYTHING, ANYTIME, ANYONE, ANY PLACE, ANY SERVICE, ANY NETWORK***
- ***A world where the real, digital and the virtual are converging to create smart environments*** that make energy, transport, cities and many other areas more intelligent.
- **Real-World-Web**

Sernsor Devices are widely Available Today



Sensors Everywhere:
Smart Environments & Applications

Smart Planet

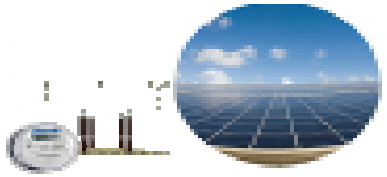
Green Environment

- Environmental sensors
- Water, power leak detection
- Pollution, weather monitoring

Smart Cities

Connected Communities

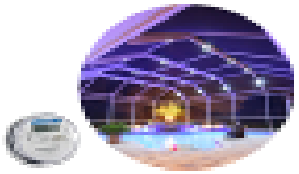
- Lighting, water management
- Monitoring & security
- Traffic control



Smart Energy

Electric Grid

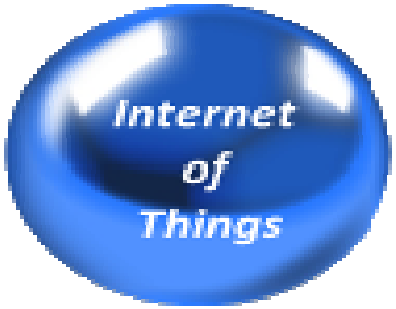
- Voltage and power sensors
- Meters and breakers
- Fault detection



Smart Buildings

Buildings, Smart Homes

- Thermostats, HVAC, lighting
- Presence sensors, lockers, actuators
- Meters, smart plugs, HEC



Smart Transport

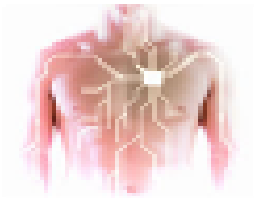
ITS, HFVs, FVs

- Electric Mobility, EVs and HEVs
- High Speed Trains
- Infrastructure, V2I, V2V, V2H

Smart Industry

Industrial Environments

- Lighting, security, actuators
- Production control
- Robotics



Smart Health

Healthcare System

- People monitoring
- Bio sensors, probes
- Remote health

Smart Living

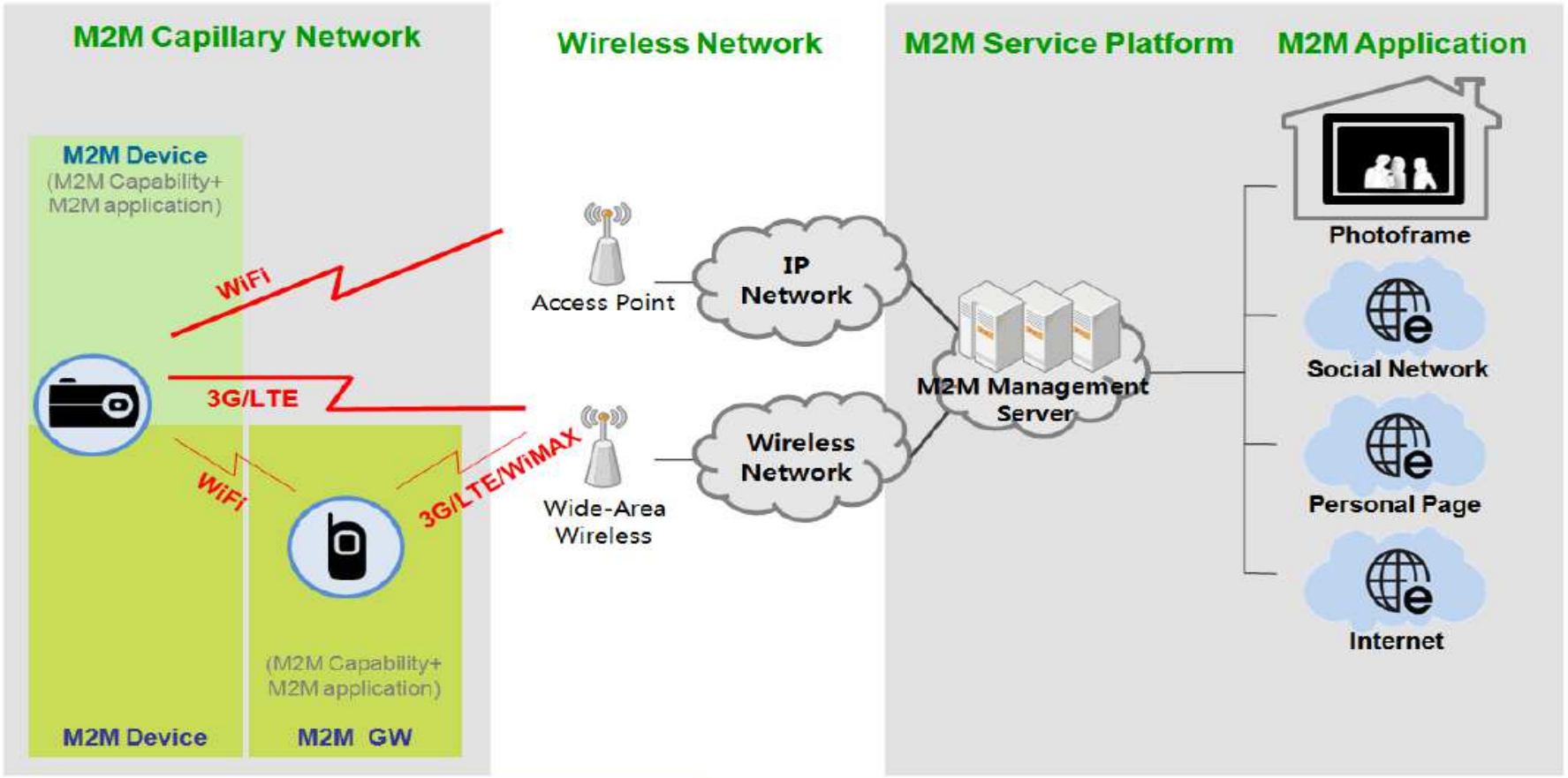
Entertaining, Leisure

- Independence through technology
- Information when you need it
- Connected when you need it

A new connectivity Era:
Things Connecting to Things

A new connectivity Era: People Connecting to Things

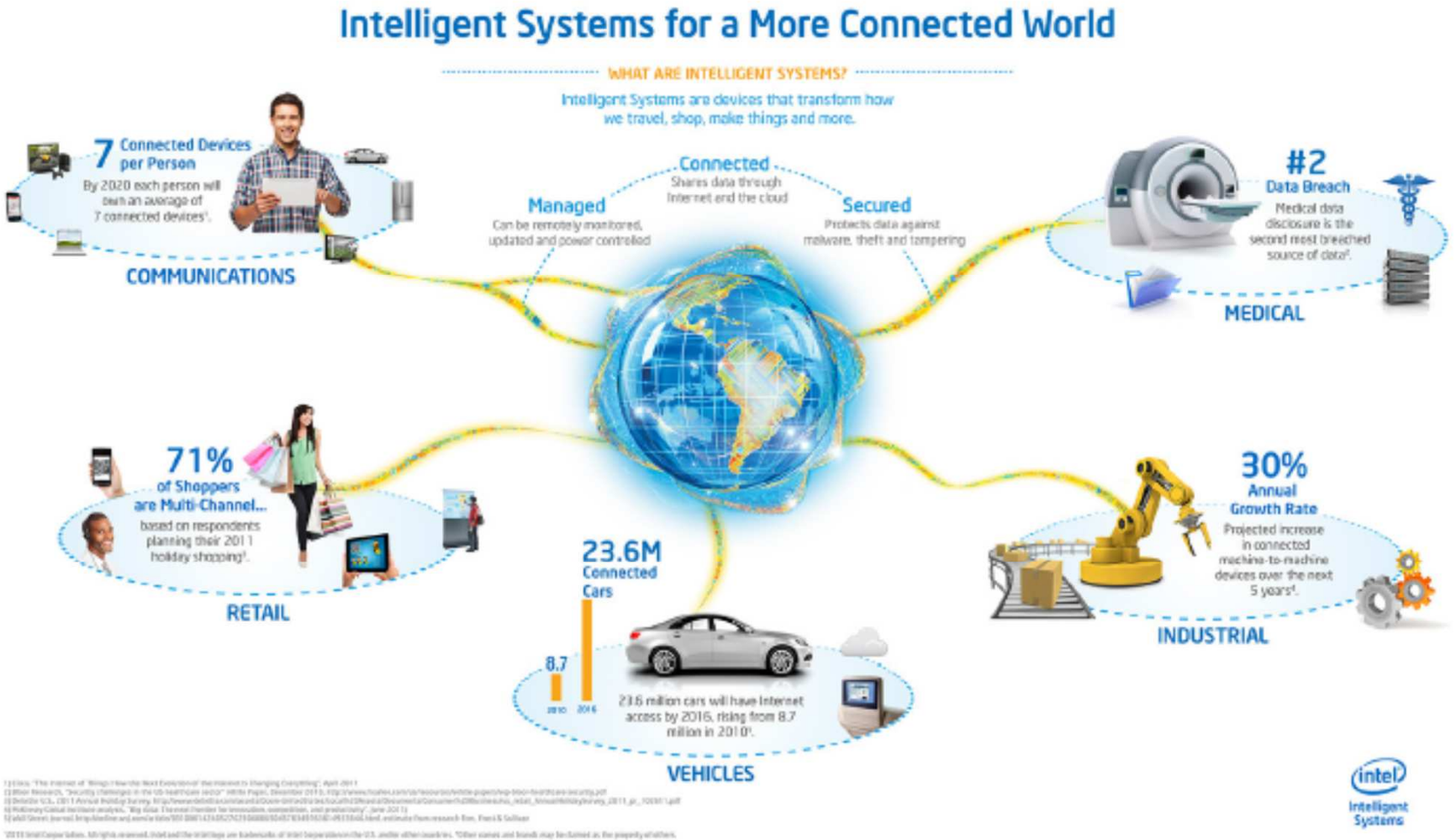
Connected Communities (Social IoT)



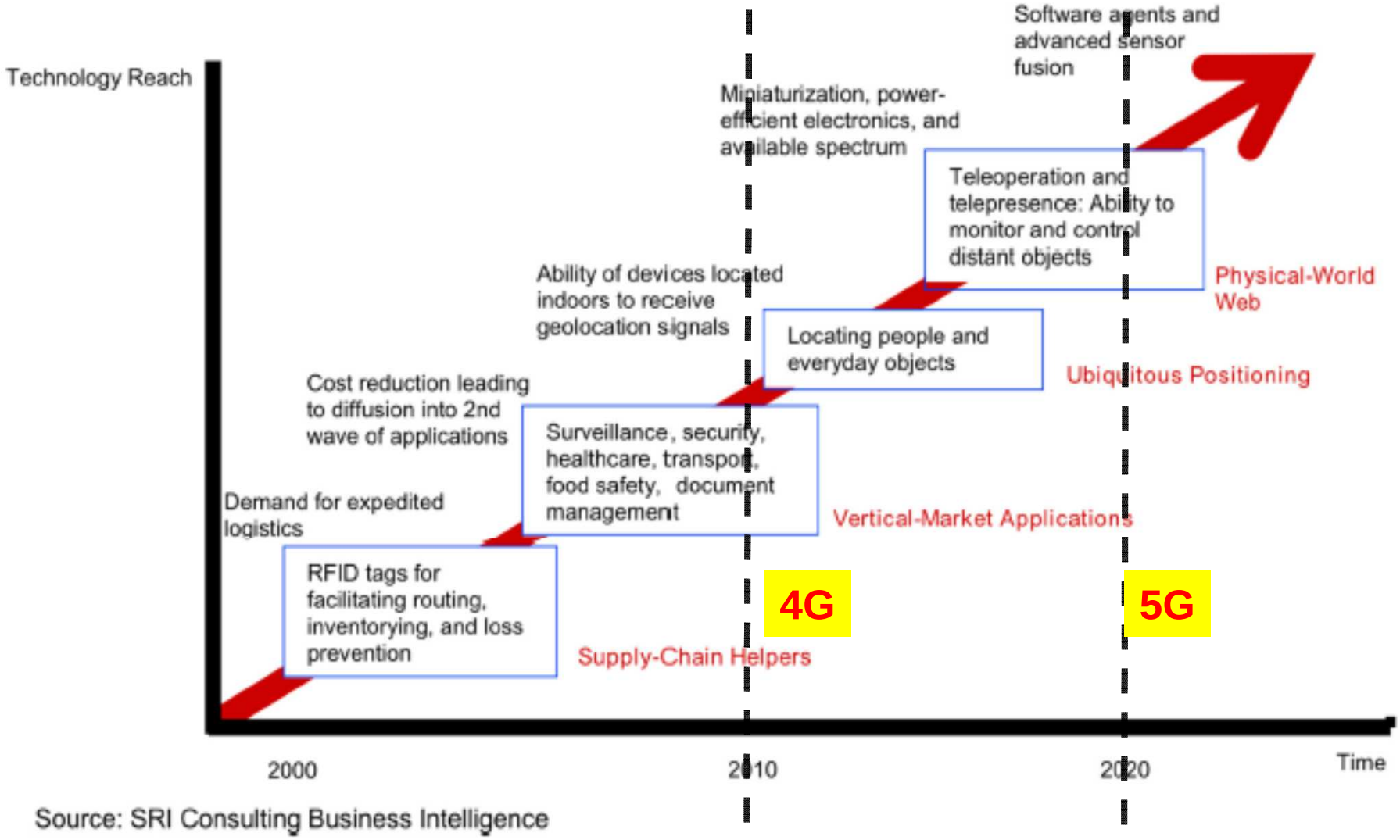
Share content and data between devices (& humans)

Aims to connect consumer equipment

Novel Opportunites From the Internet of Everything

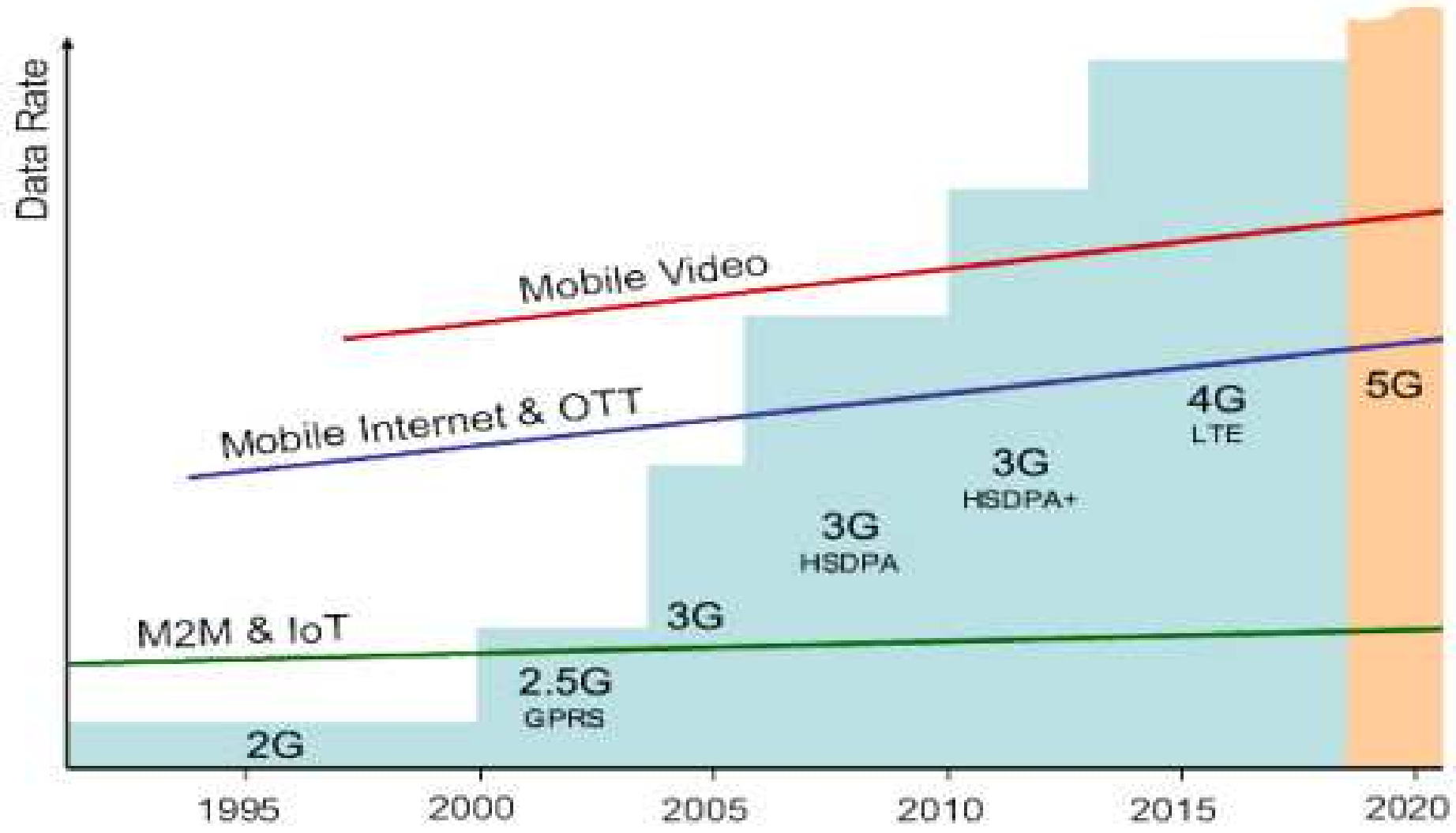


Technology Roadmap of IoT

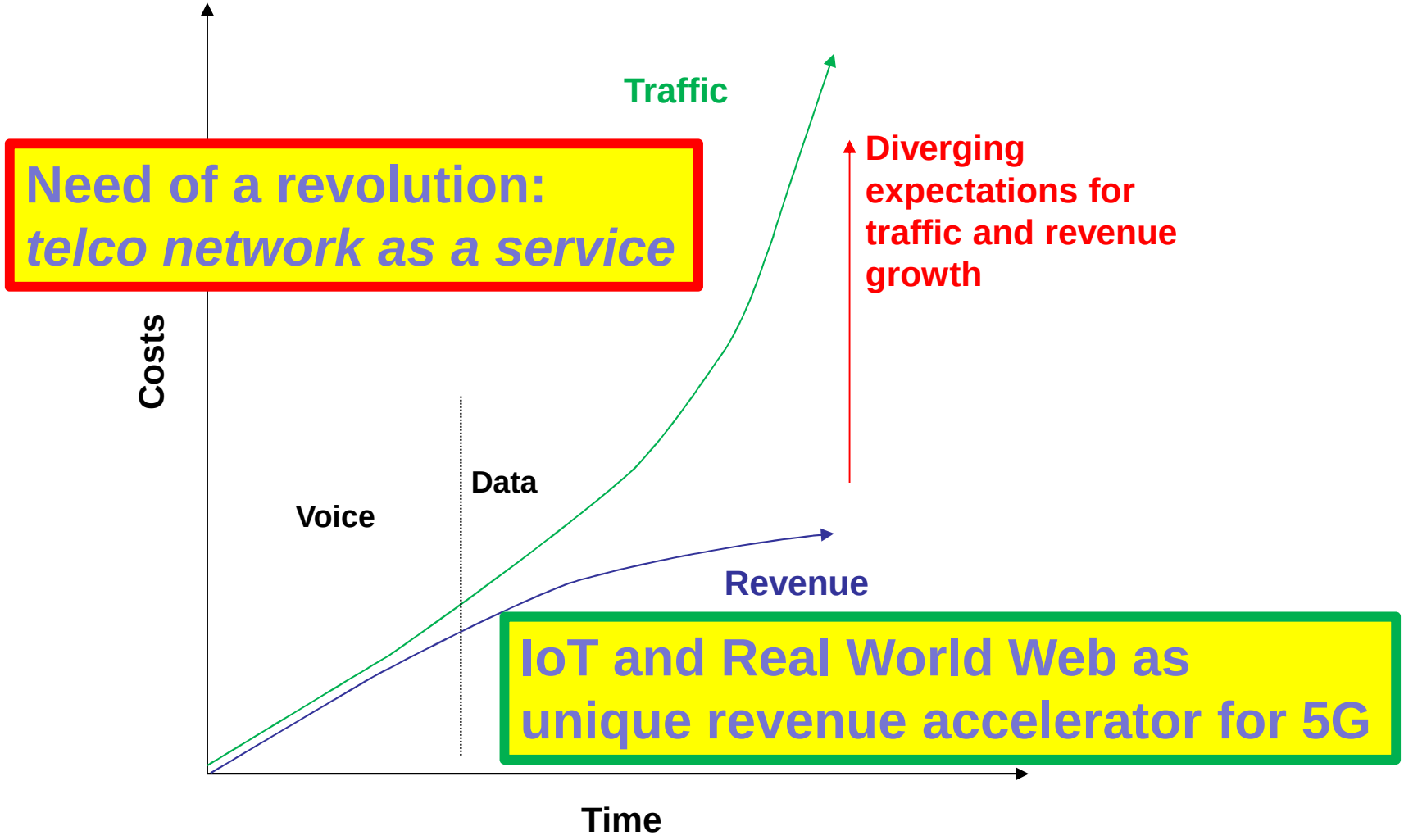


Source: SRI Consulting Business Intelligence

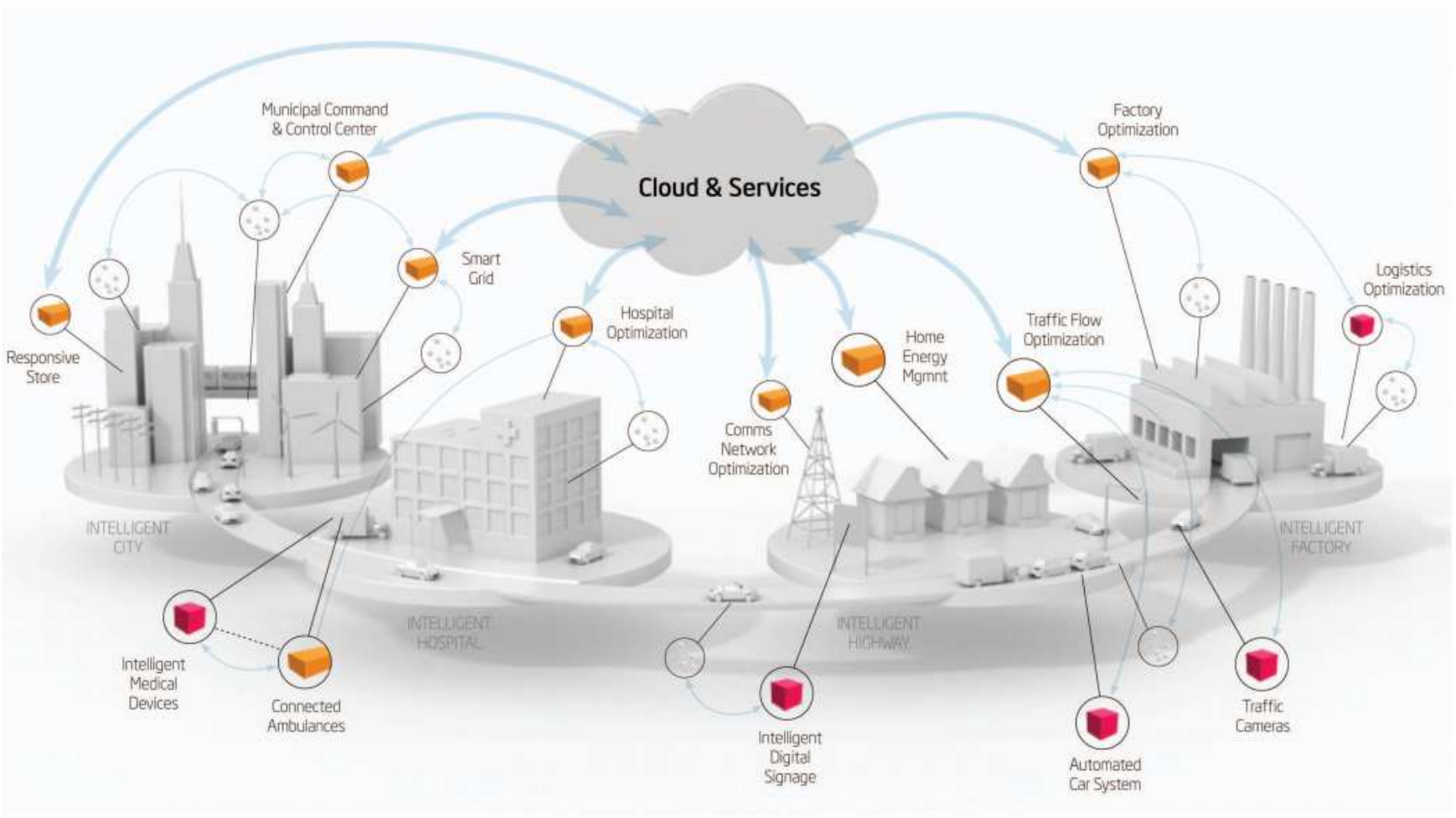
Demand in the Mobile Market



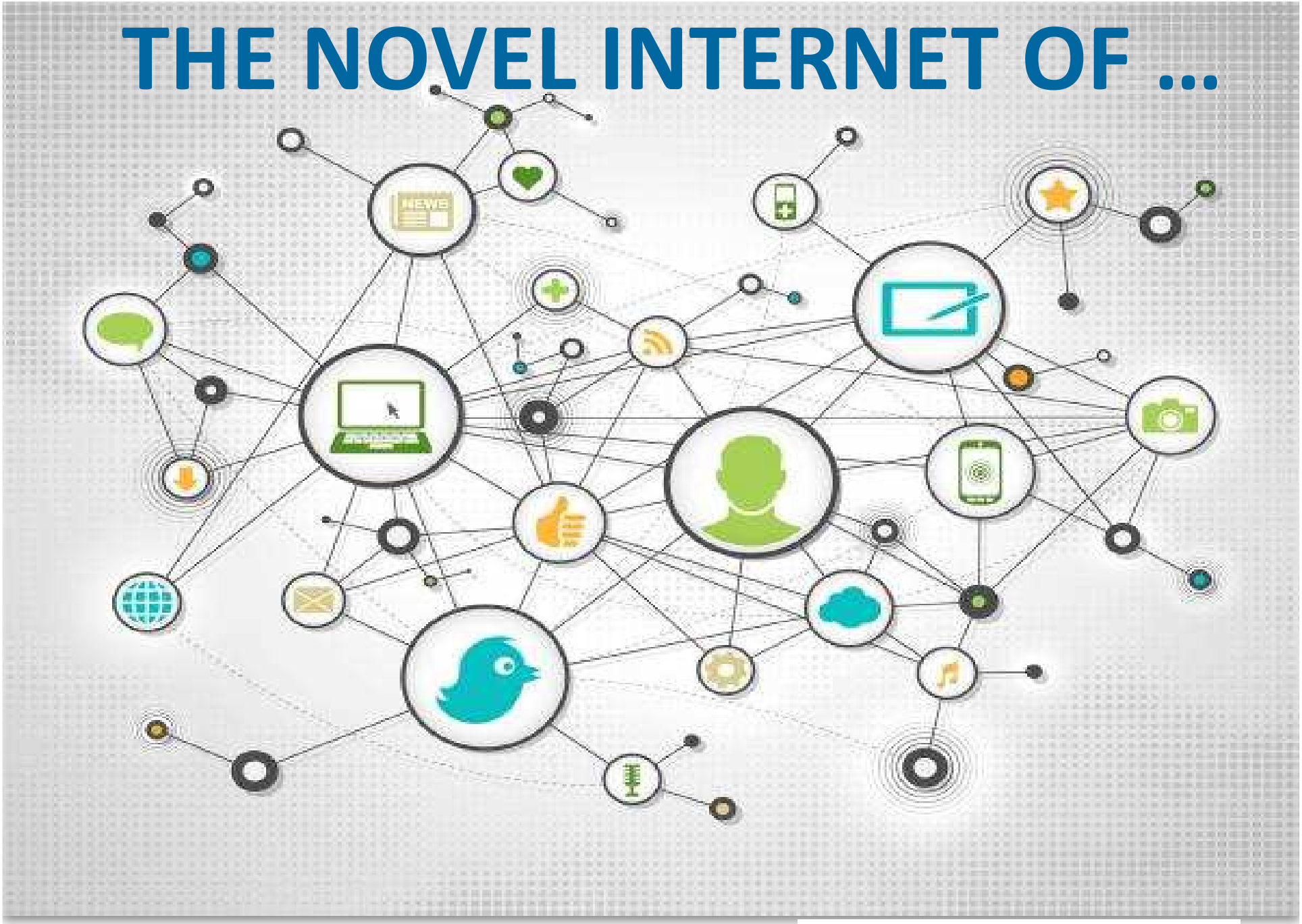
Classical Telelcom Market Revenues are going Down



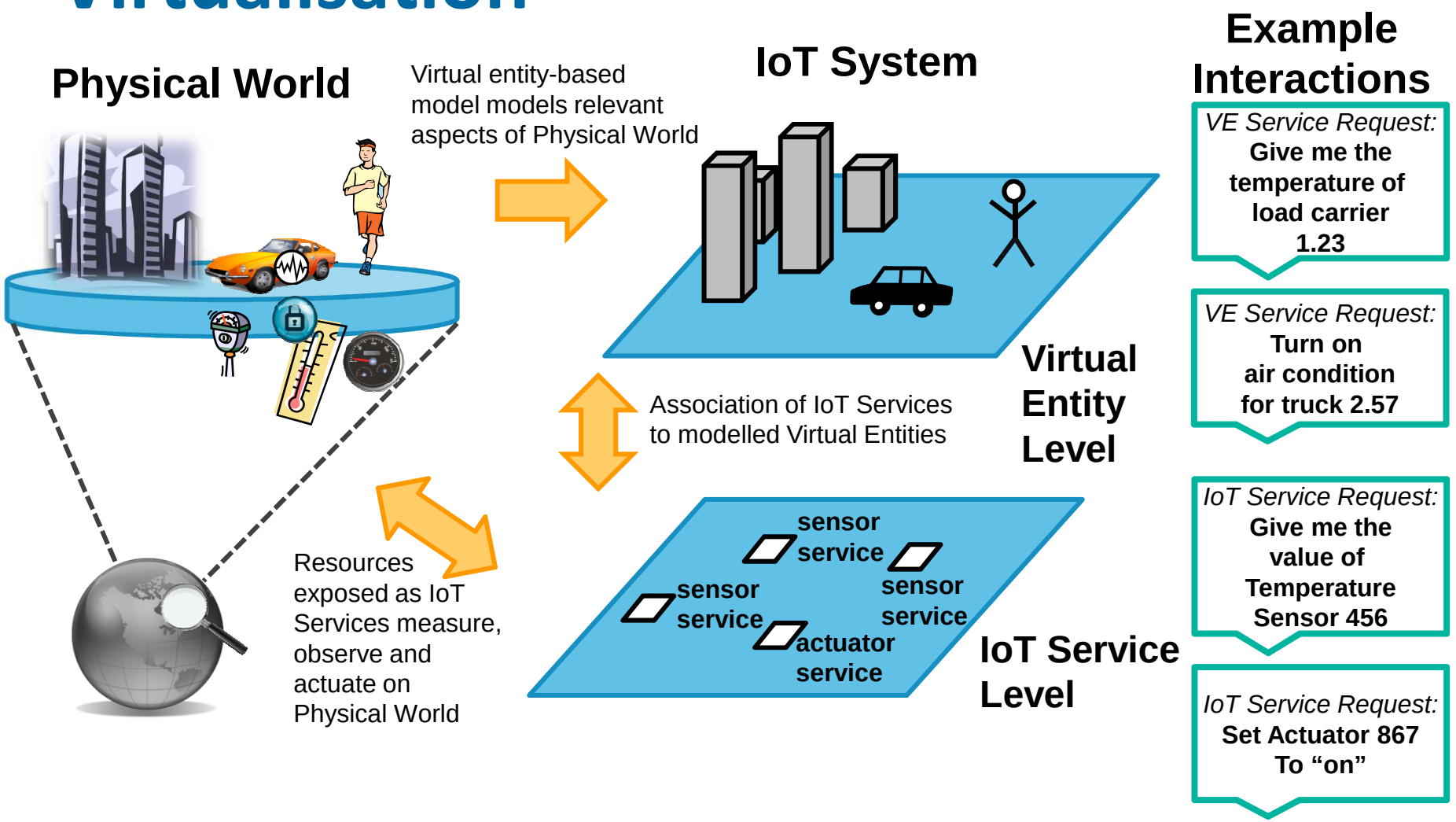
Vertical Markets will be Interconnected



THE NOVEL INTERNET OF …

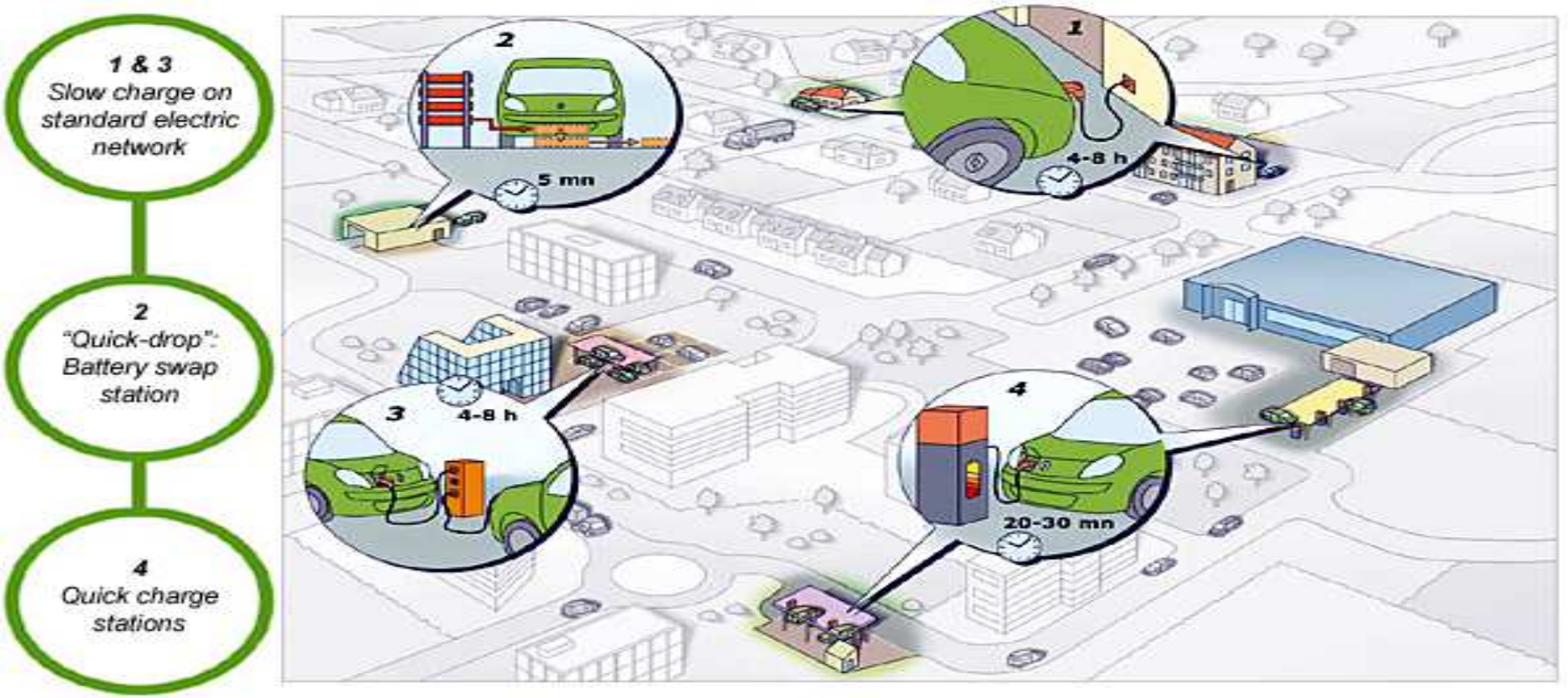


Modelling, Interactions & Virtualisation

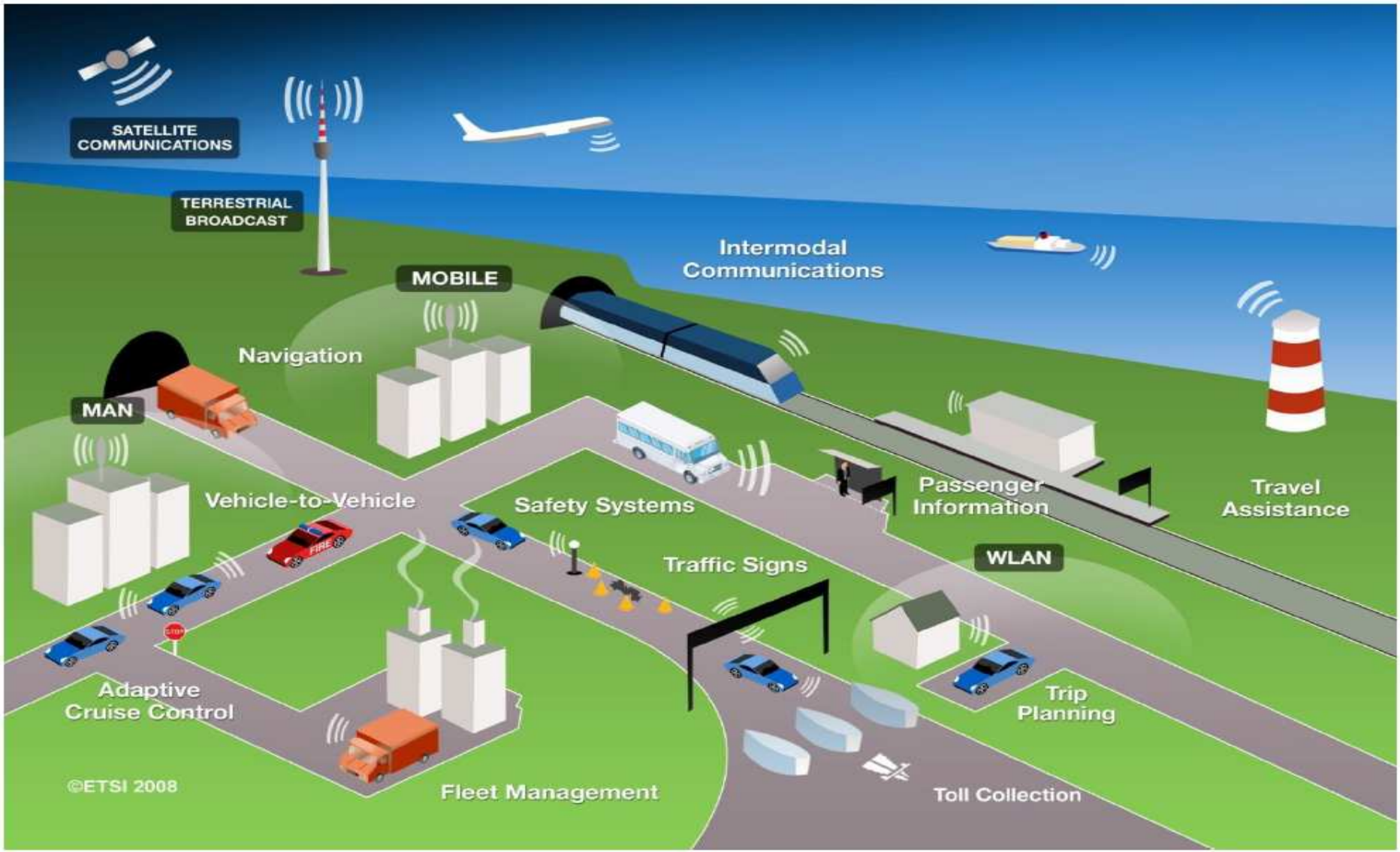


IoE: The Internet of Energy

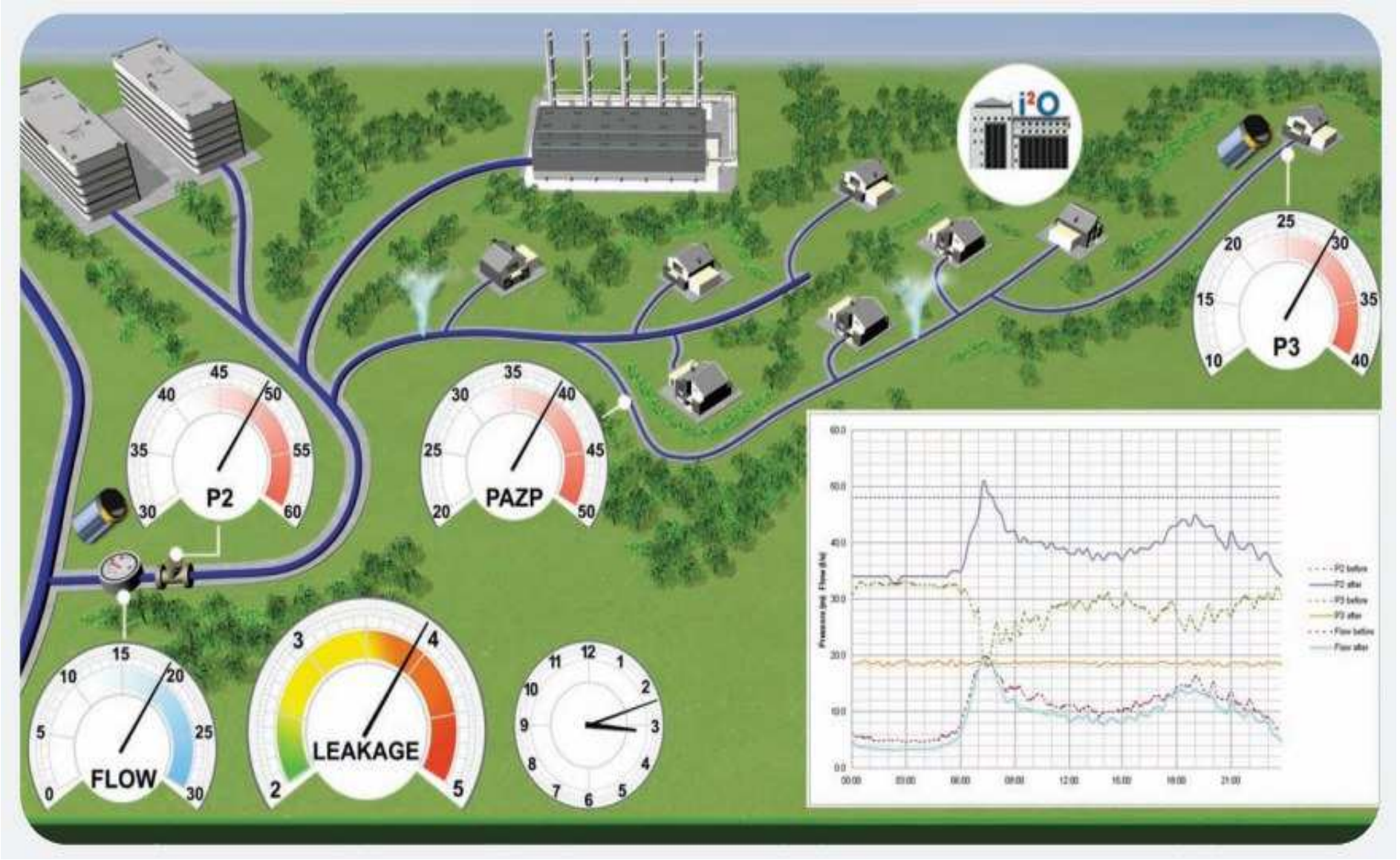
Smart Grid implemented in a kind of “Internet” in which the **energy packet** is managed similarly to the data packet - across **routers** and **gateways** which autonomously can decide the **best pathway** for the packet to reach its destination



IoV: The Internet of Vehicles



IoW: The Internet of Water



Deployment of ICT in smart cities: an Excellent IoT Use Case

Security and privacy management

- Security deployment for heterogeneous nodes
- Authentication / Key management
- Reliable communication
- Secure protocol /End-to-end security
- Lightweight cryptography for The IoT

Communication protocols

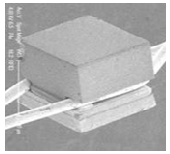
- Protocol design
- Compact antenna design
- Prototyping and deployment, ASIC design
- Low power, wearable technology

Traceability

- RFID (HF/UHF)
- Energy harvesting (zero power tags)
- Privacy and trust
- Supply and delivery chain management

Localization

- Indoor navigation and tracking
- Crowd collaborative localization
- Local based services



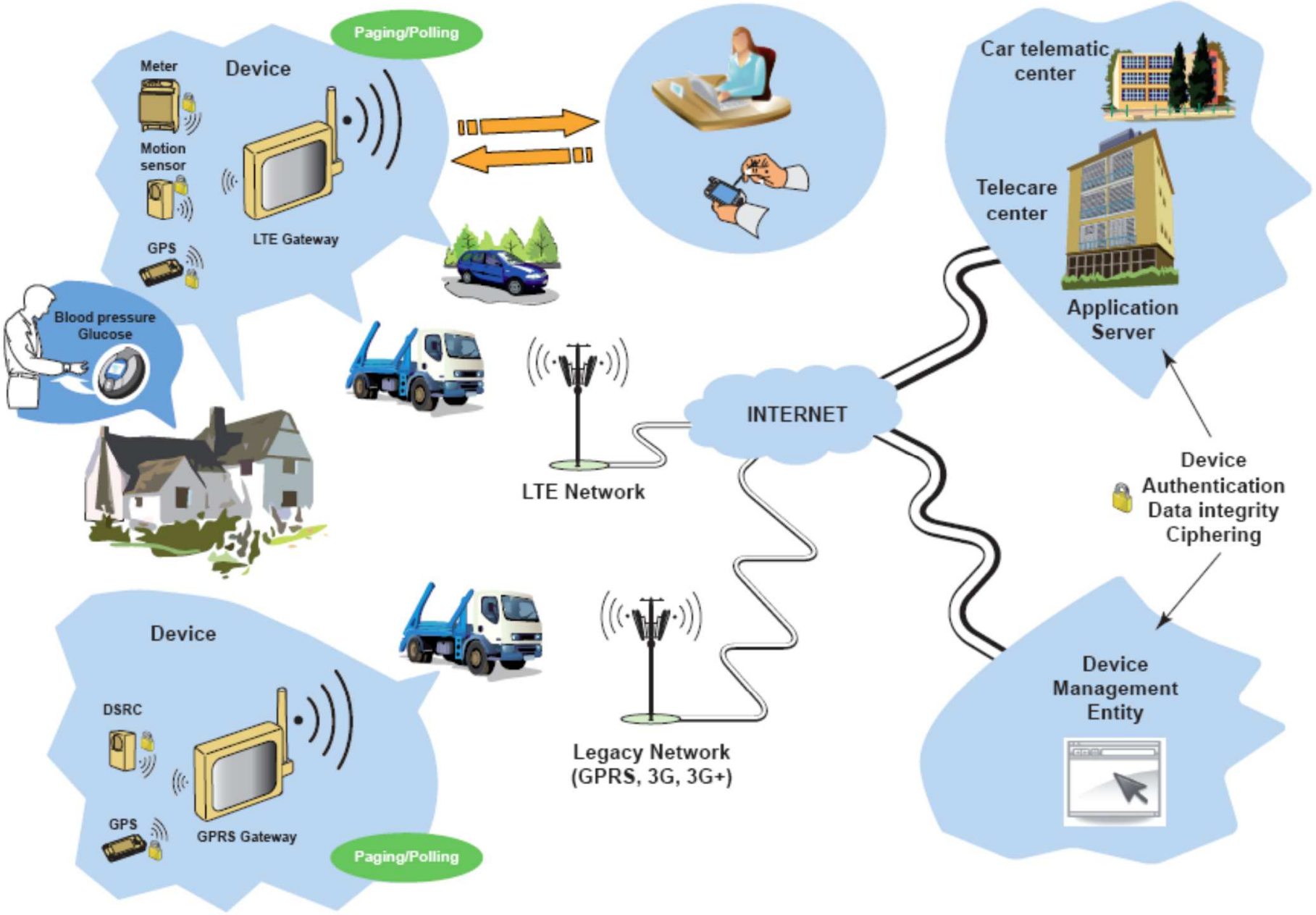
Sensors

- Sensor integration / signal processing
- Smart devices
- Low power / energy harvesting

IoT Applications: the smart-X

- The IoT application covers "**smart" environments/spaces** in domains such as:
  - Transportation
  - Building
  - City
  - Lifestyle
  - Agriculture
  - Factory
  - Supply chain
  - Emergency
  - Health care
  - User interaction
  - Culture and tourism
  - Environment
  - Energy
  - …

IoT: a large panel of applications



Cities: IoT Applications

- **Smart Parking:** Monitoring of parking spaces availability in the city.
- **Structural health:** Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
- **Noise Urban Maps:** Sound monitoring in bar areas and centric zones in real time.
- **Traffic Congestion:** Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
- **Smart Lightning:** Intelligent and weather adaptive lighting in street lights.
- **Waste Management:** Detection of rubbish levels in containers to optimize the trash collection routes.
- **Intelligent Transportation Systems:** Smart Roads and Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

Environnent: IoT Applications

- **Forest Fire Detection:** Monitoring of combustion gases and preemptive fire conditions to define alert zones.
- **Air Pollution:** Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.
- **Landslide and Avalanche Prevention:** Monitoring of soil moisture, vibrations and earth density to detect dangerous patterns in land conditions.
- **Earthquake Early Detection:** Distributed control in specific places of tremors.

Water: IoT Applications

- **Water Quality:** Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.
- **Water Leakages:** Detection of liquid presence outside tanks and pressure variations along pipes.
- **River Floods:** Monitoring of water level variations in rivers, dams and reservoirs.

Energy Smart Grid, Smart Metering: IoT Applications

- **Smart Grid:** Energy consumption monitoring and management.
- **Tank level:** Monitoring of water, oil and gas levels in storage tanks and cisterns.
- **Photovoltaic Installations:** Monitoring and optimization of performance in solar energy plants.
- **Water Flow:** Measurement of water pressure in water transportation systems.
- **Silos Stock Calculation:** Measurement of emptiness level and weight of the goods.

Security & Emergencies:
IoT Applications

- **Perimeter Access Control:** Access control to restricted areas and detection of people in non-authorized areas.
- **Liquid Presence:** Liquid detection in data centres, warehouses and sensitive building grounds to prevent break downs and corrosion.
- **Radiation Levels:** Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.
- **Explosive and Hazardous Gases:** Detection of gas levels and leakages in industrial environments, surroundings of chemical factories and inside mines.

Retail: IoT Applications

- **Supply Chain Control:** Monitoring of storage conditions along the supply chain and product tracking for traceability purposes.
- **NFC Payment:** Payment processing based in location or activity duration for public transport, gyms, theme parks, etc.
- **Intelligent Shopping Applications:** Getting advice at the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.
- **Smart Product Management:** Control of rotation of products in shelves and warehouses to automate restocking processes.

Logistics: IoT Applications

- **Quality of Shipment Conditions:** Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.
- **Item Location:** Search of individual items in big surfaces like warehouses or harbours.
- **Storage Incompatibility Detection:** Warning emission on containers storing inflammable goods closed to others containing explosive material.
- **Fleet Tracking:** Control of routes followed for delicate goods like medical drugs, jewels or dangerous merchandises.

Industrial Control: IoT Applications

- **M2M Applications:** Machine auto-diagnosis and assets control.
- **Indoor Air Quality:** Monitoring of toxic gas and oxygen levels inside chemical plants to ensure workers and goods safety.
- **Temperature Monitoring:** Control of temperature inside industrial and medical fridges with sensitive merchandise.
- **Ozone Presence:** Monitoring of ozone levels during the drying meat process in food factories.
- **Indoor Location:** Asset indoor location by using active (ZigBee, UWB) and passive tags (RFID/NFC).
- **Vehicle Auto-diagnosis:** Information collection from CAN Bus to send real time alarms to emergencies or provide advice to drivers.

Agriculture: IoT Applications

- **Wine Quality Enhancing:** Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.
- **Green Houses:** Control micro-climate conditions to maximize the production of fruits and vegetables and its quality.
- **Golf Courses:** Selective irrigation in dry zones to reduce the water resources required in the green.
- **Meteorological Station Network:** Study of weather conditions in fields to forecast ice formation, rain, drought, snow or wind changes.
- **Compost:** Control of humidity and temperature levels in alfalfa, hay, straw, etc. to prevent fungus and other microbial contaminants.

Animal Farming:IoT Applications

- **Offspring Care:** Control of growing conditions of the offspring in animal farms to ensure its survival and health.
- **Animal Tracking:** Location and identification of animals grazing in open pastures or location in big stables.
- **Toxic Gas Levels:** Study of ventilation and air quality in farms and detection of harmful gases from excrements.

Domotic & Home Automation: IoT Applications

- **Energy and Water Use:** Energy and water supply consumption monitoring to ***obtain advice*** on how to save cost and resources.
- **Remote Control Appliances:** Switching on and off remotely appliances to avoid accidents and save energy.
- **Intrusion Detection Systems:** Detection of window and door openings and violations to prevent intruders.
- **Art and Goods Preservation:** Monitoring of conditions inside museums and art warehouses.

eHealth: IoT Applications

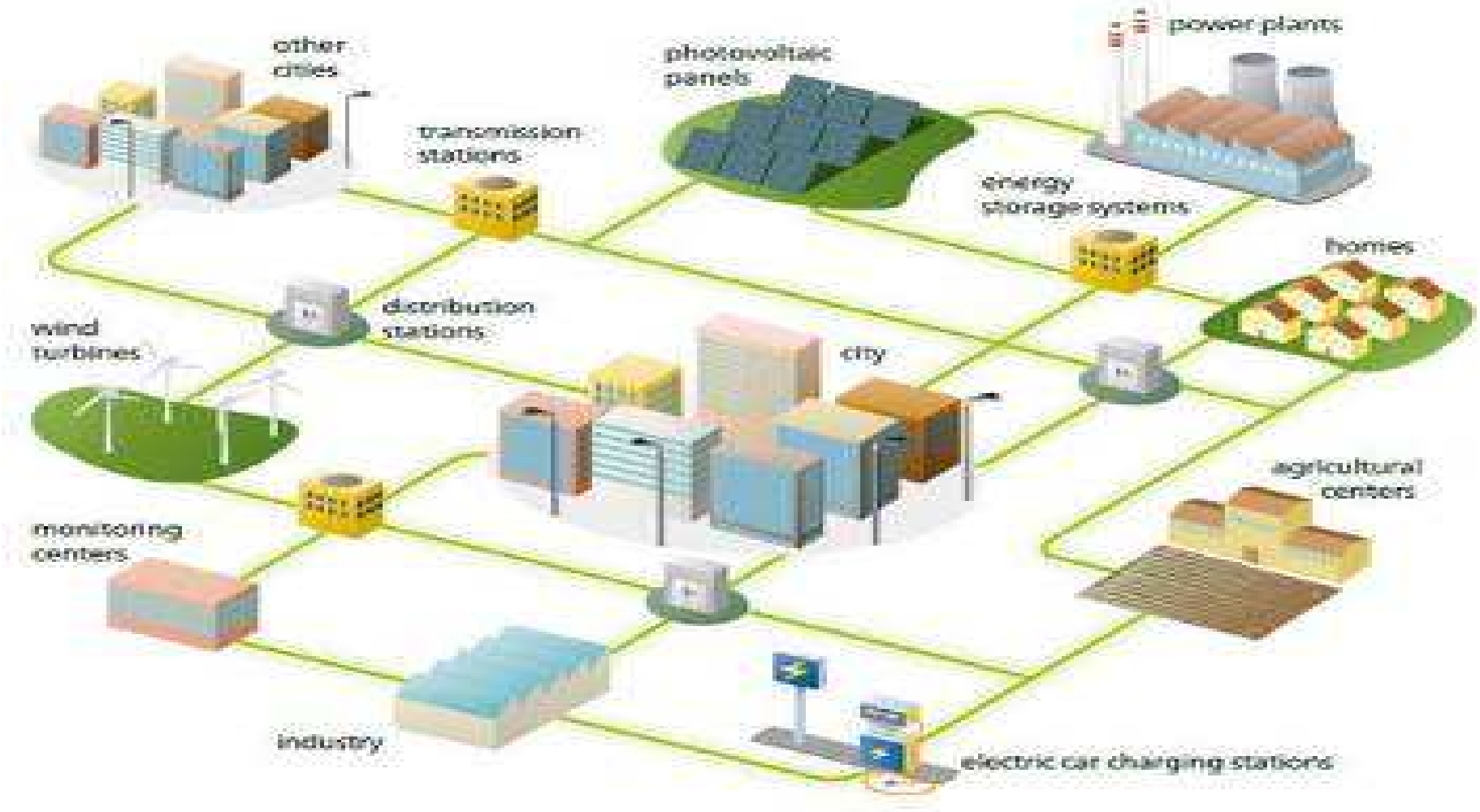
- **Fall Detection:** Assistance for elderly or disabled people living independent.
- **Medical Fridges:** Control of conditions inside freezers storing vaccines, medicines and organic elements.
- **Sportsmen Care:** Vital signs monitoring in high performance centres and fields.
- **Patients Surveillance:** Monitoring of conditions of patients inside hospitals and in old people's home.
- **Ultraviolet Radiation:** Measurement of UV sun rays to warn people not to be exposed in certain hours.

RESEARCH CHALLENGES

Smart Cities: Research Challenges

- Creating algorithms and schemes to **describe information created by sensors in different applications** to enable useful exchange of information between different city services
- Mechanisms for **cost efficient deployment** and even more important **maintenance** of such installations, including energy scavenging
- Ensuring **reliable readings from a plethora of sensors**
- **Efficient calibration** of a large number of sensors deployed everywhere from lampposts to waste bins
- **Low energy** protocols and algorithms & energy harvesting
- Algorithms for **analysis and processing of data acquired** in the city and ***making "sense" out of it***.
- **IoT large scale deployment and integration**
  - The exemple of SmartSantander

Smart Energy & Smart Grids



Smart Energy & Smart Grids : Research Challenges

- **Reliable network**: blackout free electricity generation and distribution
- **Flexibility**: to allow heterogeneous energy supply to or withdrawal from the grid, and is impervious to accidental or intentional manipulations
- **Evolution**: The increased system complexity poses technical challenges that must be considered as the system is operated in ways that were not intended when the infrastructure was originally built
- **Security**:
  - to lower **system vulnerability** and protect stakeholder and citizens data
  - **Communication security**: Absolutely safe and secure communication with elements at the network edge
- **Scalability** of security functions
- **Privacy**: Technologies for data anonymity addressing privacy concerns

Smart Energy & Smart Grids : Research Challenges

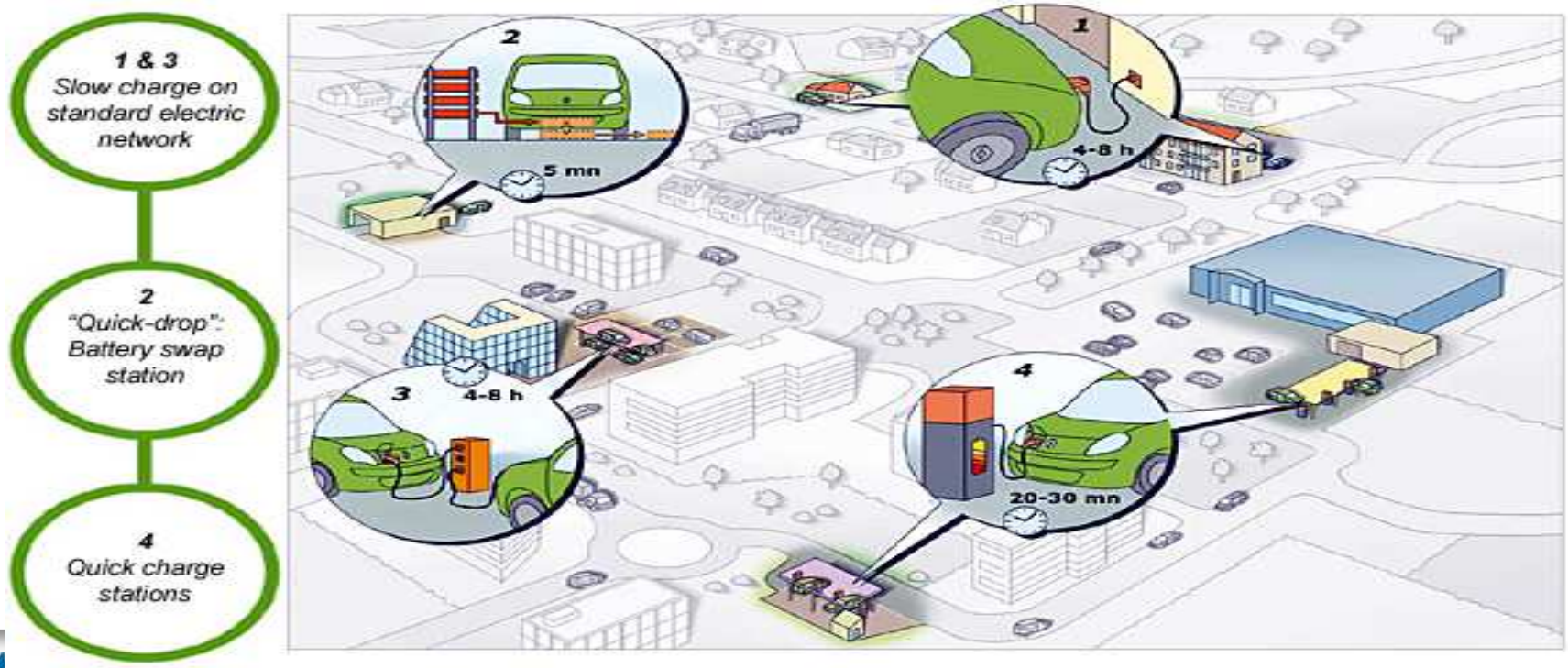
- **Real-Time**: Latencies are critical when talking about electrical control loops
  - Issue of cloud based solutions and related processing and communication delays
- **Standardization** of communication stacks: ex LTE-M and interoperability
- Scalability
- **Energy Saving**: combined with robust and reliable smart sensors/actuators activity
- **System partitioning** (local/cloud based intelligence)
- **Mass data processing, filtering and mining**; avoid flooding of communication network

Smart Energy & Smart Grids : Research Challenges

- **Real-time Models and design methods** describing reliable interworking of heterogeneous systems
  - Identifying and monitoring critical system elements.
  - Detecting critical overall system states in due time
- **Self-healing** and containment of damage; strategies for failure contingency management
- **Interoperability** between classical and renewable energies:
  - Power grids have to be able to react correctly and quickly to fluctuations in the supply of electricity from renewable energy sources such as wind and solar facilities

Smart Transport and Mobility

- **Internet of Vehicules**: connection of vehicles to the Internet
- **Goal**: making of transport easier, safer and sustainable
- **Future trends:** connect the Internet of Vehicules with the internet of Energies



Smart Transport and Mobility: Open Problems

- Representing human behavior in the design
  - Ex. limited understanding of **how driver behaviour** will be affected by adaptive traffic control cyber physical systems
  - Ex. difficult to account for the stochastic effects of the human driver in a **mixed traffic environment**
- development, and operation of cyber physical systems in **autonomous vehicles**
- **Incorporating human-in-the-loop**: safety, dependability, and predictability (low latency control

Smart Transport and Mobility : Application Scenarios

- **charging voltage of the power electronics**: open question → whether the recharging processes should be controlled by a system within the vehicle or one installed at the charging station
- **IoT based vehicule management:** data from on-board sensors are collected by a smart on-board unit and communicated via the Internet to the service centre
- **IoT self traffic management and control:** Cars should be able to organise themselves in order to avoid traffic jams and to optimise drive energy usage
  - Done in coordination and cooperation with the infrastructure of a smart city's traffic control

Smart Transport and Mobility : Application Scenarios

- Dynamic **road pricing** and parking tax
- Mutual **communications between** the **vehicles** and with the **infrastructure** (mobility and coverage)
- **Multi-Modal Transport**:
  - based on
    - momentary traffic situation
    - available and suitable transport means: individual vehicles, vehicle sharing, railway, …

Smart Transport and Mobility : Research Challenges

- **Safe and secure communication** with elements at the network edge, inter-vehicle communication, and vehicle to infrastructure communication
- **smart sensors and actuators design** in vehicles and infrastructure
- Technologies for **data anonymity** addressing privacy concerns
- **System partitioning** (local/cloud based intelligence)
- **Detecting critical** overall **system states** in due time
- **self-organisation** and dynamic formation of structures / re-structuring
- Ensure an adequate level of **trust and secure exchange of data among different vertical ICT infrastructures** (e.g., intermodal scenario)

Food & Water Tracking and security

Food and fresh water are the most important natural resources in the world

- offering "from pasture to plate" traceability

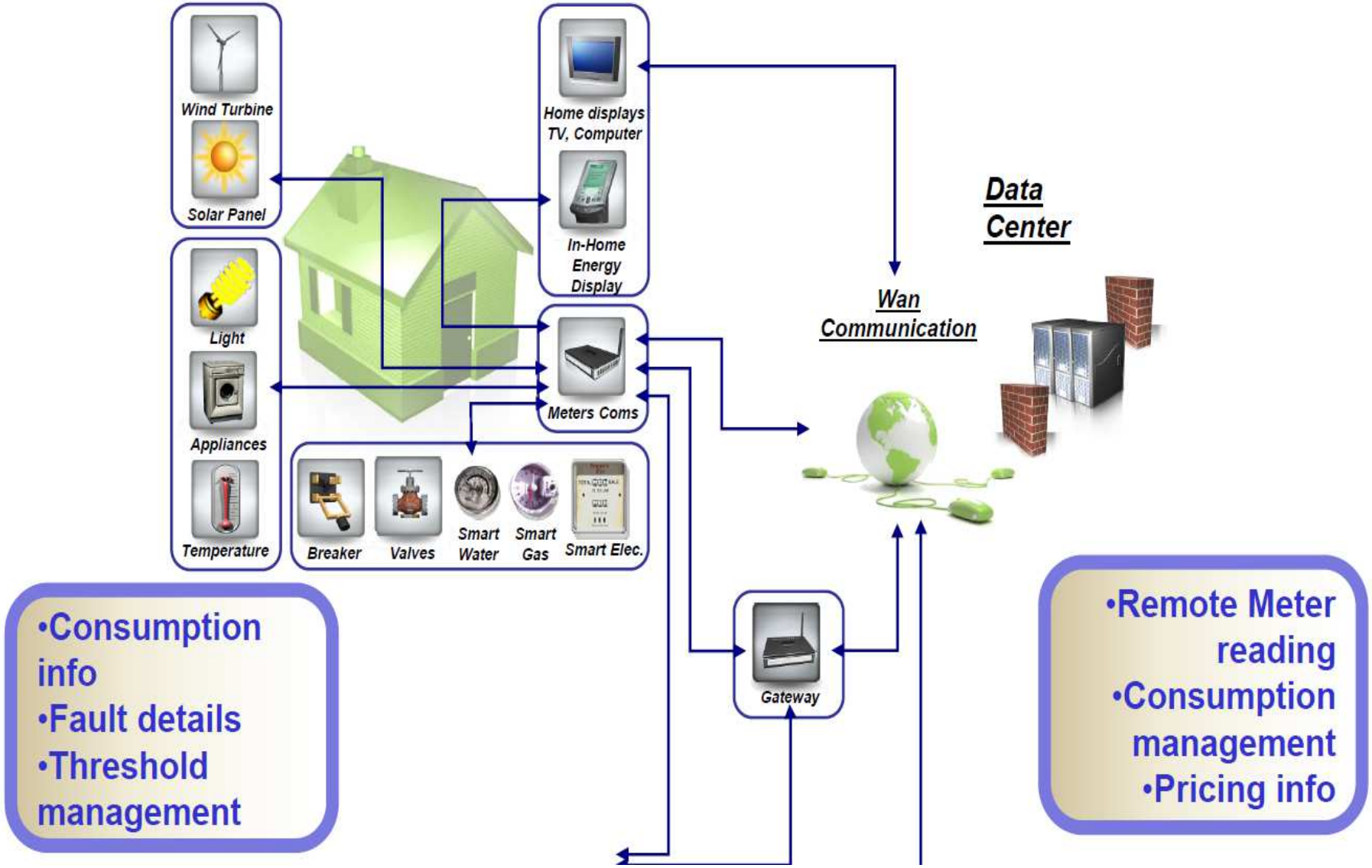
- Use of IoT to secure tracking of food or water from the production place to the consumer

- On going now: beef meat but horse scandals are on the table!

Food & Water Tracking and security: Research Challenges

- Design of **secure and cost-efficient** mechanisms for **tracking food and water** from production to consumers
- **Secure monitoring production processes**
  - providing sufficient information and confidence to consumers.
  - Privacy: time details of the production processes which might be considered as intellectual property
- Ensure **trust and secure exchange of data** among applications and infrastructures (farm, packing industry, retailers)
  - to prevent the introduction of false or misleading data

Smart metering



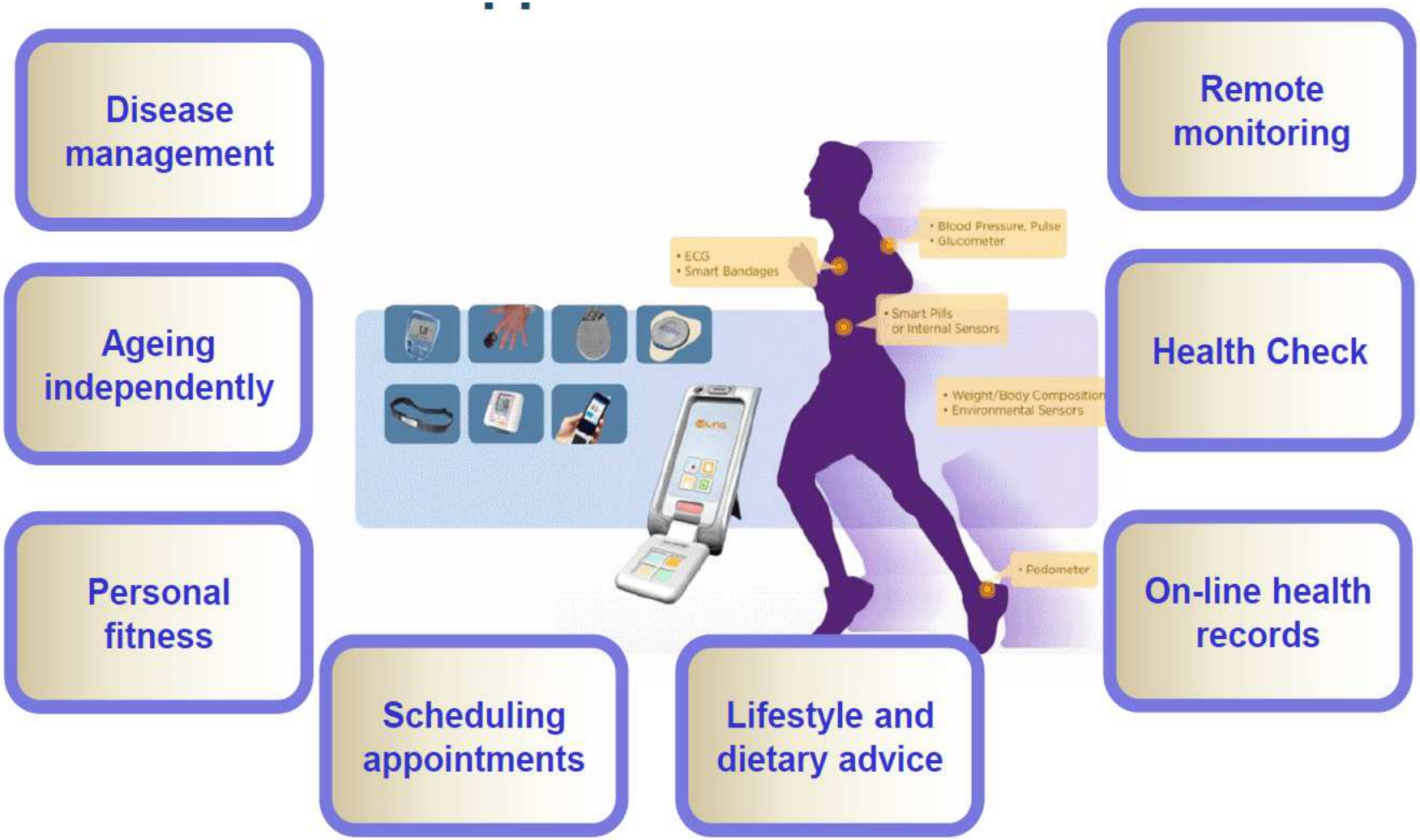
Smart metering:
Challenges at Application level

- **Network management** – network technologies should be reliable, intelligent, self-managed, context aware and adaptable
- **Interfaces** – to refine interaction between HW, SW, algorithms, devices, ...; smart human / machine interfaces, enabling mobile SW
- **Embedded smart functionality** – further development of sensors, actuators, storage, energy sources, middleware, sensor networks, etc.
- **Multi-domain communications** – to enhance information and signal processing, identification technology, discovery and search engine technologies
- **Security, privacy, business safety** – improvements needed by developing novel security techniques and concepts
- **Standardisation, interoperability, validation and modularization** of the IoT technologies needs enhancements
- **New governance principles** should be defined – free access to knowledge for further technology and business development (while maintaining respect for privacy, security and safety)

Smart metering:
Challenges at Technology level

- **Energy** – ultra low power devices & energy Harvestin needed
- **Intelligence** – capabilities of self-awareness, adaptability, inter-machine communication, knowledge discovery, etc.
- **Communication** – new smart antennas, protocols, APIs, together with network management and visualization techniques need to be developed
- **Integration** – wireless ID technologies (RFID) should be integrated to devices
- **Dependability** – individual authentication of billions of heterogeneous devices
- **Semantic technologies** – large scale distributed ontologies, semantic discovery of devices, semantic web services, rule engines, ...
- **Real world IoT scenarios** – to evaluate IoT solutions in real large-scale industrial applications; to illustrate business-based scenarios
- **Modeling and design** – innovative M-D frameworks needed for large scale IoT systems
- **Interoperability, standards** – ensure interoperability of devices by integrating different standardized architectures, protocols, etc.; define open standards and reference models
- **Manufacturing** – to lower costs of key technologies (e.g., RFID)

e-Health



IoT Related Open Challenges

- ***Making "sense" out of it***
  - **Mass data processing, filtering and mining**
  - **analysis and processing of data acquired**
  - **Describe information created by sensors in different applications**
  - **Efficient calibration of heterogeneous sensors**
- **Deployment**
  - **Cost efficiency**
  - **Maintenance**
  - **Scalability**
    - **Ex: IoT large scale deployment and integration**
      - SmartSantander
  - **Evolution & Interoperability between classical, novel and future functions**
- **Energy**
  - **Low energy**
  - **Energy harvesting**
  - **Energy Saving**
  - **Low power communications**

IoT Related Open Challenges

- **System partitioning** (local/cloud based intelligence)
- **Incorporating human-in-the-loop**
  - **Representing human behavior in the design**
  - **User awareness & Serious Gaming**
- **Reliable Network**
  - **Reliable readings from a plethora of sensors**
  - **Self-healing**
  - **Real-Time**
- **Security & Privacy**:
  - **System vulnerability**
  - **Communication security**
  - **Consumers and stakeholders data privacy**
  - **Data anonymity**
  - **Scalability of security functions**
- **Standardization**

3G/4G Limitation for IoT Applications

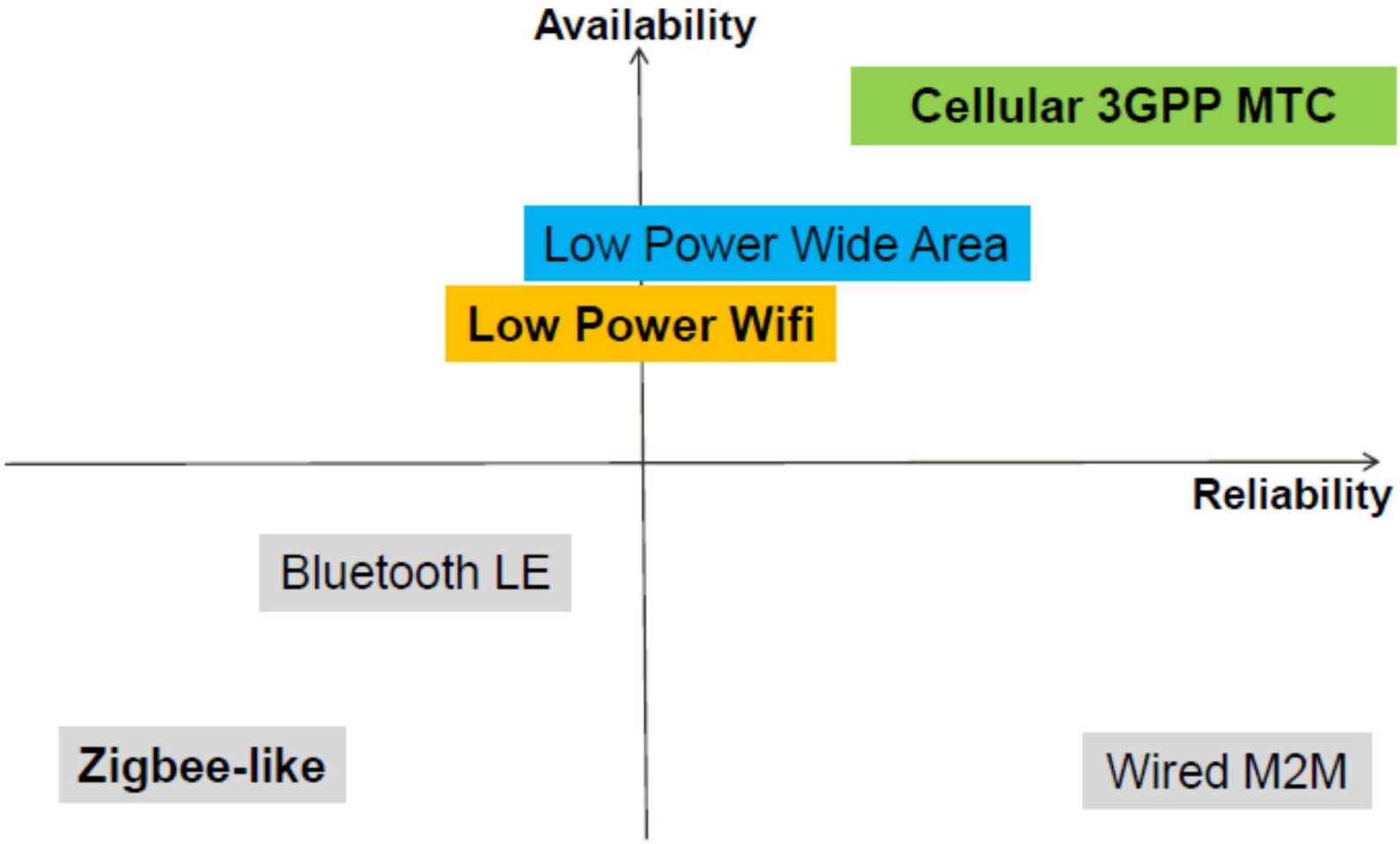
Wireless IoT markets is limited in potential with 3G/4G (LTE-M) networks since limitations are experienced in:

- **Backhaul/fronthaul** connections are mostly wired and indeed costy for ad hoc deployment
  - Wireless backhaul/fronthaul faces capacity and reliability limitations in 3G/4G
- **Reliability** of wireless connection is not enough for mission critical applications. Target reliability should be > 99.9999
- **Energy consumption of devices** due to today communication networks is too large to meet battery life duration targets

3G/4G Limitation for IoT Applications

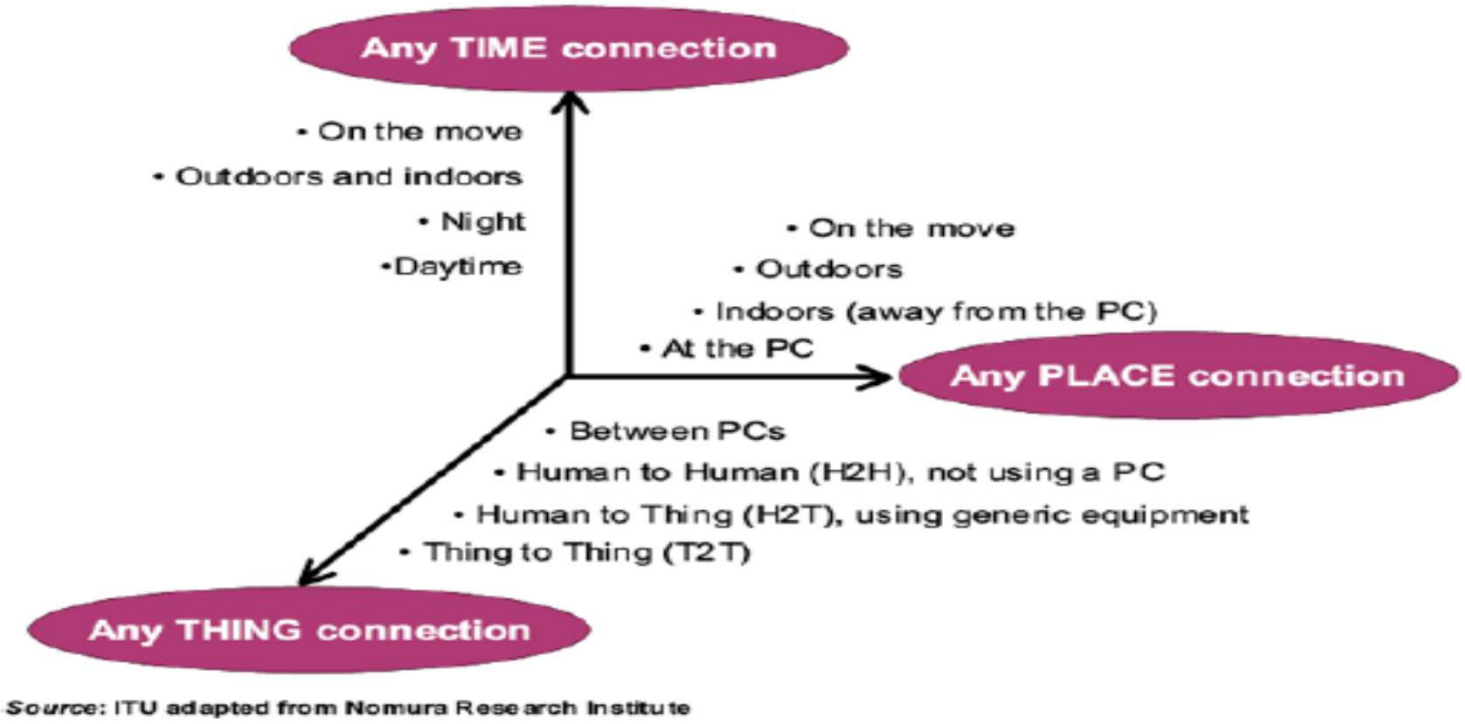
- **E2E delay** is too long and not predictable for remote controal and actuation
- **Delocalized computing** is starting to be introduced but requires high uplink bandwidth that 3G/4G systems cannot ensure
  - Fog/edge and Centralized cloud solution are under investigation and experimentation
- **Extreme density** of IoT devices is not supported
- **Communication overhead** of low rate IoT communication breaks optimized functioning of 3G/4G networks

IoT Weaknesses Today:
Need of an Effective Communication Network



Networks are Changing

- We are extending the current internet to the internet of things
- Connectivity will be **any time any where** with **any thing**



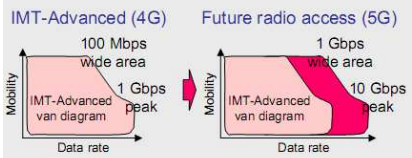
Source: ITU adapted from Nomura Research Institute

5G NETWORKS

AN EXCELLENT OPPORTUNITY FOR INTERCONNECTING THE INTERNET OF THINGS

Key Technical Challenges in 5G

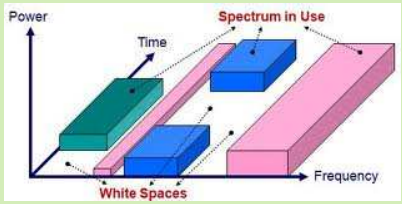
Targets 1 Gbps in wide area
(Peak data rate ~ 10 Gbps)

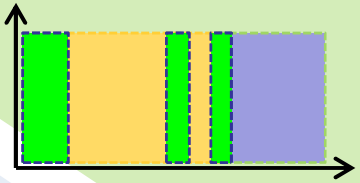


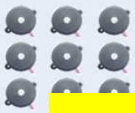
At least 10x improvement is needed

High data rate, coverage HetNets, cooperative Nets, ultra-densification

Ad hoc deployment, dynamic spectrum access, white spaces, shared spectrum, fragmented spectrim







Expected 1 million connection / Km²

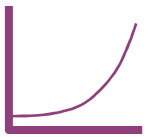
M2M, scalability, security, privacy, WSN

5G Challenges

Avalanche of
Traffic Volume

Further expansion of mobile broadband

Additional traffic due to communicating machines



“1000x in ten years”

Massive growth in
Connected Devices
“Communicating machines”

“50 billion devices in 2020”

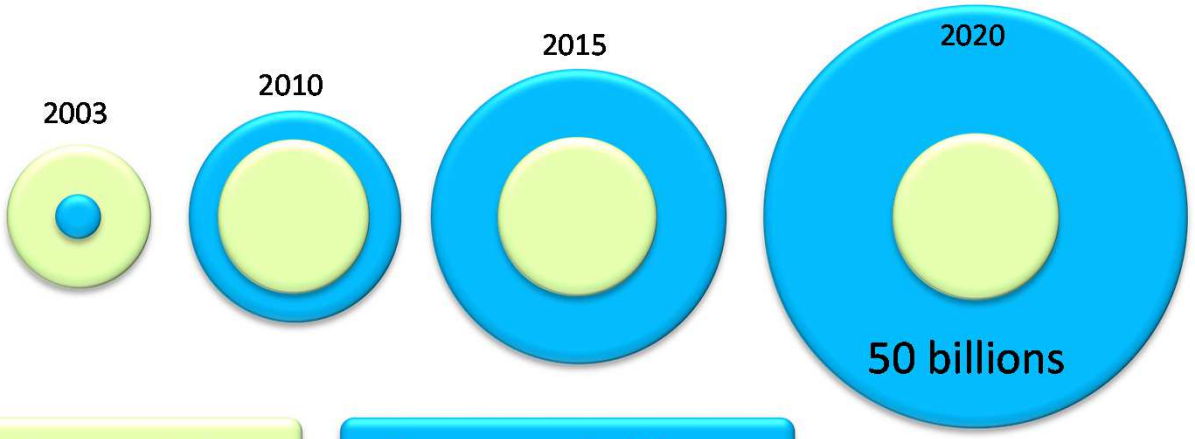
Large diversity of
Use cases & Requirements

Device-to-Device Communications

Car-to-Car Comm.

New requirements and characteristics due to communicating machines

5G & the IoT Verticals Applications



Worldwide population

Connected objects

Source: CISCO, AT&T

Smart Homes

Intelligent transport system

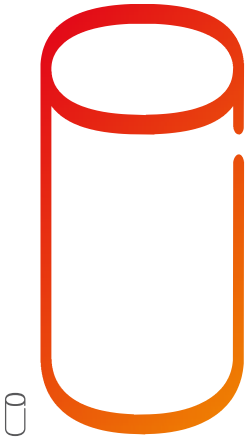
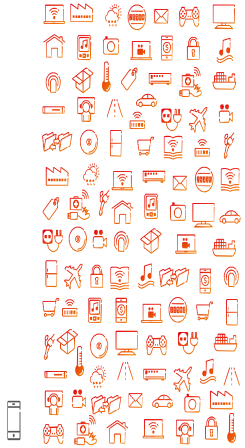
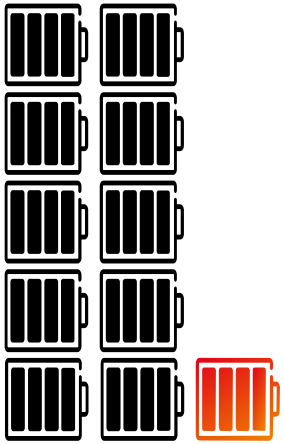
Business environment

Logistics and retail environment

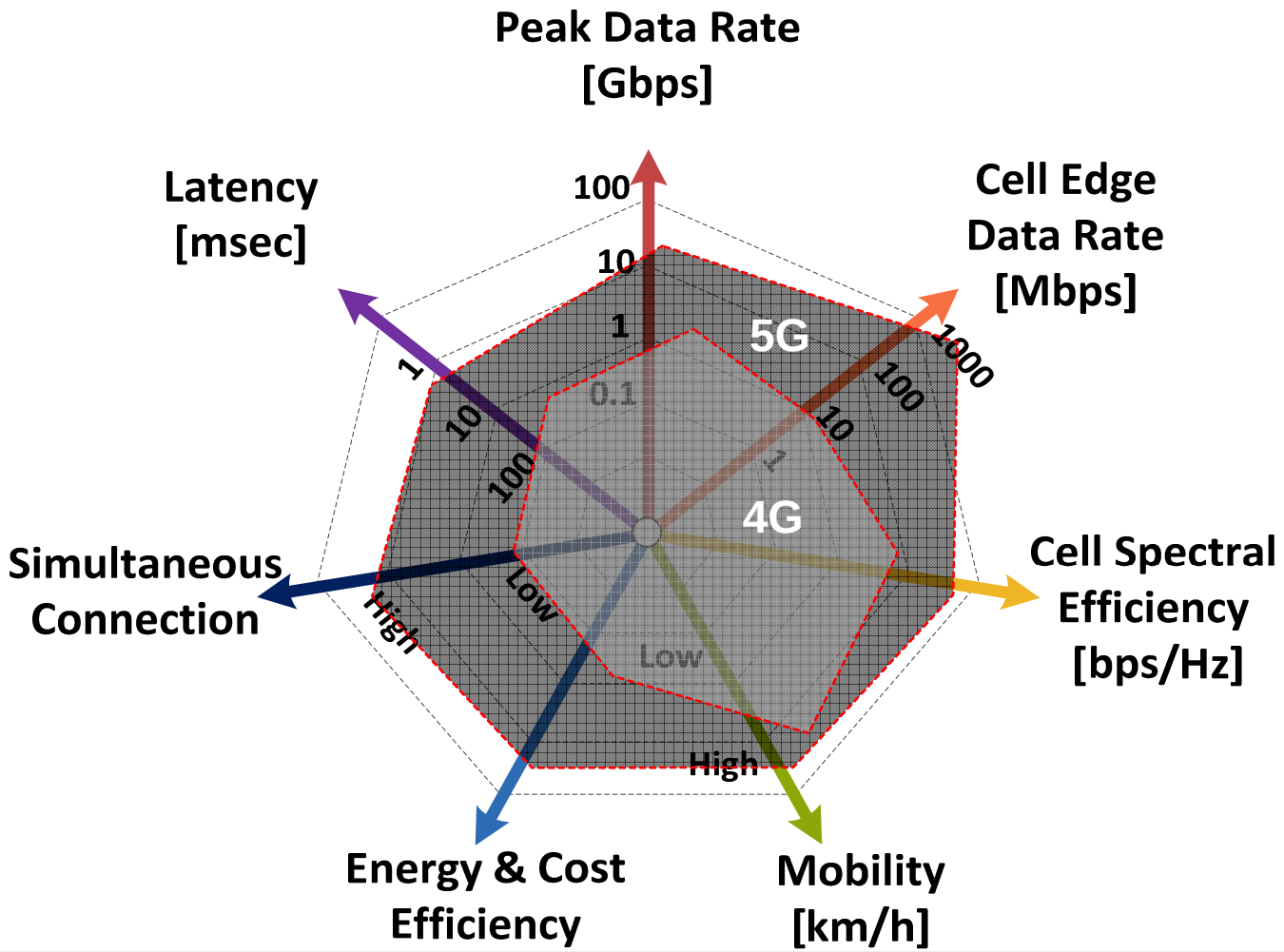
Health monitoring system

5G Scenarios

5G Technical Objectives

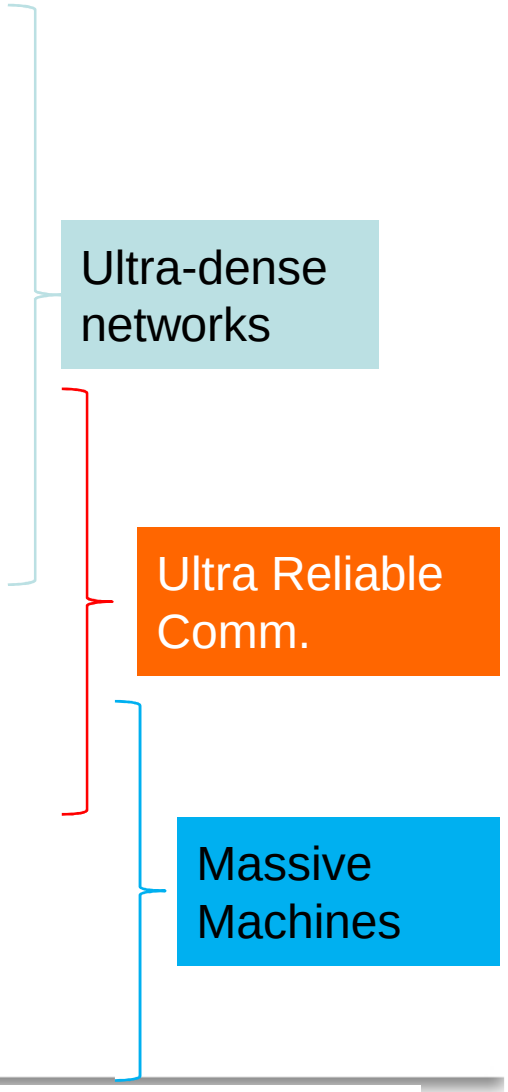
1000x data volume	50/500 B devices	Up to 10Gbps	Few ms E2E	10 years
				
1000x higher mobile data volumes	**10-100x higher number of connected devices**	10-100x typical end-user data rates	5x lower latency	**10x longer battery life for low-power devices**

5G Technical Objectives

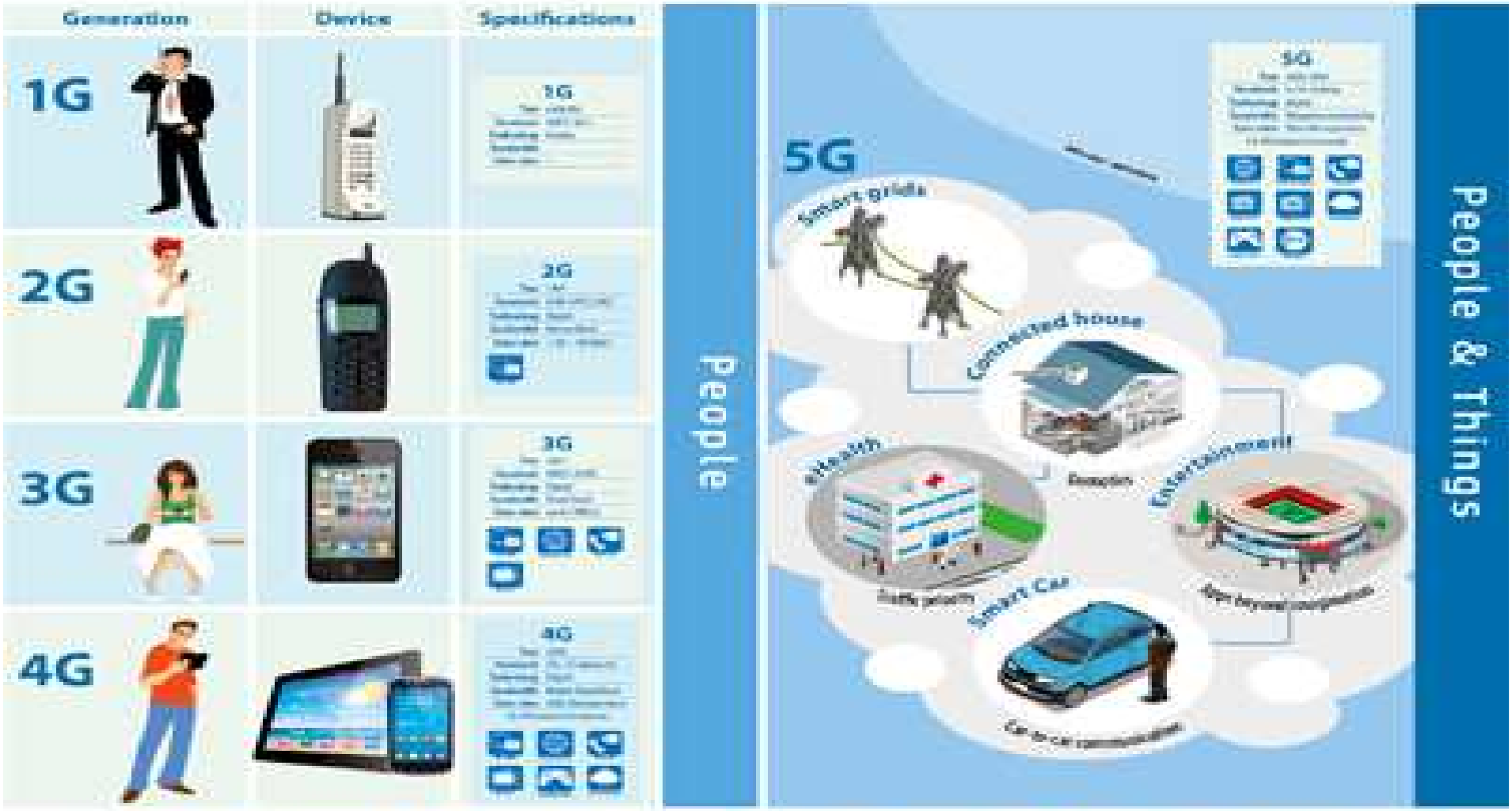


Typical 5G Requirements

Data rates	1-10Gbps (resp.100s of Mbps)
Capacity	36TB/month/user (resp. 500 GB)
Spectrum	Higher frequencies & flexibility
Energy	~10% of today's consumption
Latency reduction	~ 1ms (e.g. tactile internet)
D2D capabilities	NSPS, ITS, resilience, …
Reliability	99.999% within time budget
Coverage	>20 dB of LTE (e.g. sensors)
Battery	~10 years
Devices per area	**300.000 per access node**



Mobile communications: from 1G to 5G



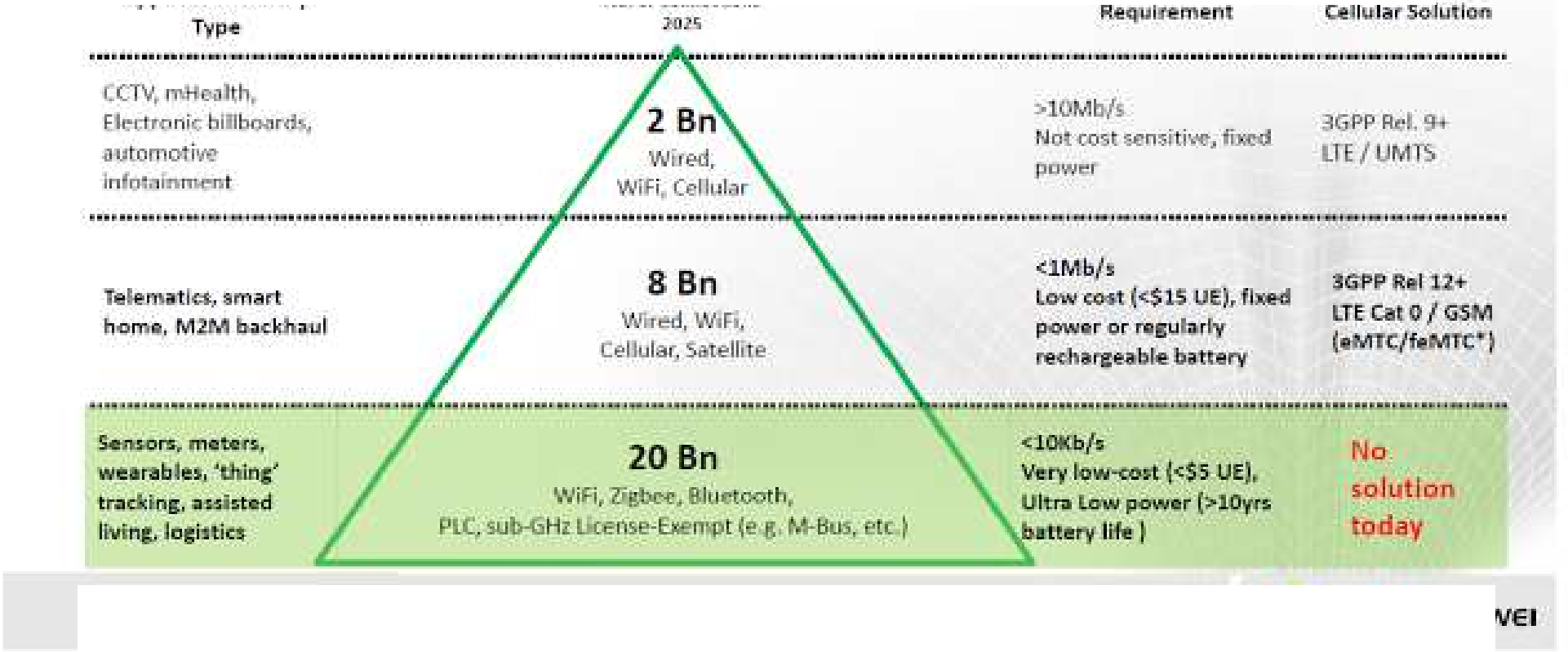
5G is about Communication, Storage, Processing…

From 1G to 5G

Generation→ Features↓	1G	2G	3G	4G	5G
Deployment	1970 – 1980	1990 - 2001	2001-2010	2011	2015-20 onwards
Data Rates	2kbps	14.4-64kbps	2Mbps	200 Mbps to 1 Gbps	1Gbps and higher
Technology	Analog Cellular Technology	Digital Cellular Technology: Digital narrow band circuit data Packet data	Digital Broadband Packet data: CDMA 2000 EVDO UMTS EDGE	Digital Broadband Packet data: WiMax LTE Wi-Fi	wwww Unified IP seamless combination of broadband LAN PAN MAN WLAN
Service	Analog voice service No data service	Digital voice with higher clarity SMS, MMS Higher capacity packetized data	Enhanced audio video streaming video conferencing support Web browsing at higher speeds IPTV support	Enhanced audio, video streaming IP telephony HD mobile TV	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing Switching	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet
Standards	MTS AMTS IMTS	2G:GSM 2.5:GPRS 2.75:EDGE	IMT-2000 3.5G-HSDPA 3.75G:HSUPA	Single unified standard LTE, WiMAX	Single unified standard
WEB Standard		www	www(IPv4)	www (IPv4)	wwww (IPv6)
Handoff	Horizontal only	Horizontal only	Horizontal & Vertical	Horizontal & Vertical	Vertical
Shortfalls	Low capacity, Unreliable handoff, Poor voice links, Less secure	Digital signals were reliant on location & proximity, required strong digital signals to help mobile phones	Need to accommodate higher network capacity	Being deployed	Yet to be implemented

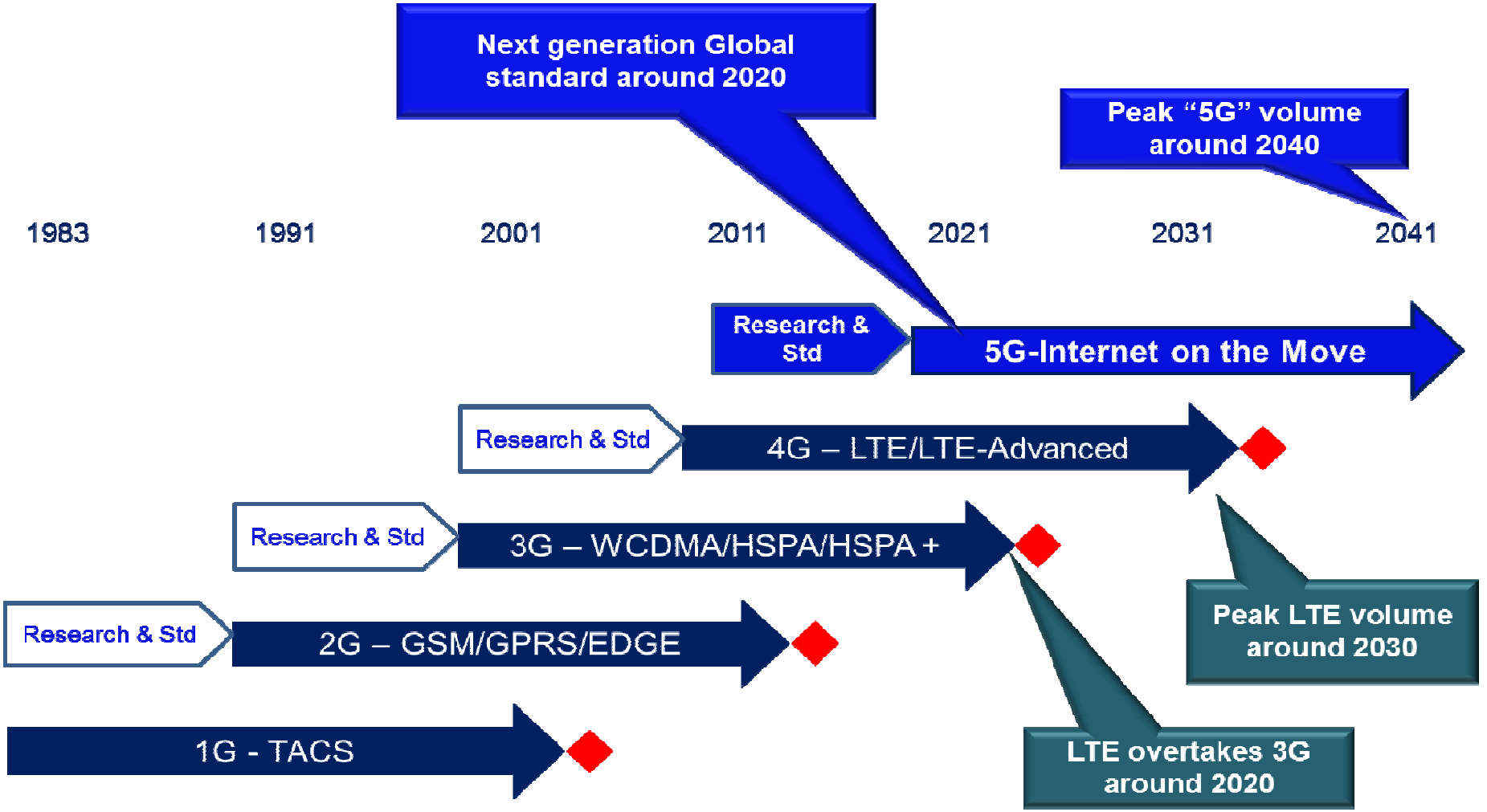
How 5G Networks will Adress IoT

How will Cellular technologies address the IoT?



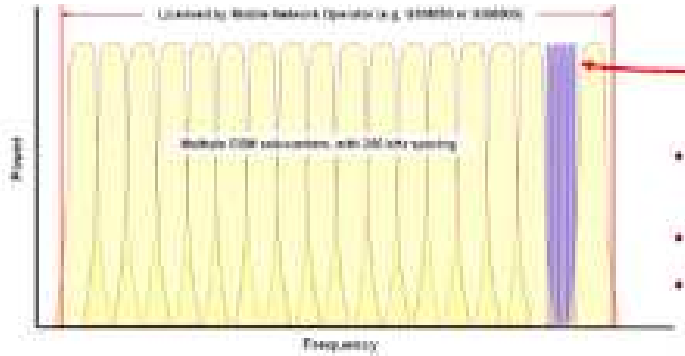
Via: The 3G4G Blog - blog.3g4g.co.uk

5G & The IoT



Average of 10 years research and standardisation, 20 years from introduction to peak volume

3GPP Rel 13: Cellular IoT



Small spectrum cost and easy to deploy

- Extended coverage compared with existing cellular (20dB enhancement)
- Very large terminal capacity (tens of thousands)
- Reuse of existing cellular infrastructure (soft update to base stations)

Technology Characteristics	Chip design implications
Low throughput	Lower processing
Narrow band	Simpler PHY
Established modulation & coding techniques	Less IPR, simpler PHY
Simple protocols	Less complicated stack

Via: The 3G4G Blog - blog.3g4g.co.uk

Conclusions

- ***IoT devices are available today***
- ***A new connectivity era***
  - *Things connected to things*
  - *People connected to things*
  - *Comunities connects (social IoT)*
- **CPSs enable the internet of X**
  - Smart grid
  - Smart energy
  - Smart water
  - Smart transport
  - Smart cities
  - Smart Health
  - Smart Manifacturing (FoF, Industry 4.0)
- **Telecom market is limited if only for voice and data communication**
  - New paradigm: ***network as a service***
  - 5G best market will be the ***real world web***

Conclusions

- ***Making "sense" out of it***
  - ***Create knowledge*** *and* ***make it available***
  - ***Process massive data*** *with open interfaces for* ***simple integration*** *into* ***heterogeneous applications***
- **The IoT application space:** very **diverse, heterogeneous**
  - Each application has its **specific traffic** (Communications)
  - **Ad hoc** infrastructure versus **virtualized** approach
  - ***Design flexibility through open API***
    - *Enable to* ***include*** *appropriate sensors and 'things'* ***regardless*** *original scope and implementation* ***details of each device***
  - **Dynamic Interoperability and advanced adaptation**
    - Massive number of heterogeneous IoT solutions, protocols, semantics

Conclusions

- ***Industry and service provides cannot relay on today 3G/4G wireless systems for providing the target immersive experience***
  - *Reliability*
  - *Short delay*
  - *Device energy efficiency and EE long distance communication*
  - *Security*
  - *Privacy*
  - *X-haul Throughput*
  - *Local cloud computing and storage support*
- **5G and IoT have a Win-Win joint future**
  - Network as a service for real world web
- An **Universal solutions** is the hot topic
  - Future **5G Networks** is the best candidate today for efficient integration of telecom infrastructure, verticals and the smart-X paradigm

Thanks for your attention

Leti

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