Image credit: venturebeat.com

COMPUTING

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

AI6128 Urban Computing

Lecture 1

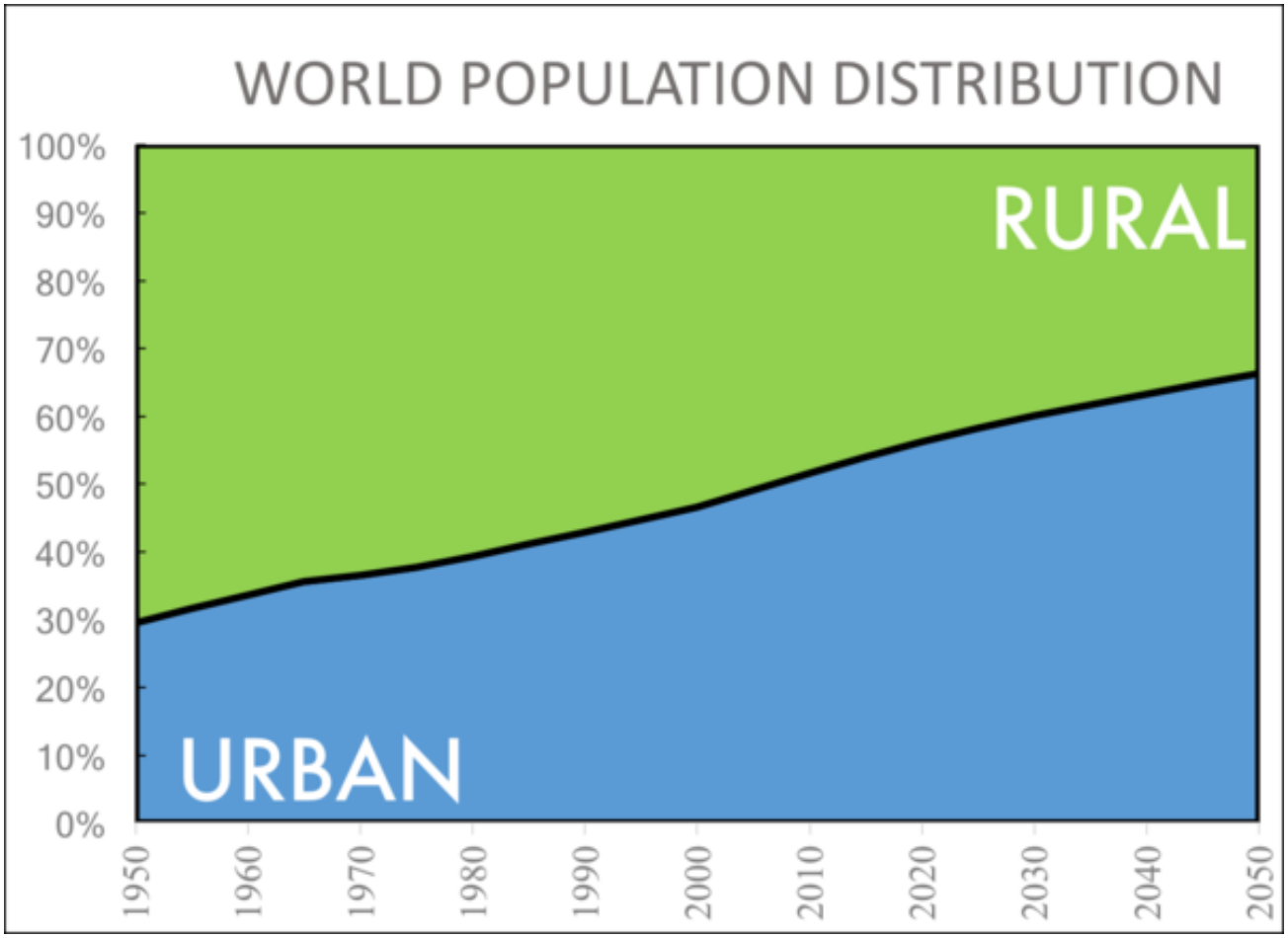
Introduction to Urban IoT

Content

- What is urban computing?
- Definition of Internet of Things (IoT)
- IoT applications
- IoT architecture

What is Urban Computing?

Urbanization



Challenges Faced by Urban Cities

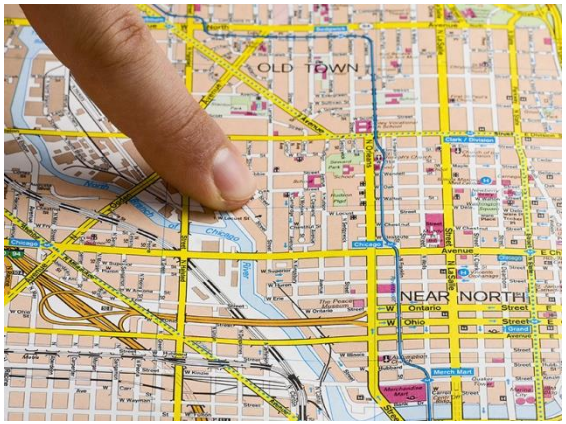
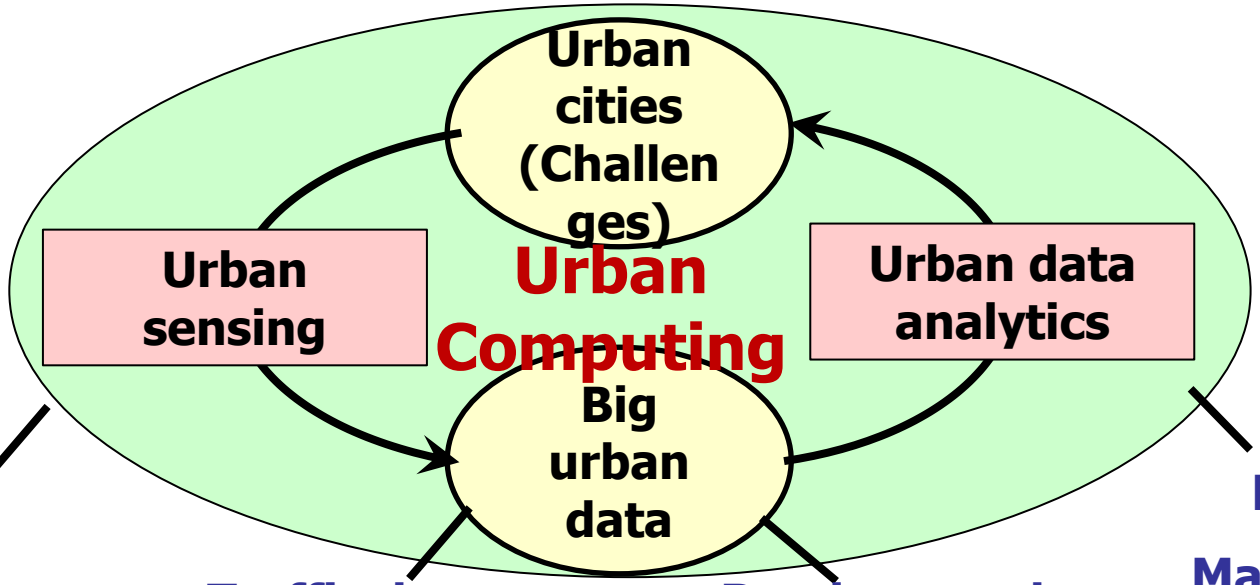


Photo sources: http://knaphill.org/a322-increased-congestion-already/, https://www.huffingtonpost.com/entry/beijing-air-pollution-photos_us_5698a1c6e4b0b4eb759e0155, https://auto.howstuffworks.com/fuel-efficiency/fuel-economy/how-to-calculate-your-cars-fuel-consumption.htm, http://www.thehindu.com/migration_catalog/article14600967.ece/alternates/FREE_660/31BM_HUGE_GANESH_IDOL

Urban Computing: A Data-Driven Approach



GPS
Loops
PM2.5 sensors
CCTVs
…

Traffic data
Social media data
Air quality data
Weather data
…

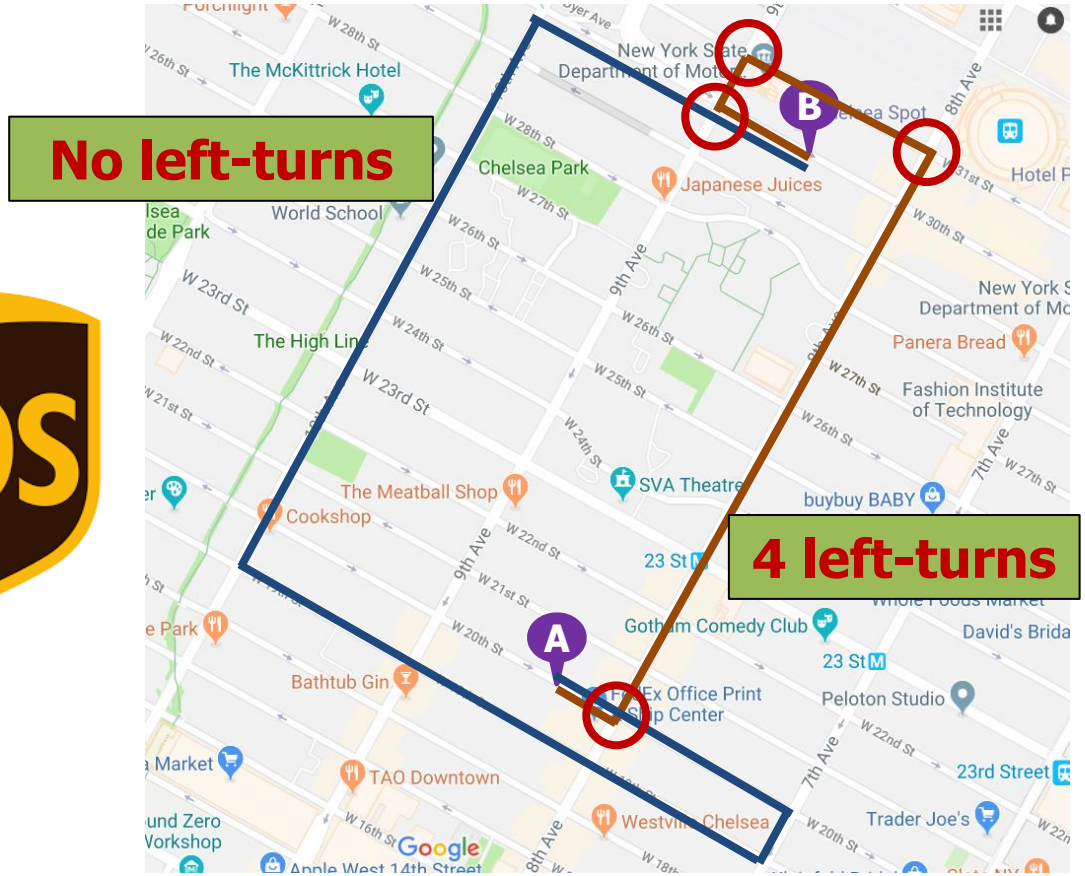
Road networks
Census data
Land use data
Event data
…

Data mining
Machine learning
Statistics
…

Example Application: Routing

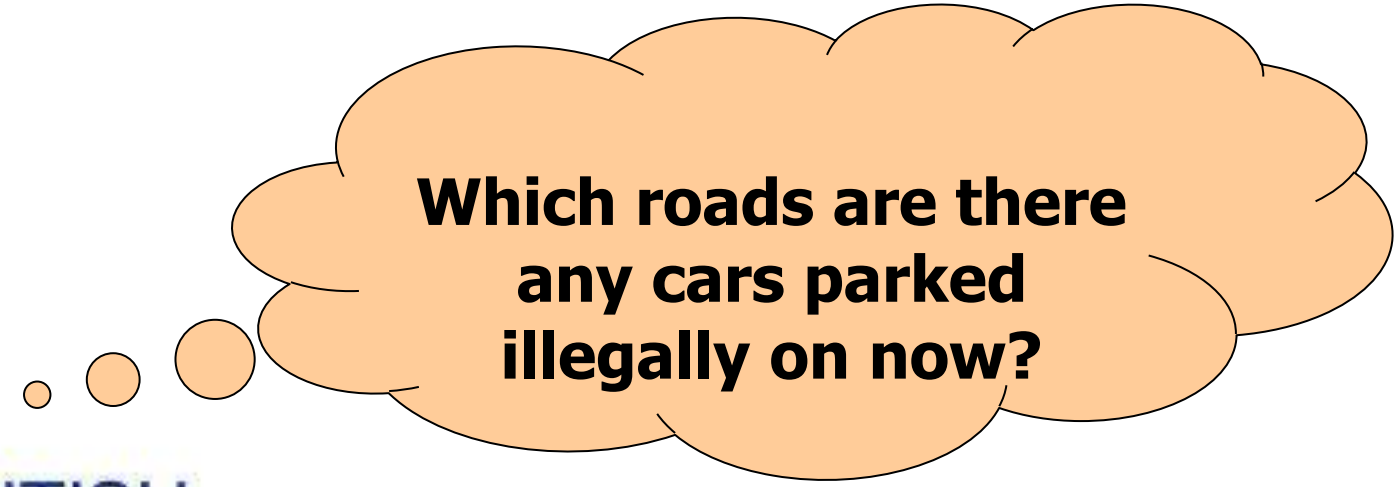
Which route to take to go from a source to a destination?

Example Application: Routing



10 million
gallons of fuel a year

Example Application: Illegal Parking Detection



BRITISH TRANSPORT POLICE

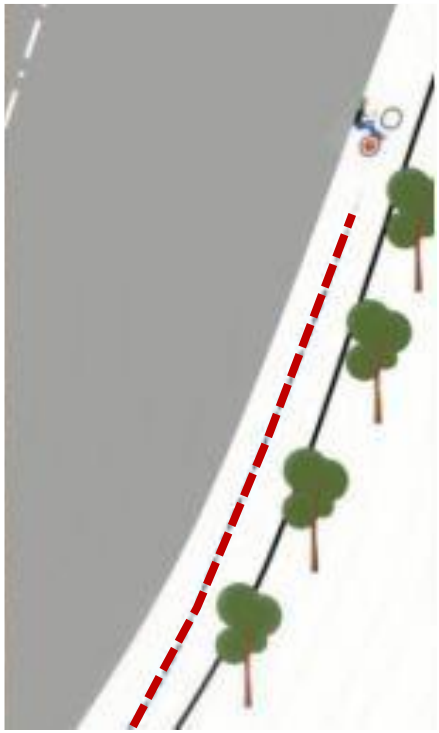
Example Application: Illegal Parking Detection

Limited coverage

Low efficiency

Example Application: Illegal Parking Detection

A shared bike with GPS and cellular network modules

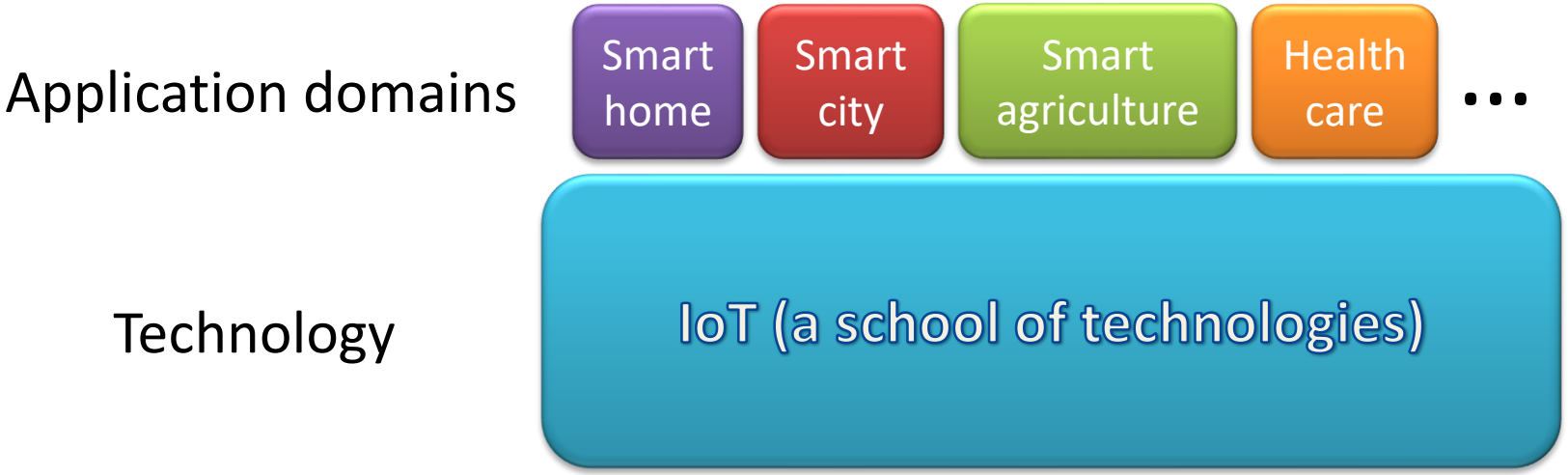


Example Application: Illegal Parking Detection

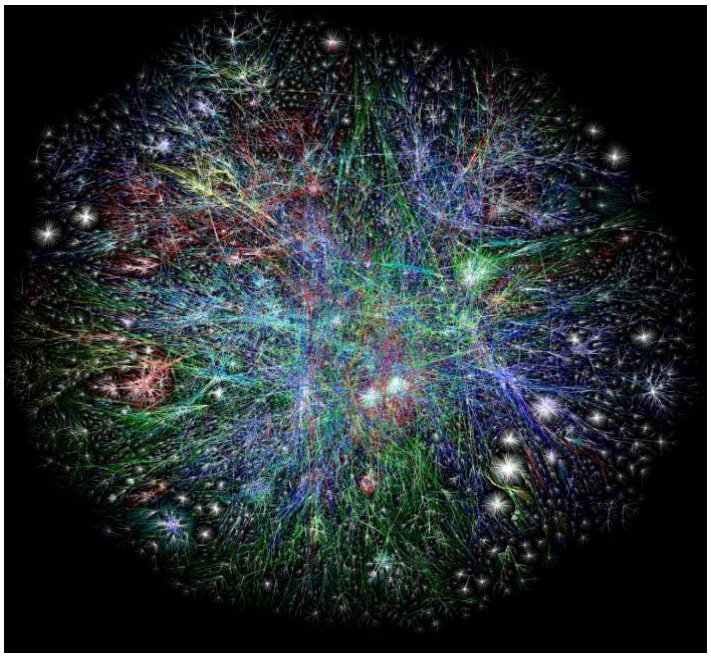
Definition of IoT

IoT and Urban Computing

- IoT ≈ pervasive/ubiquitous computing
- Urban computing ≈ smart city
- IoT provides technological support for urban sensing



Starting From Internet



- Internet appears everywhere in the world
- But it is still a connection between people and people

What is IoT?

- Internet connects all people, so it can be called “the Internet of People”
- IoT connects all things, so it is called “the Internet of Things”

What is IoT? (cont'd)

- Definitions

  (1) The Internet of Things, also called The Internet of Objects, refers to a wireless network between objects, usually the network will be wireless and self-configuring, such as household appliances.

  ------Wikipedia

  (2) By embedding short-range mobile transceivers into a wide array of additional gadgets and everyday items, enabling new forms of communication between people and things, and between things themselves.

  ------WSIS 2005

What is IoT? (cont'd)

(3) The term "Internet of Things" has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects.

------IoT in 2008

(4) “Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts”.

-------IoT in 2020

15-Year Law

- 1940s Theory & 1st-gen computers

Alan Turing
(1912-1954)

John von Neumann
(1903-1957)

- 1965 Main frame
- 1980 Personal computing
- 1995 Cloud computing
- 2010 Mobile computing
- 2025 **IoT?**

Evolution of Computing

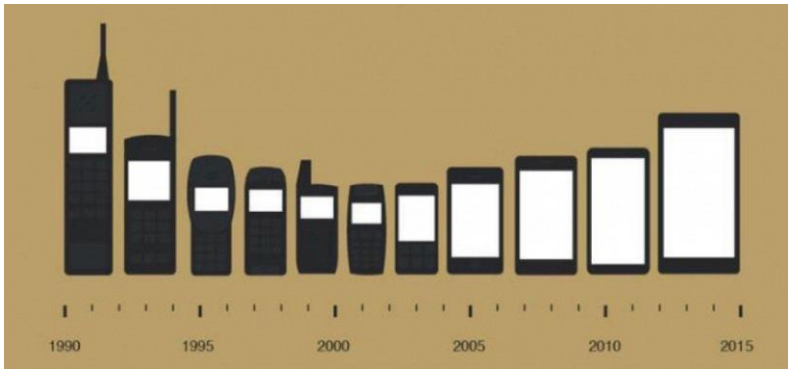
- Mainframe computing in 1960s, 1970s
  - Centralized computing
  - Thin terminals

Mainframe

Terminal

Evolution of Computing (cont'd)

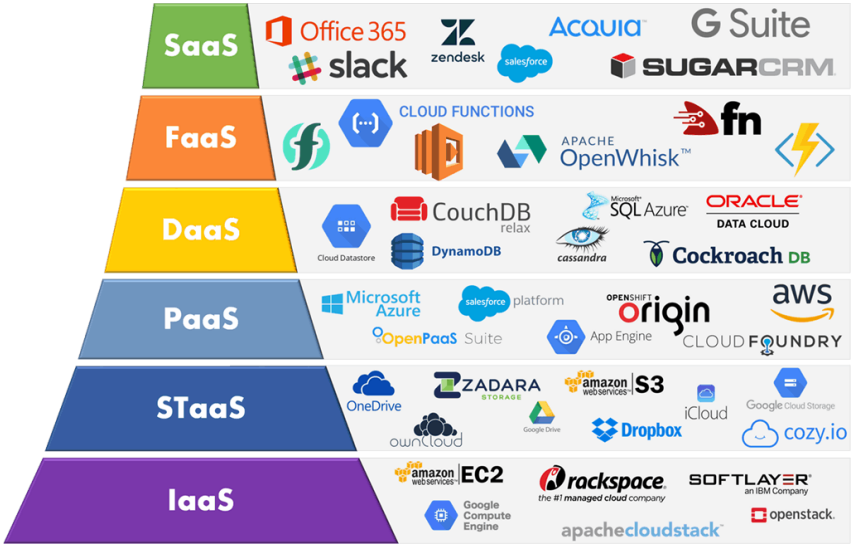
- Personal computing from 1980s
  - Everyone has a "mini mainframe"
  - Decentralized computing



Evolution of Computing (cont'd)

- Cloud computing from 2000s
  - Many server-class computers
  - Centralized again!
  - Backend of IoT

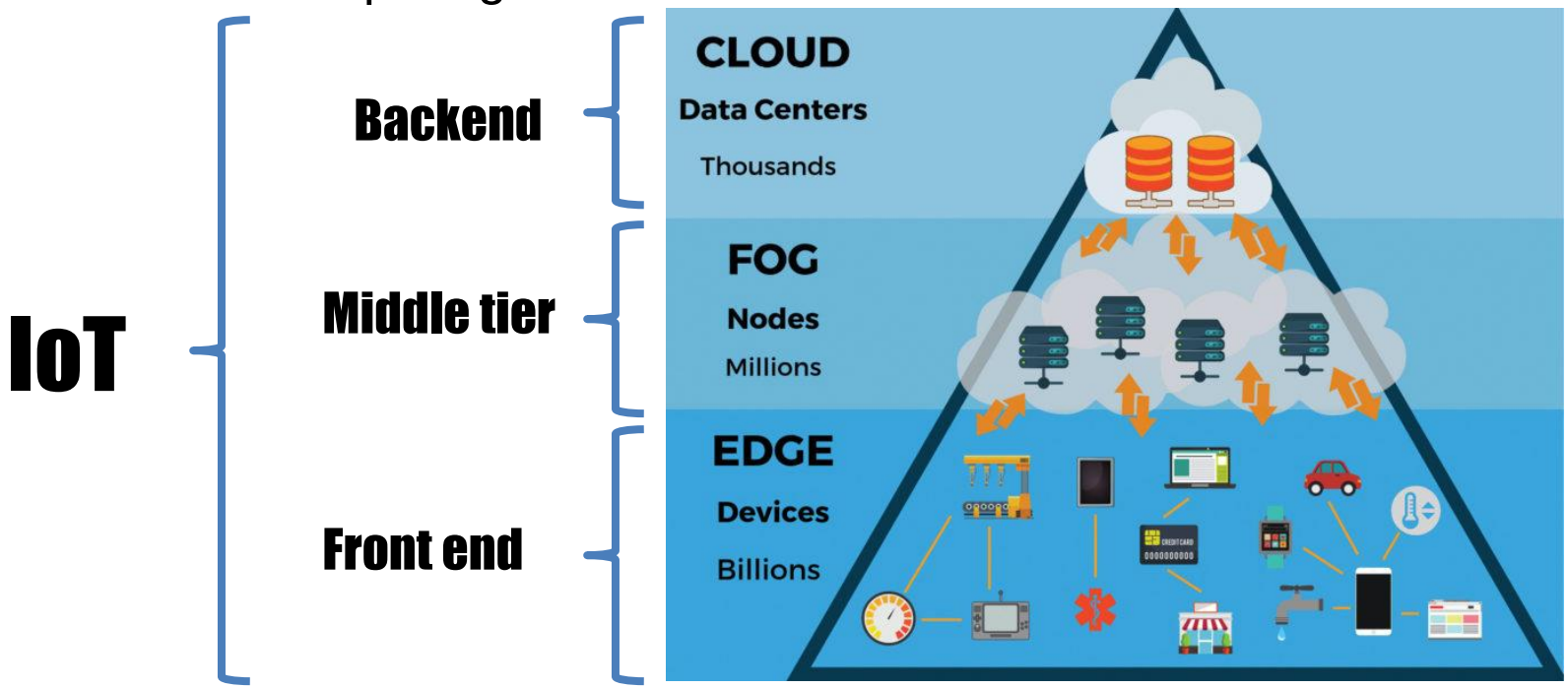
Server farm



XaaS (X as a service)

Evolution of Computing (cont'd)

- Fog and edge computing from 2015
  - Embedded computers (things)
  - Decentralized again!
  - Push computing to the data sources



First IoT Device

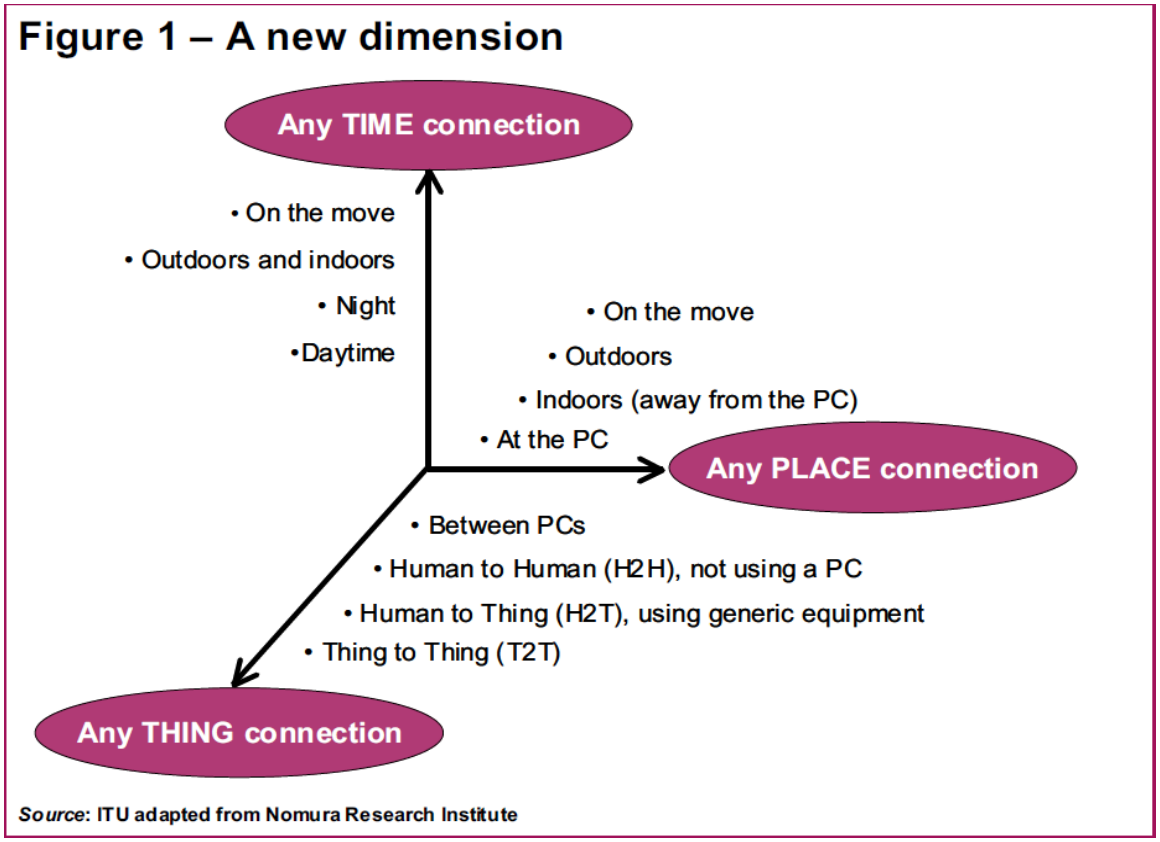
1982

A modified Coke machine at CMU becomes the first internet connected appliance capable of reporting its inventory

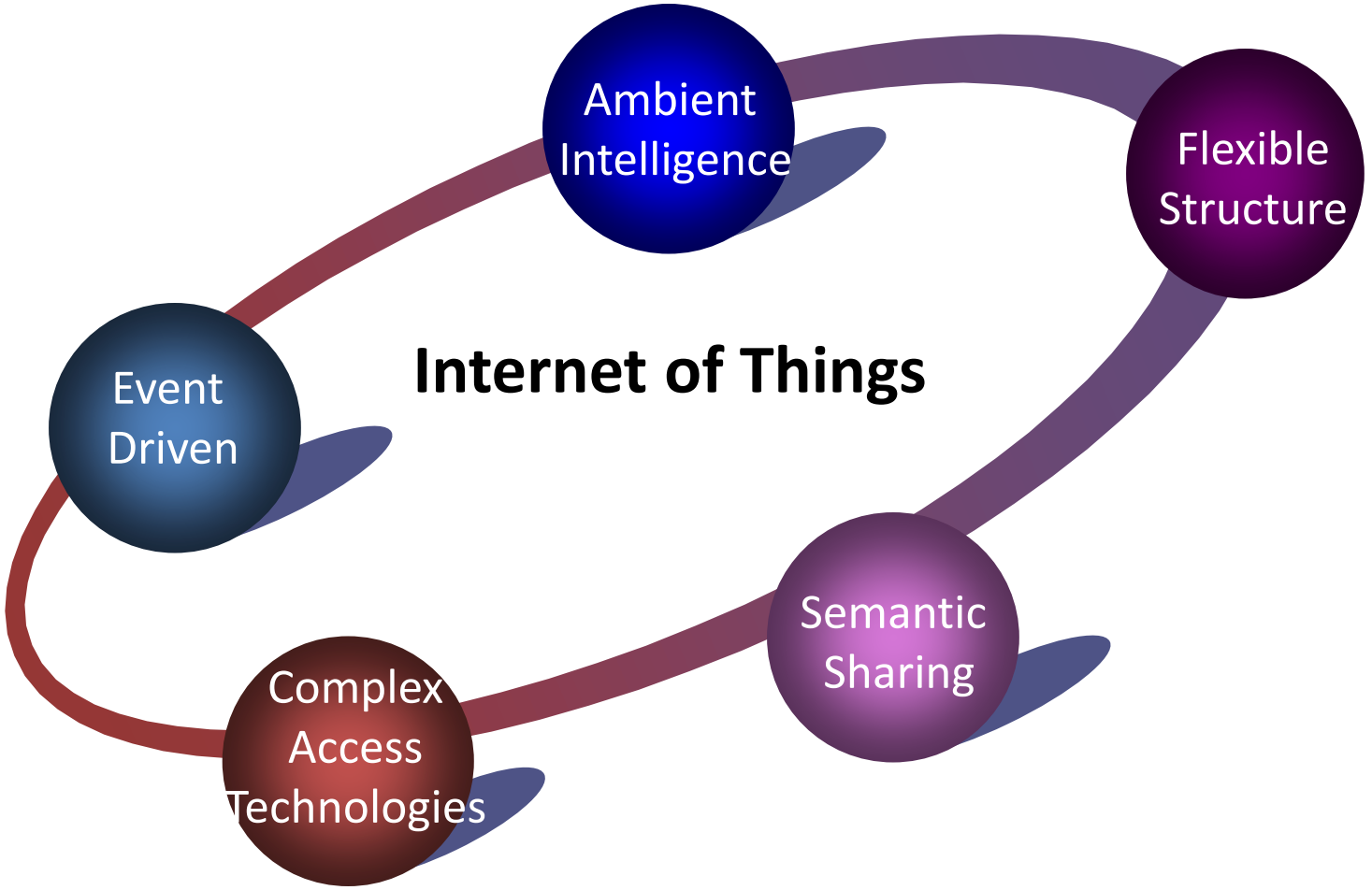
IoT History

- 1997, “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”.
- 1999, Auto-ID Center founded in MIT
- 2003, EPC Global founded in MIT
- 2005, Four important technologies of the internet of things was proposed in WSIS conference.
- 2008, First international conference of internet of things: The IoT 2008 was held at Zurich.

IoT Dimensions



IoT Characteristics



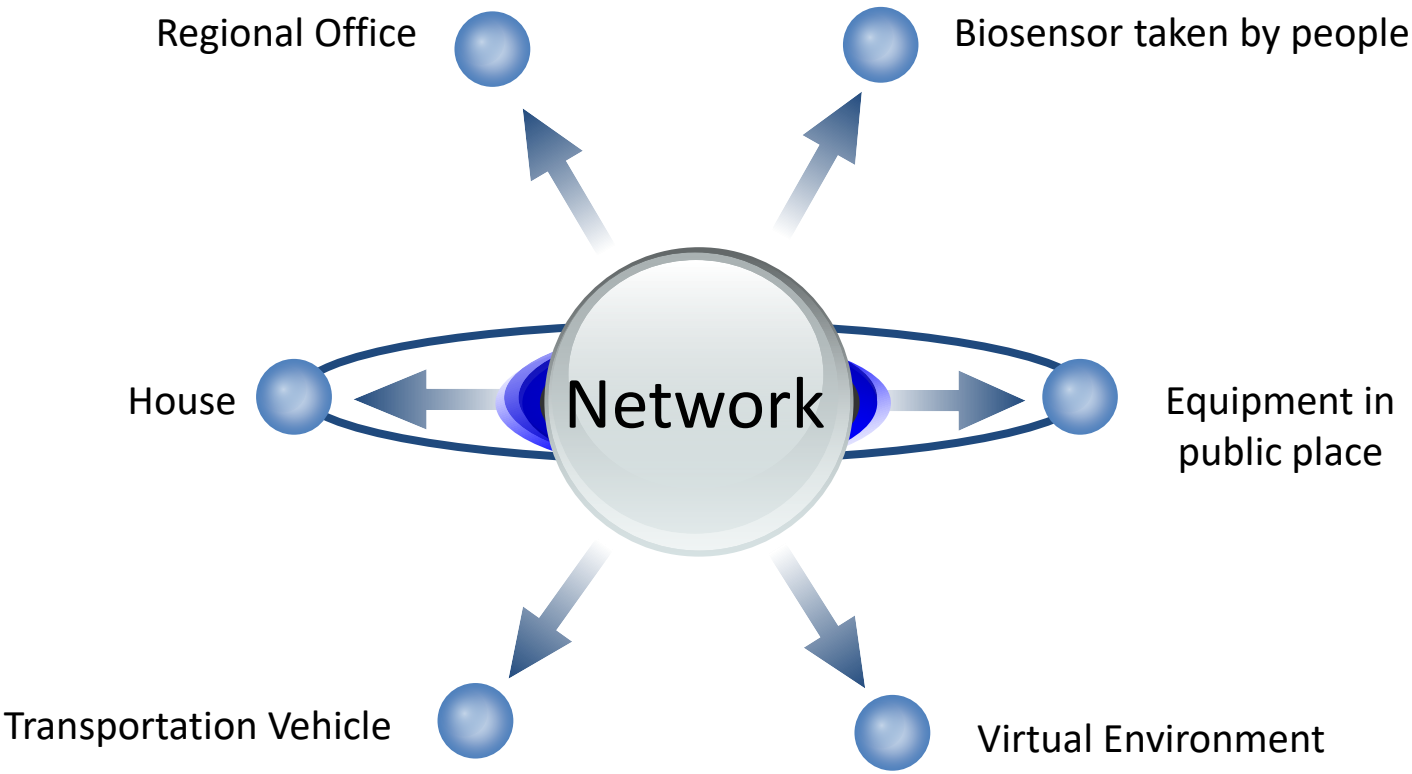
Why IoT?

- Dynamic control of industry and daily life
- Improve the resource utilization ratio
- Better relationship between human and nature
- Forming an intellectual entry by integrating human society and physical systems
- Flexible configuration
- Universal transport & internetworking
- Accessibility & usability
- Acts as technologies integrator

Communication btw Physical & Information Worlds

IoT Applications

Application Domains



Scenario 1: Shopping

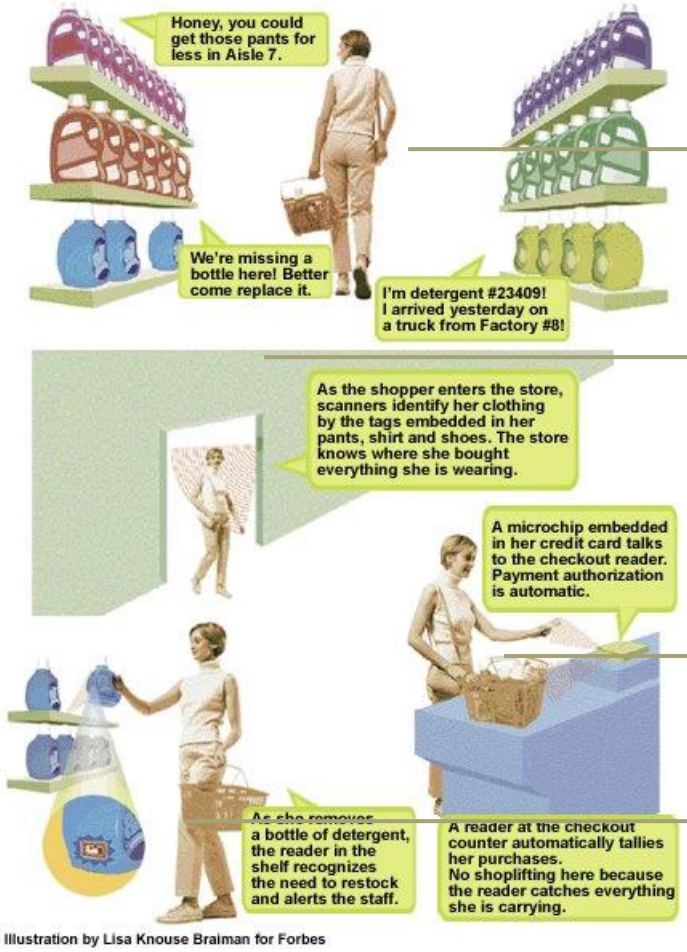


Illustration by Lisa Knouse Braiman for Forbes

(2) When shopping in the market, the goods will introduce themselves.

(1) When entering the doors, scanners will identify the tags on her clothing.

(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

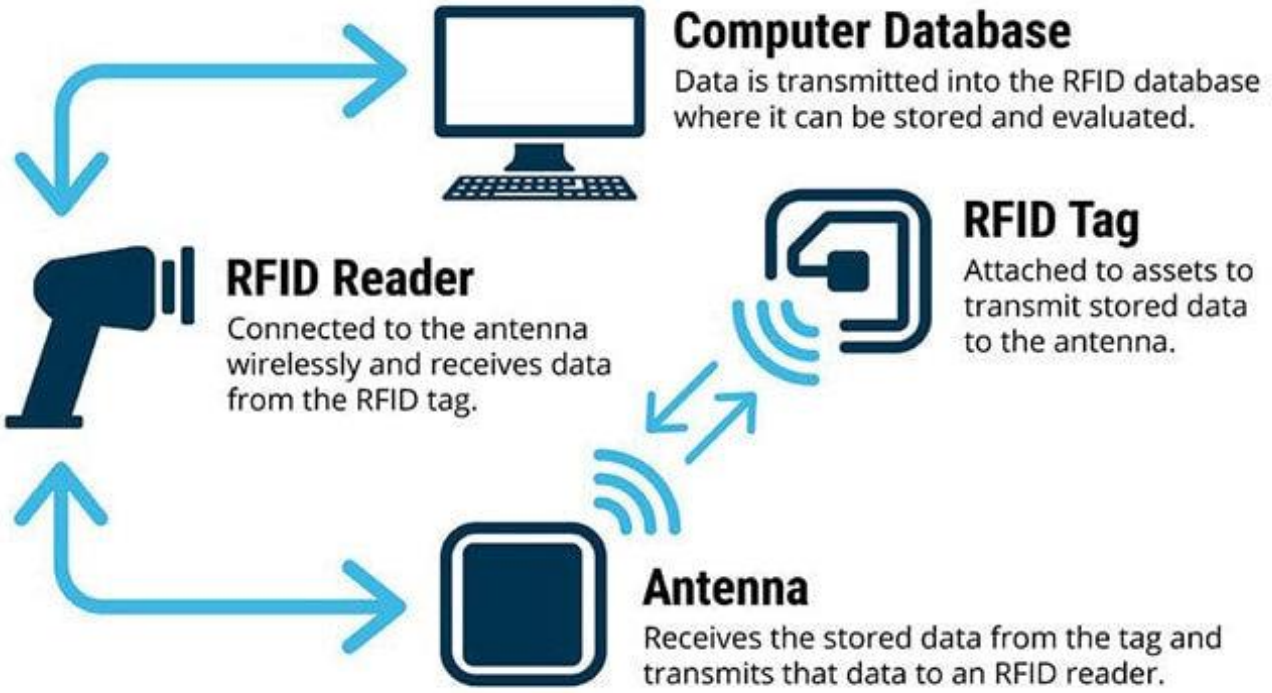
(3) When moving the goods, the reader will tell the staff to put a new one.

NTU's Unmanned Store

- Customer identification
  - Palmprint
- Goods identification
  - RFID
- Payment
  - Credit card
  - Palmprint

RFID

- Radio Frequency Identification



Scenario 2: Health Care

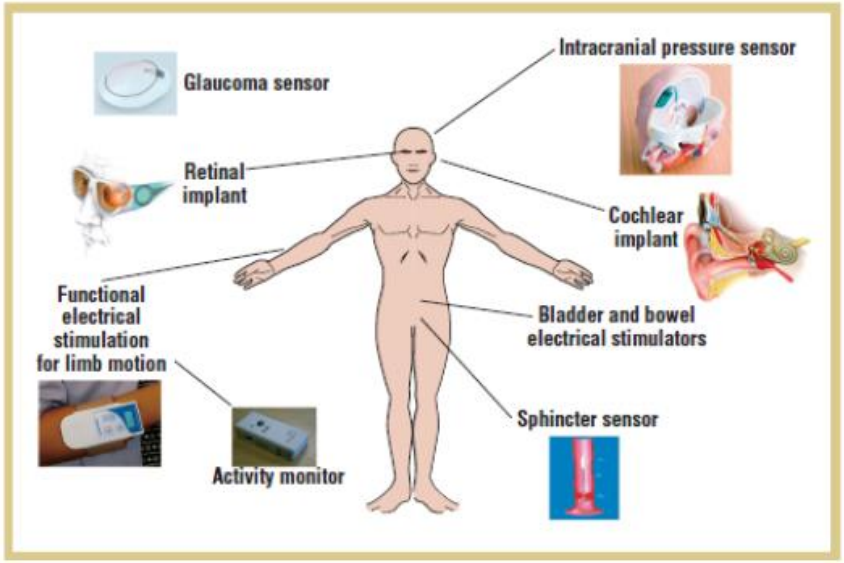


Figure 6. Fully implantable wireless sensor for the intracranial pressure monitoring system.

- Various sensors for various conditions
- Example ICP sensor: Short or long term monitoring of pressure in the brain cavity
- Implanted in the brain cavity and senses the increase of pressure
- Sensor and associated electronics encapsulated in safe and biodegradable material
- External RF reader powers the unit and receives the signal

Continuous Physiological Monitoring

- "This technology isn't ready for prime time yet. But detecting various heart problems with a smart watch could become a reality within the decade."
  - Harvard Health Publishing

Operating Room

- National Health Information Network, Electronic Patient Record

- Home care: monitoring and control
  - Pulse oximeters, blood glucose monitors, infusion pumps, accelerometers, etc

- Operating Room of the Future
  - Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery
  - System coordination challenge

- Progress in bioinformatics: gene, protein expression, systems biology, disease dynamics, control mechanisms

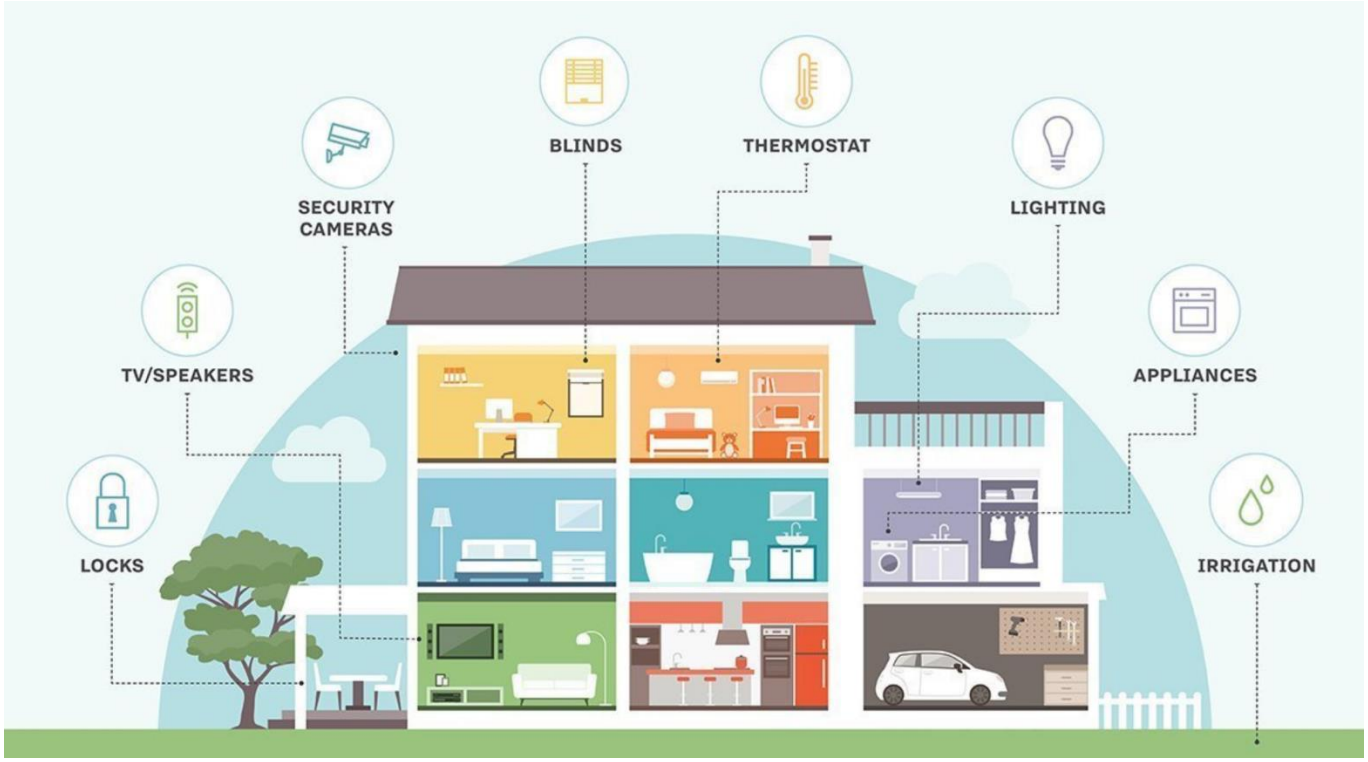
Pre/Post-Surgery Monitoring

From a keynote speech at ACM/IEEE Cyber-Physical Systems & IoT Week 2024 by Washington University in St. Louis
https://www.cse.wustl.edu/~lu/talks/CPS-IoT_Week_keynote.pdf

- Pancreatic cancer has a 5-year survival rate less than 5%
- Surgery is the only cure but commonly followed by complications
- Predict postoperative complications before surgery with
  - Wearable data collected by Fitbit wristband
  - Patient clinical characteristics from medical record

Scenario 3: Smart Home/Space

- Ubiquitous sensing
- Remote/automated control of home appliances



Telepresence

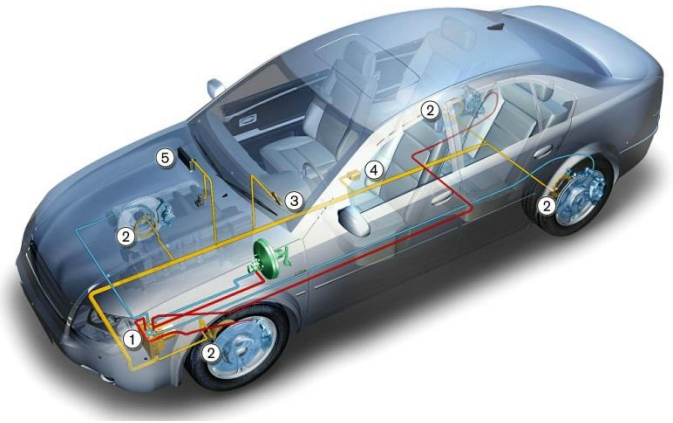
- Reduce carbon emissions from travels
- Deal with elderly loneliness

Now

Future:
Holographic telepresence + synchronized ambients

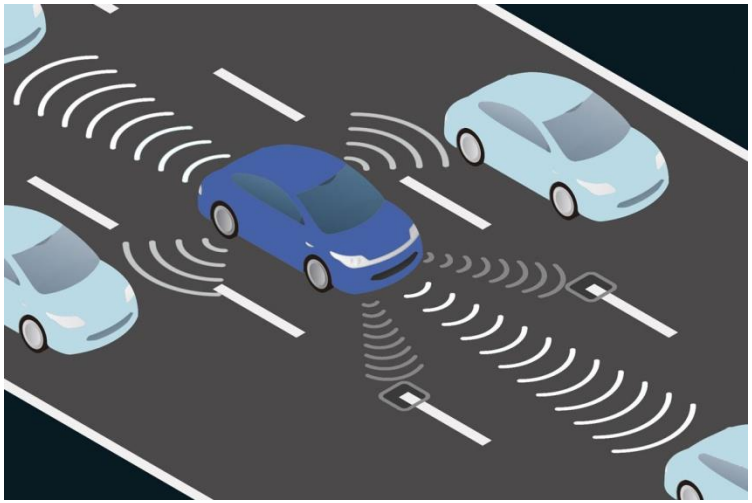
Scenario 4: Transportation

- A network of sensors set up throughout a vehicle can interact with its surroundings to provide valuable feedback on local roads, weather and traffic conditions to the car driver, enabling adaptive drive systems to respond accordingly
- This may involve automatic activation of braking systems or speed control via fuel management systems. Condition and event detection sensors can activate systems to maintain driver and passenger comfort and safety through the use of airbags and seatbelt pre-tensioning
- Sensors for fatigue and mood monitoring based on driving conditions, driver behavior and facial indicators can interact to ensure safe driving by activating warning systems or directly controlling the vehicle



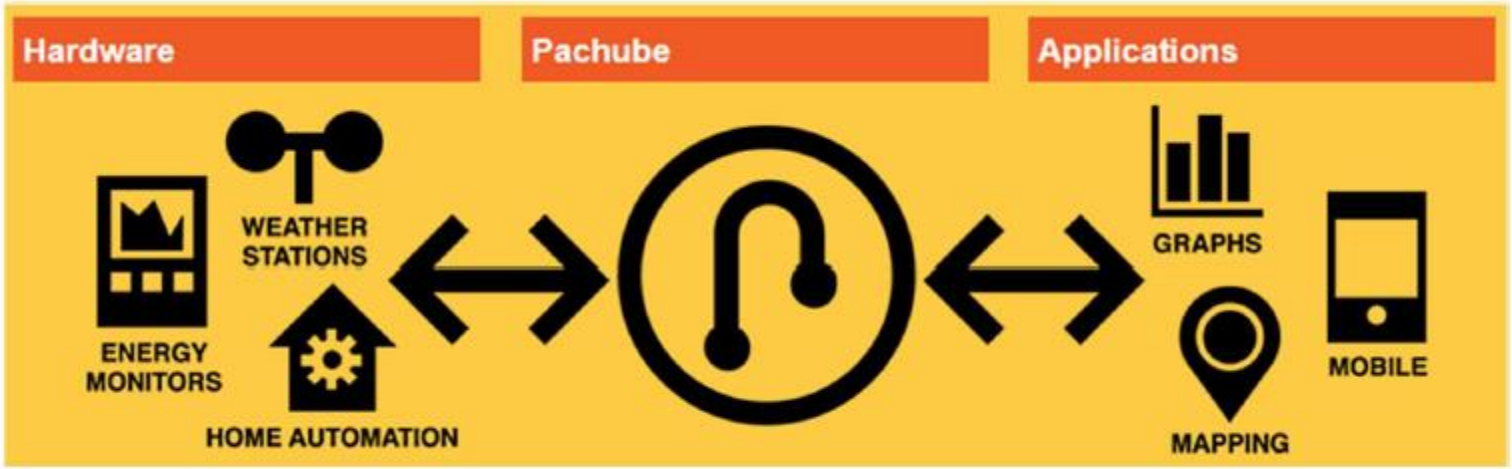
Scenario 4: Transportation (cont'd)

- In 2005, 30 – 90 processors per car
  - Engine control, break system, airbag deployment system, windshield wiper, door locks, entertainment system
- Cars are sensors and actuators in V2V networks
  - Active networked safety alerts
  - Autonomous navigation
- Future transportation systems
  - Incorporate both single person and mass transportation vehicles, air and ground transportations
  - Achieve efficiency, safety, stability using real-time control and optimization



Scenario 5: Urban Safety

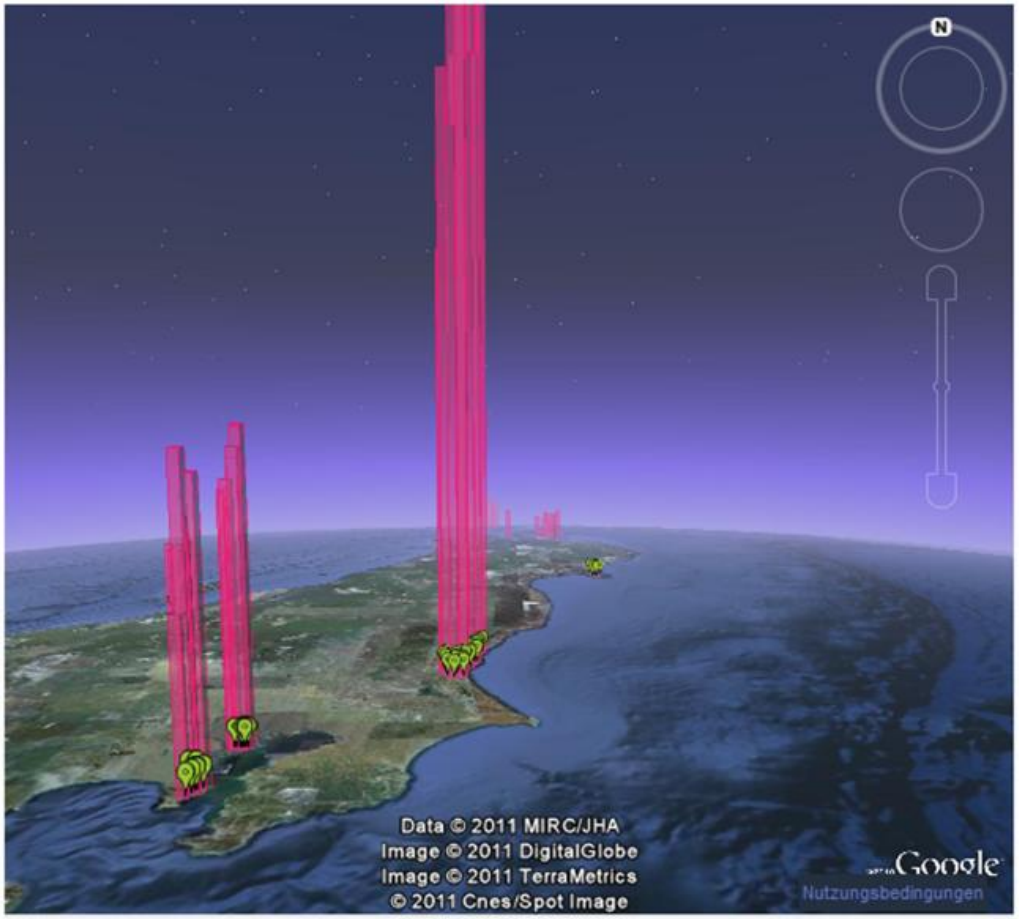
- Xively (formerly Pachube) – IoT Real-Time Web Service and Applications
  - Platform to connect sensors and other hardware
  - Platform to build IoT services and applications
  - RESTful APIs
  - Now part of Google Cloud IoT



Source: https://pachube.com/

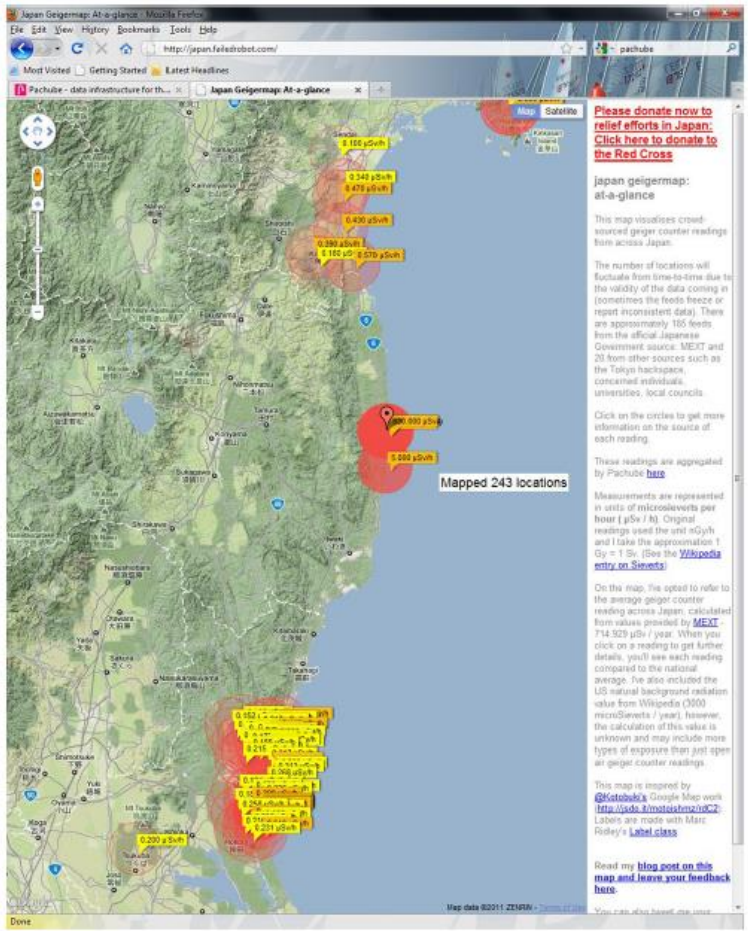
Scenario 5: Urban Safety (cont'd)

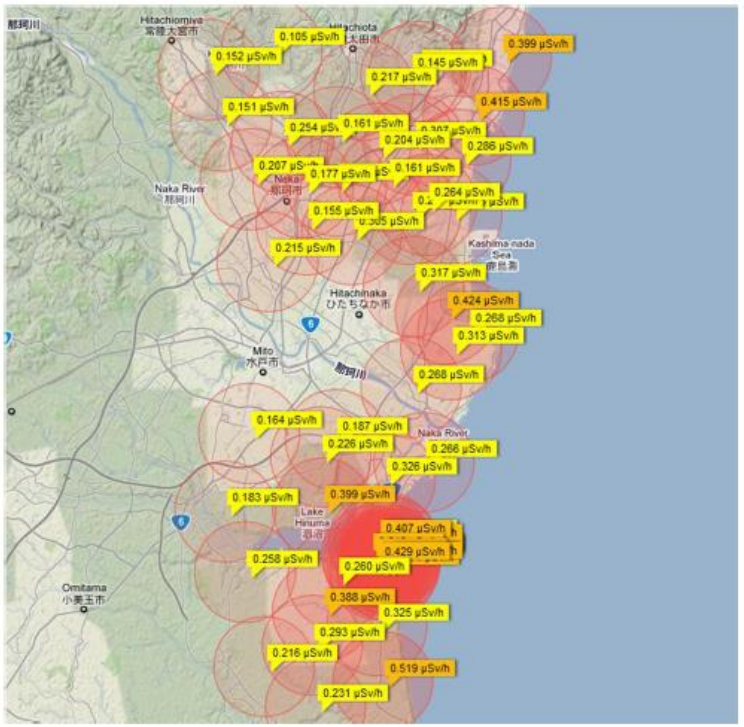
- After the Fukushima Disaster on Pachube
- Many people deployed radiation sensors



http://community.pachube.com/node/611#3d, 31.3.2011

Scenario 5: Urban Safety (cont'd)



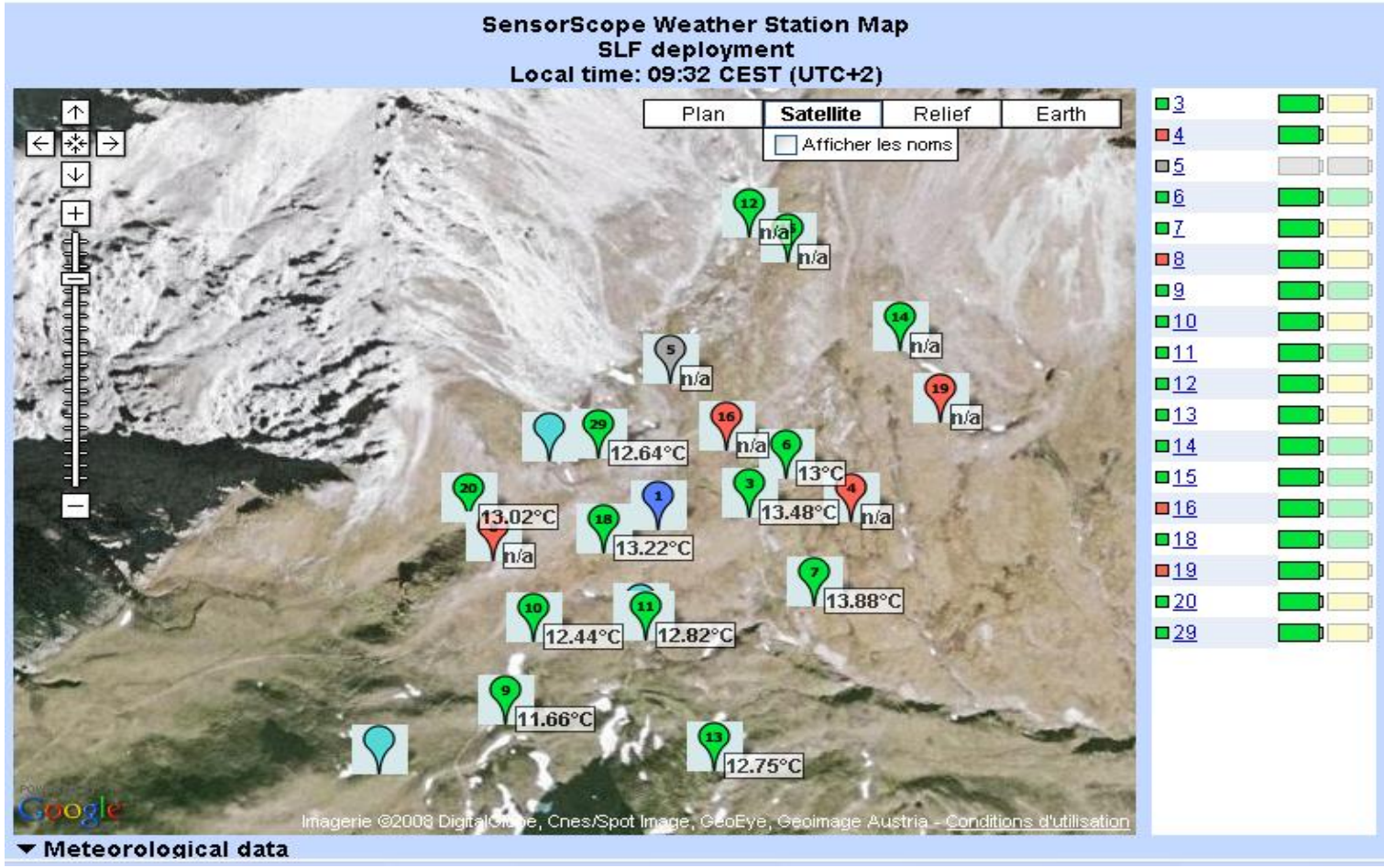


http://japan.failedrobot.com/, 31.3.2011

Scenario 5: Urban Safety (cont'd)

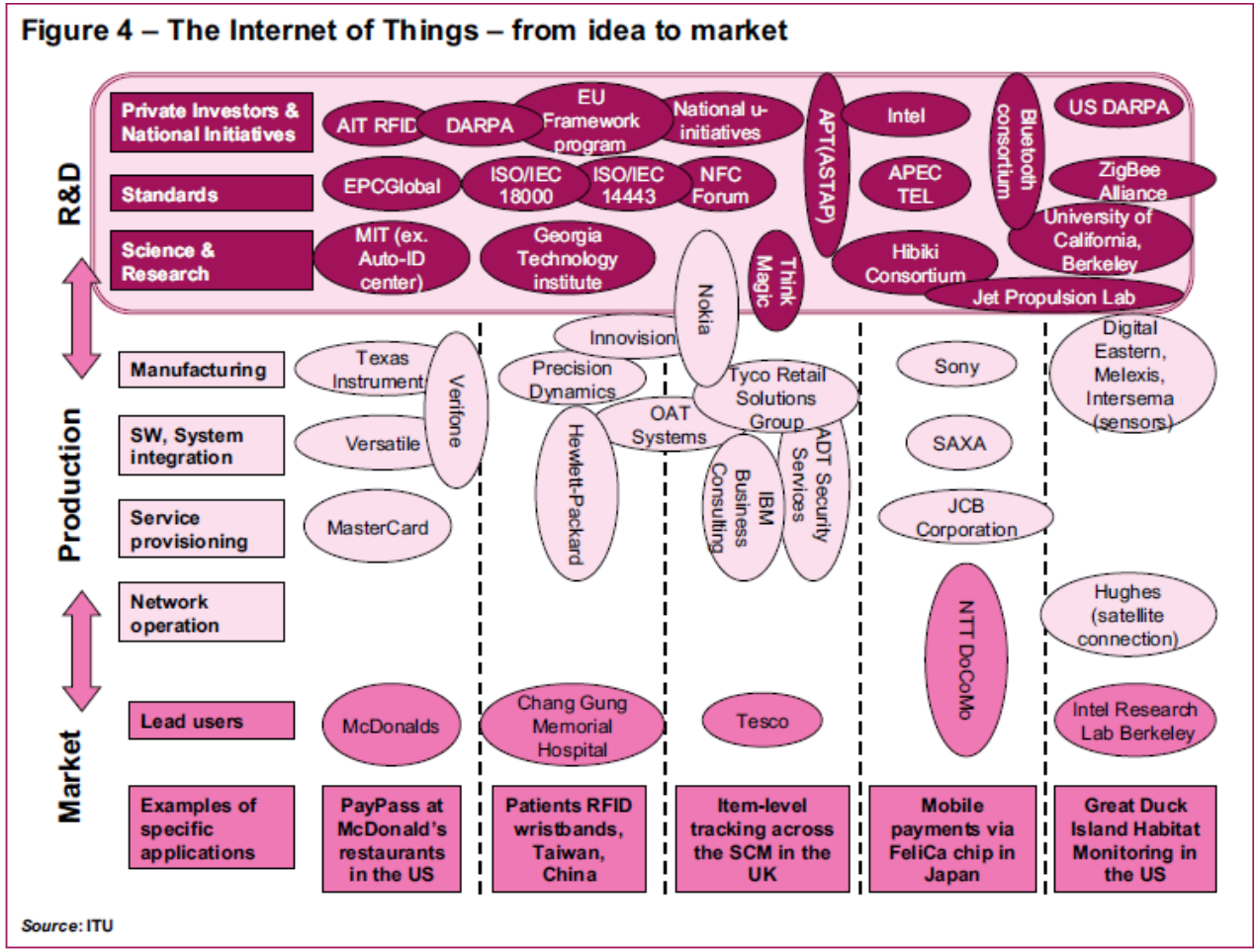
- Cool, but
  - Data quality of various sources
    - Accuracy of each data point
    - Sensor reliability and availability
    - Time of measurement
    - Important for trust!
  - Unit jungle:
    - nGy/s, mSv/h, Sv/h, Bq/kg, cpm …
    - Sometimes misleading, sometimes just hard to compare…
  - Mix of data sources
    - Real sensors
    - Virtual sensors (data scraping from web pages, e.g., http://www.houshasen-pref-ibaraki.jp/present/map.html)

Scenario 6: Wild Monitoring

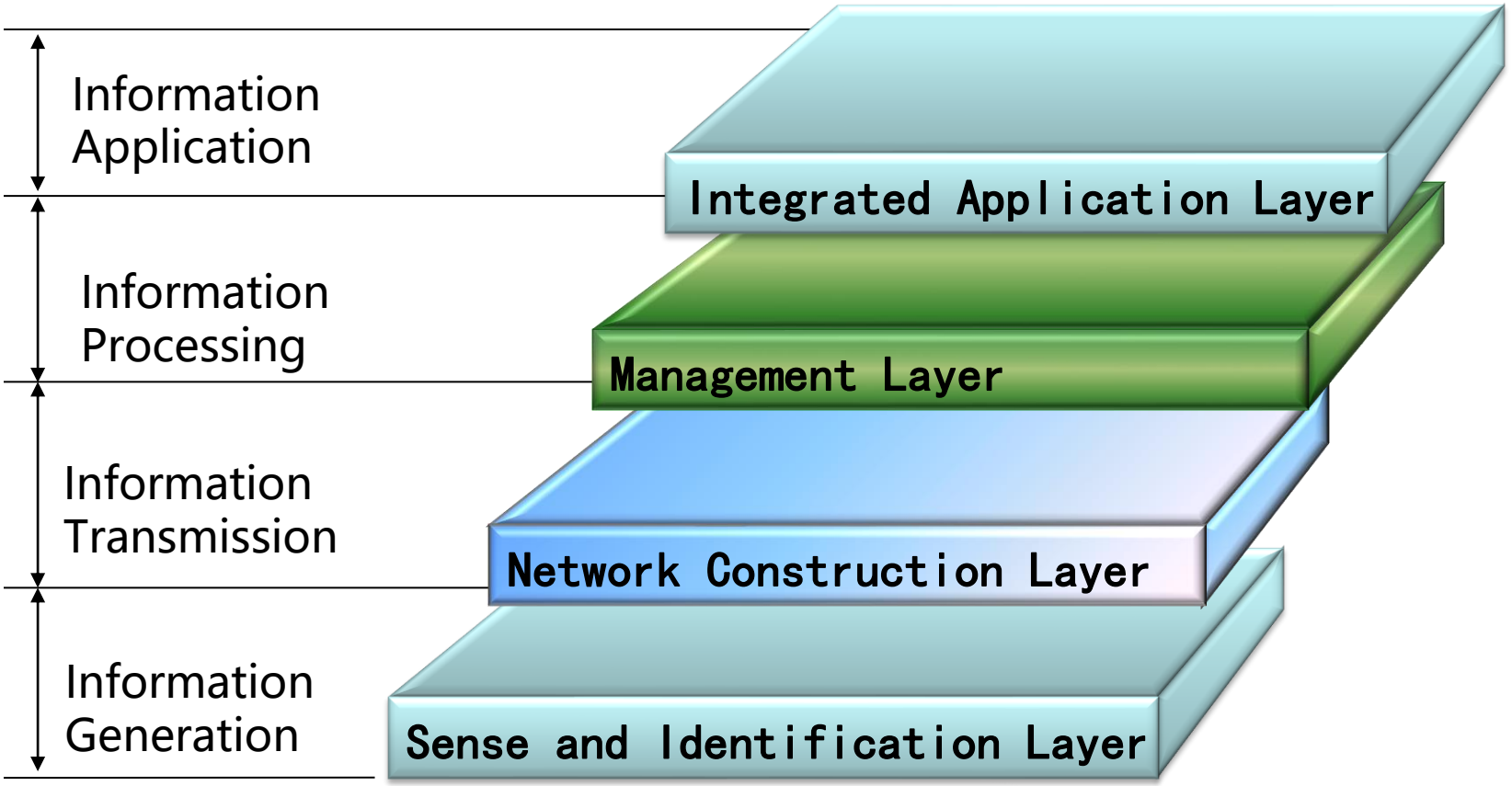


IoT Architecture

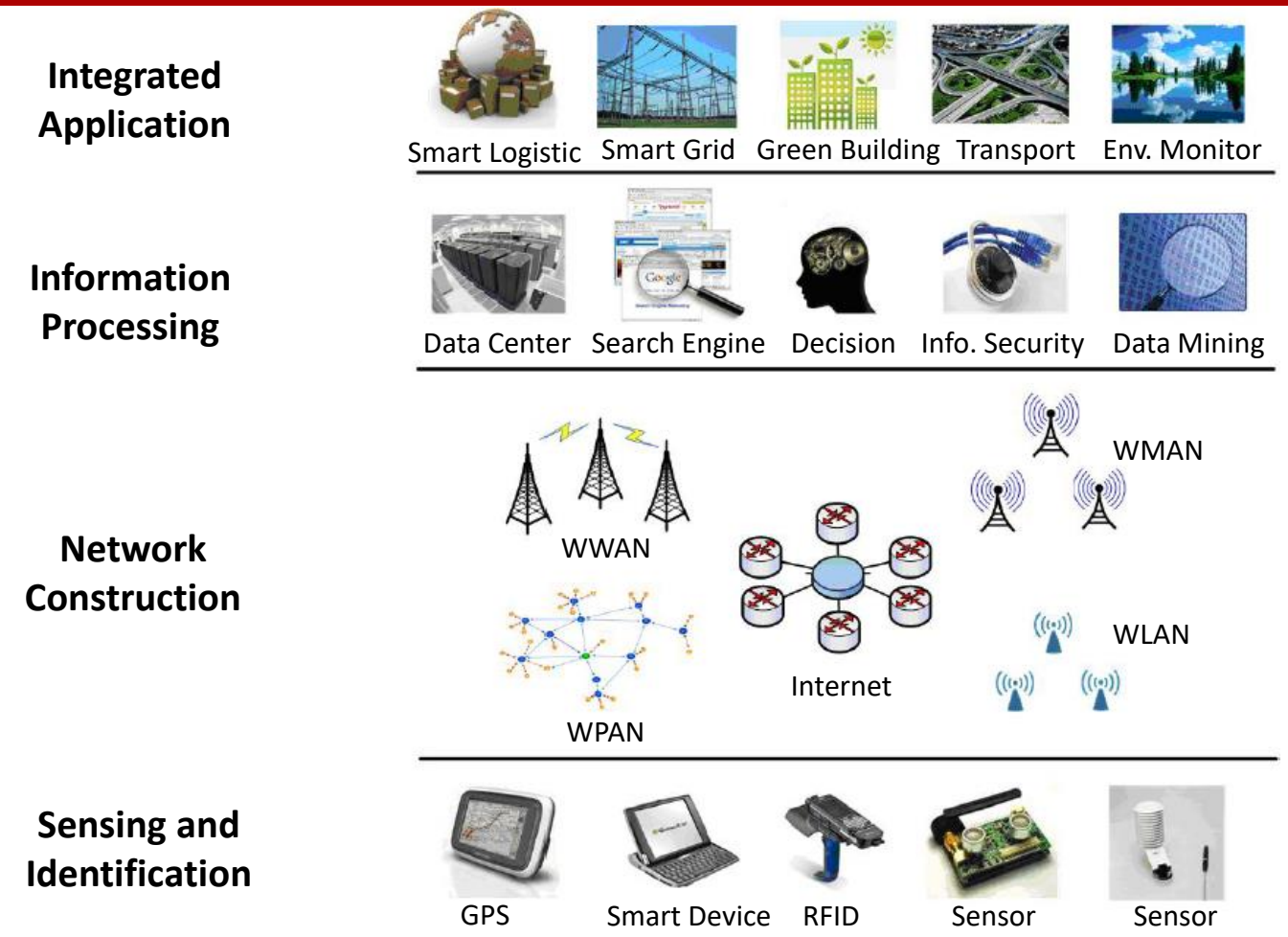
IoT Ecosystem



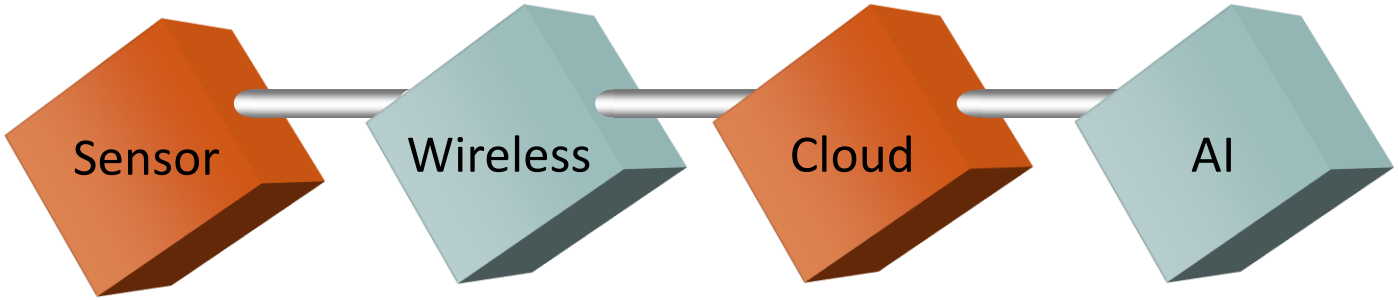
4-Layer Model for IoT



More on 4-Layer Model



Enabling Technologies



To collect and process the data to detect the changes in the physical status of things	To enable the transfer of data across geographic areas potentially with timing constraints	To leverage the processing power and storage capability of many server-class computers	To achieve advanced understanding of the data generated by IoT sensors and make decisions

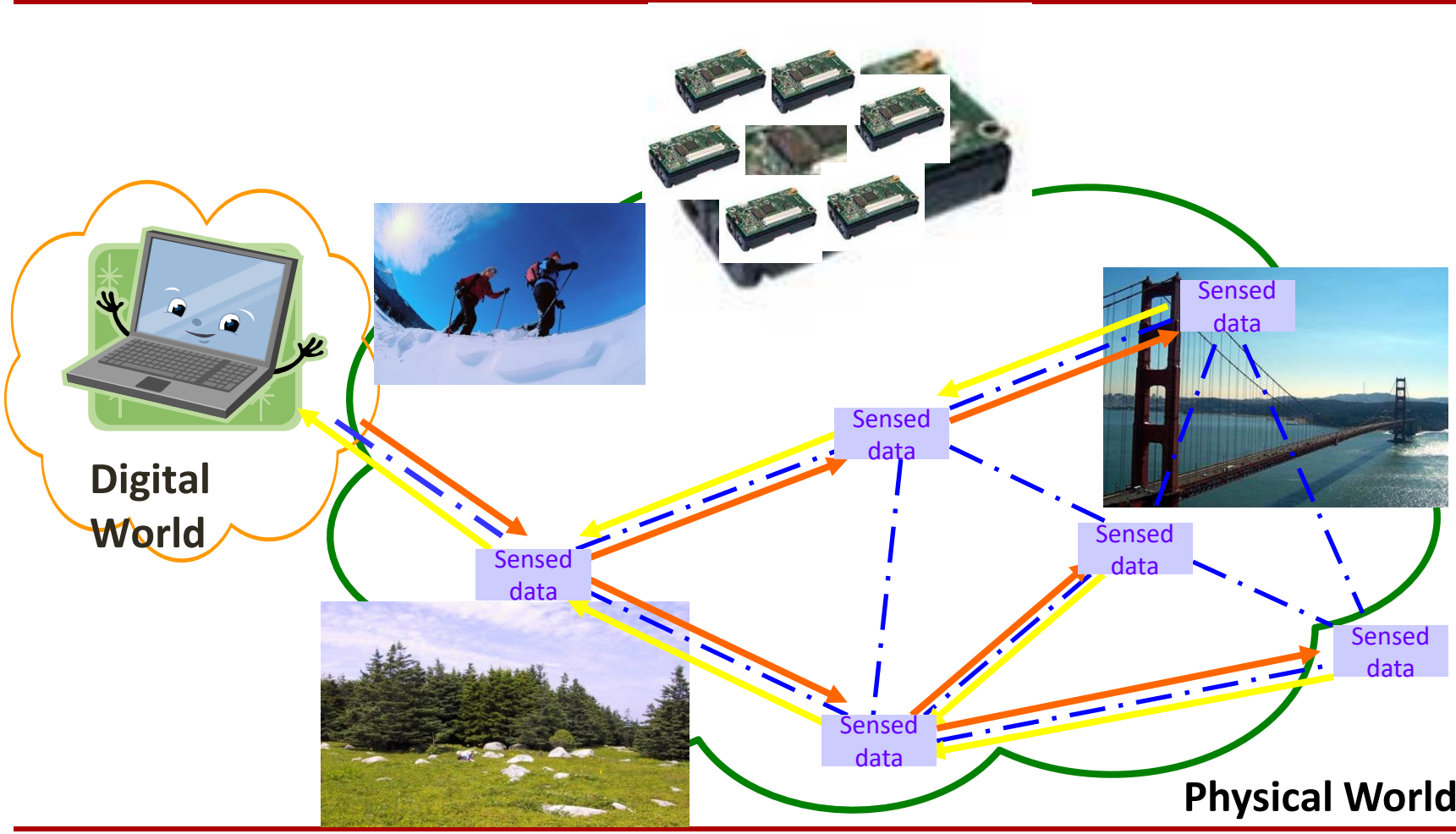
Sensor Technology

- The ability to detect changes in the physical status of things is essential for recording changes in the environment.
  - Example: sensors in an electronic jacket can collect information about changes in external temperature and the parameters of the jacket can be adjusted accordingly

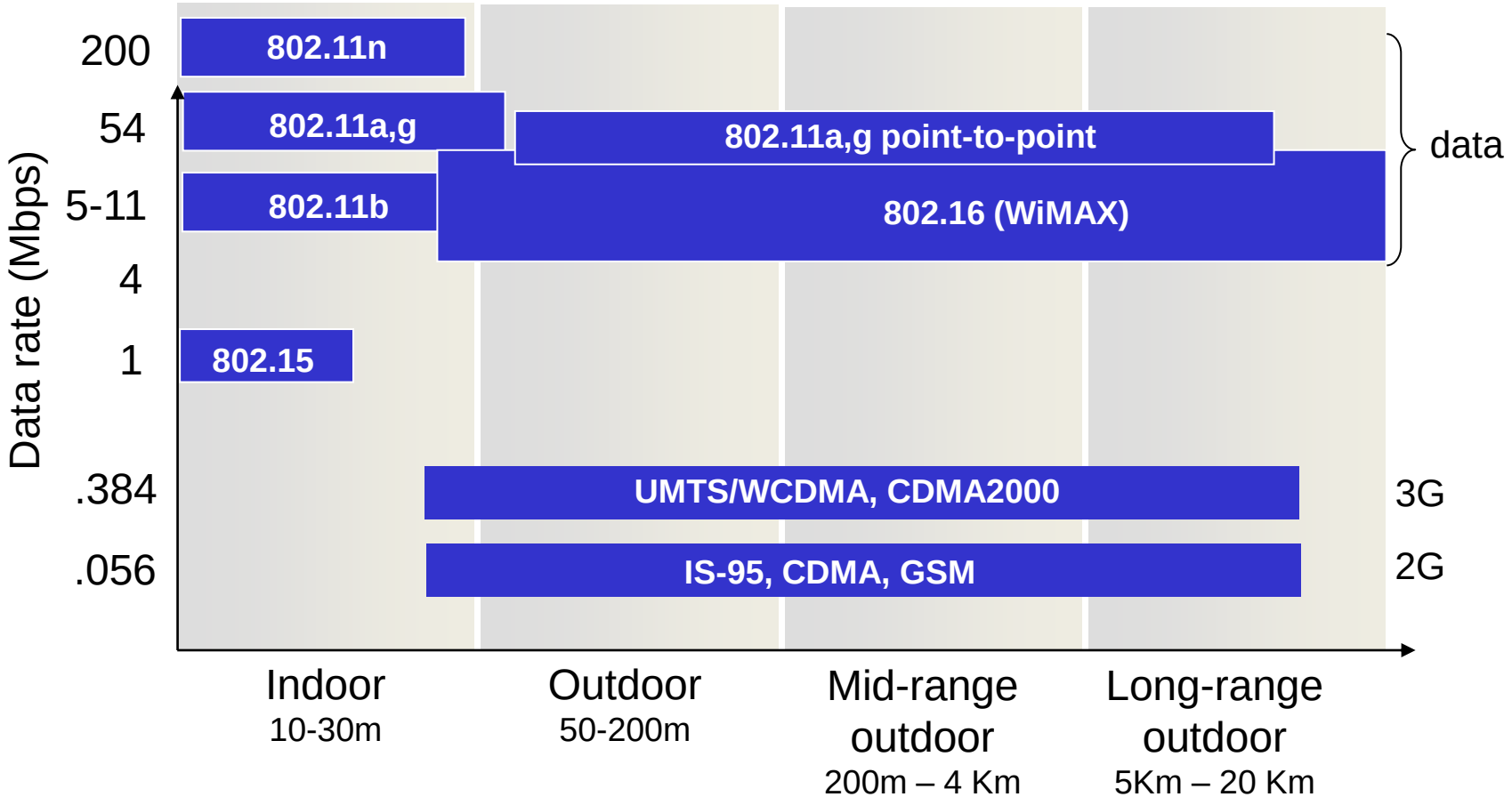
- Wireless sensor technology play a pivotal role in bridging the gap between the physical and virtual worlds, and enabling things to respond to changes in their physical environment. Sensors collect data from their environment, generating information and raising awareness about context.

- Wireless sensor networks: connect physical world and digital world at large scales

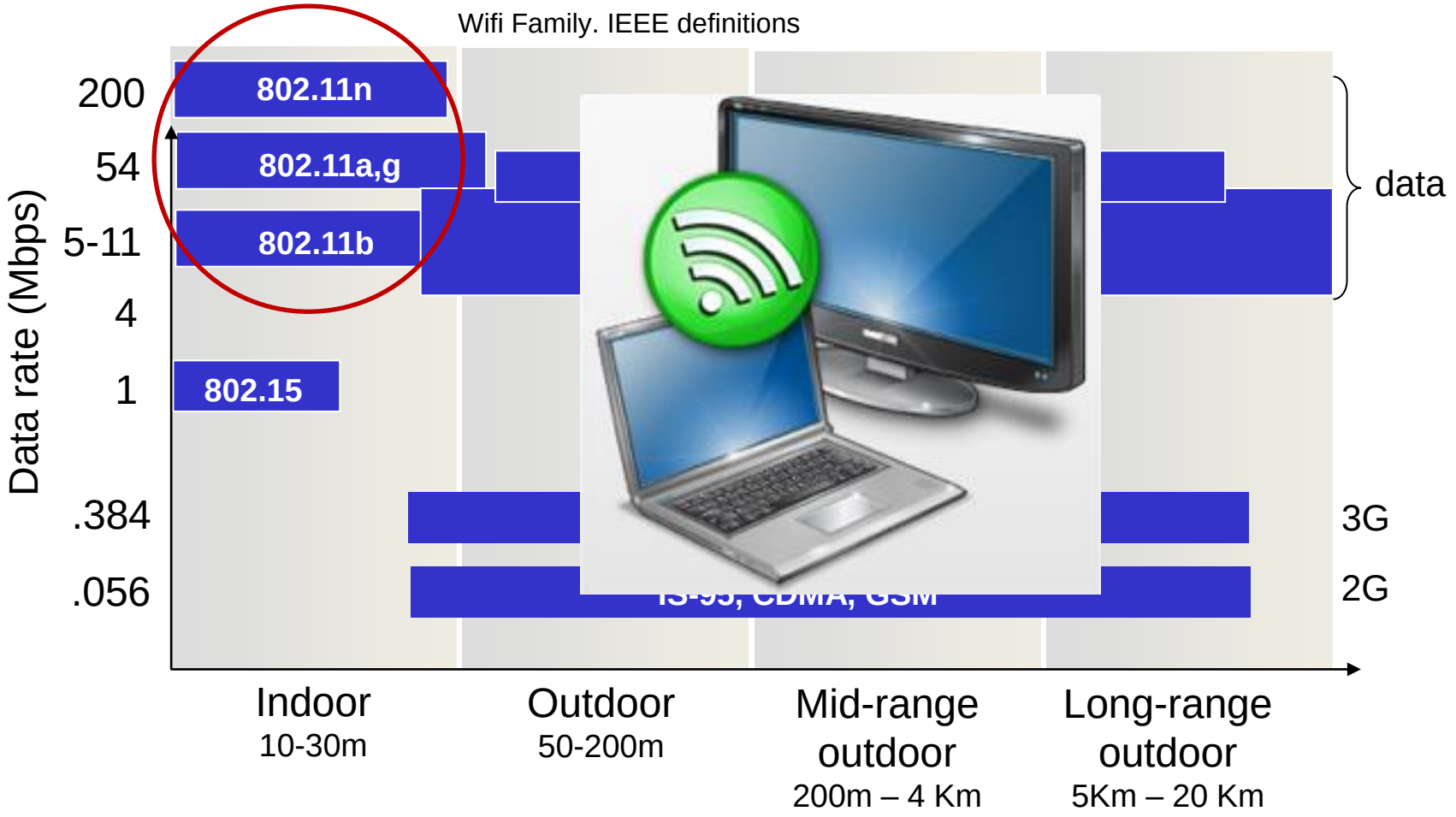
Sensor Technology (cont'd)



Wireless Technology

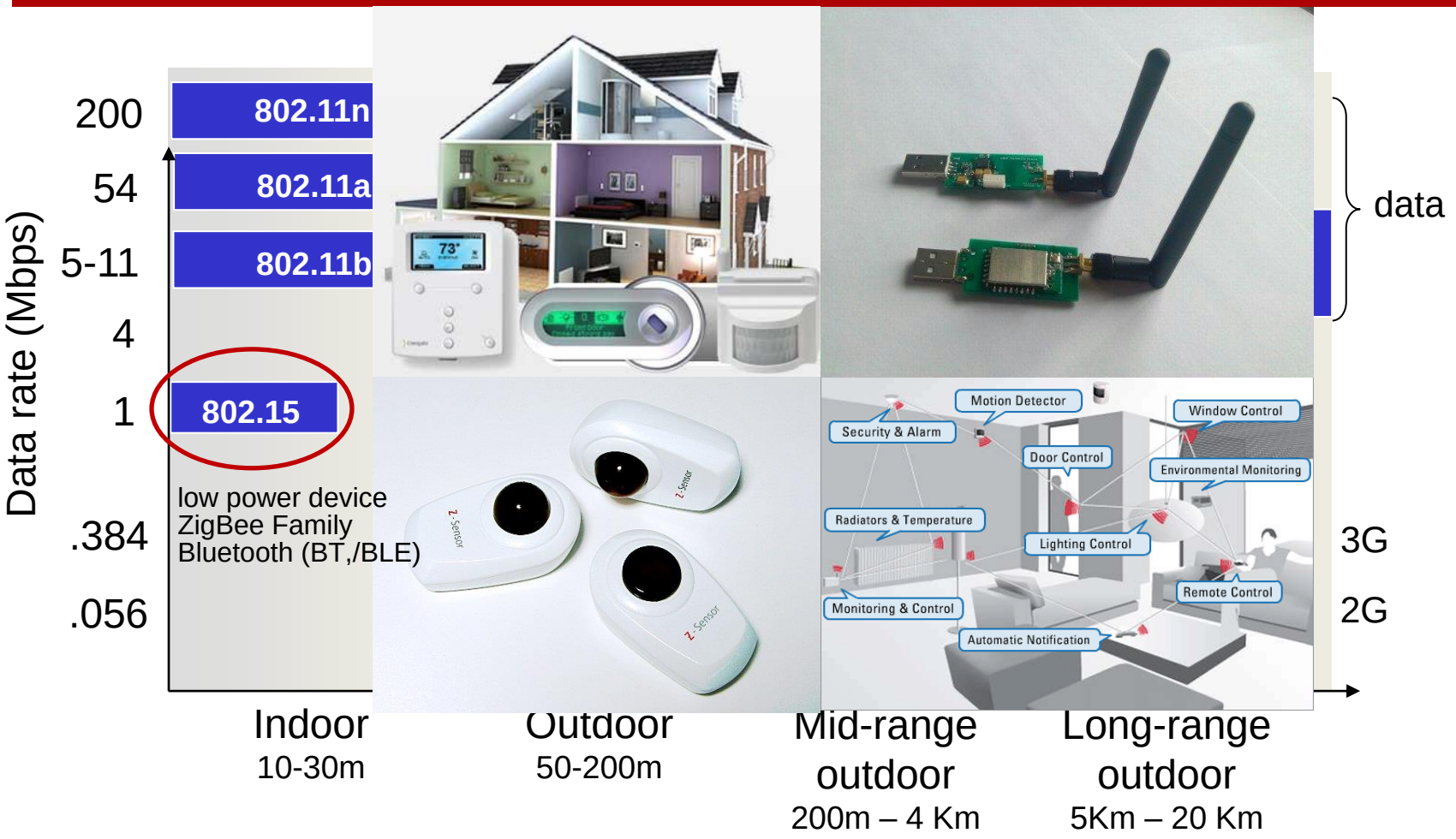


Wireless Technology (cont'd)

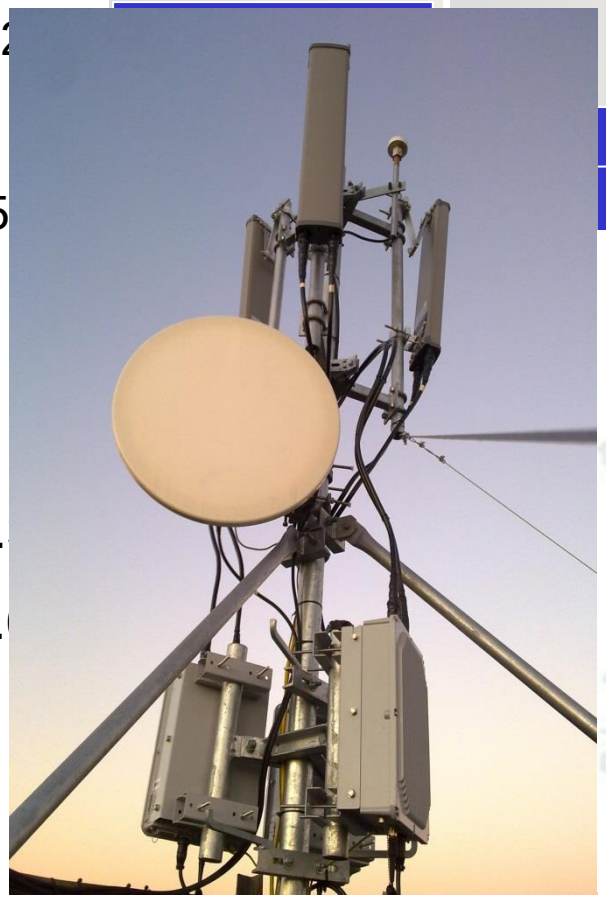


Wireless Technology (cont'd)

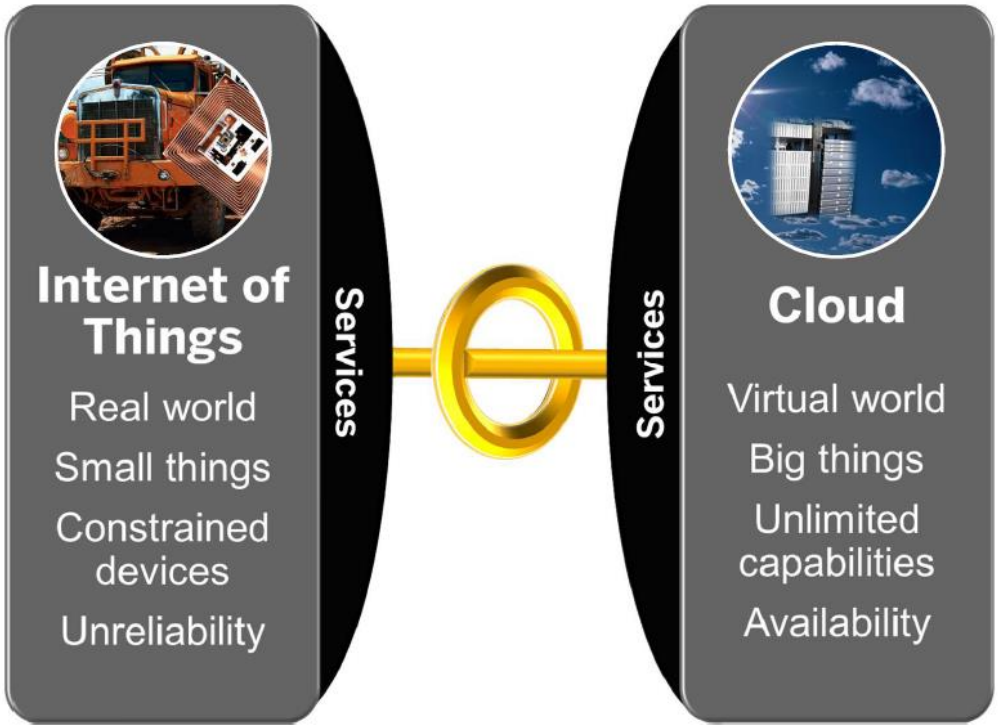
Wireless Technology (cont'd)



Wireless Technology (cont'd)



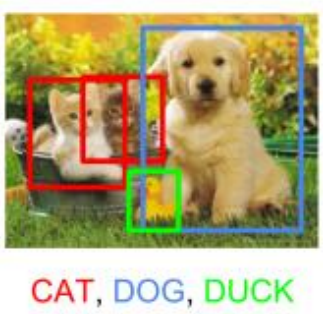
Cloud Technology



Data center
(Image credit: Google)

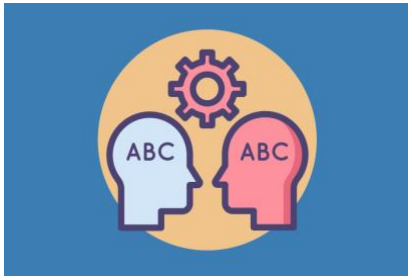
AI Technology

- The exploitation of GPU's parallel computing capability unleashes the power of deep neural networks
  - AlexNet 2012: 8 layers
  - VGG Net 2014: 19 layers
  - GoogLeNet 2015: 22 blocks (>100 layers)
  - Microsoft ResNet 2015: 152 layers



Object detection and classification

Automated speech recognition

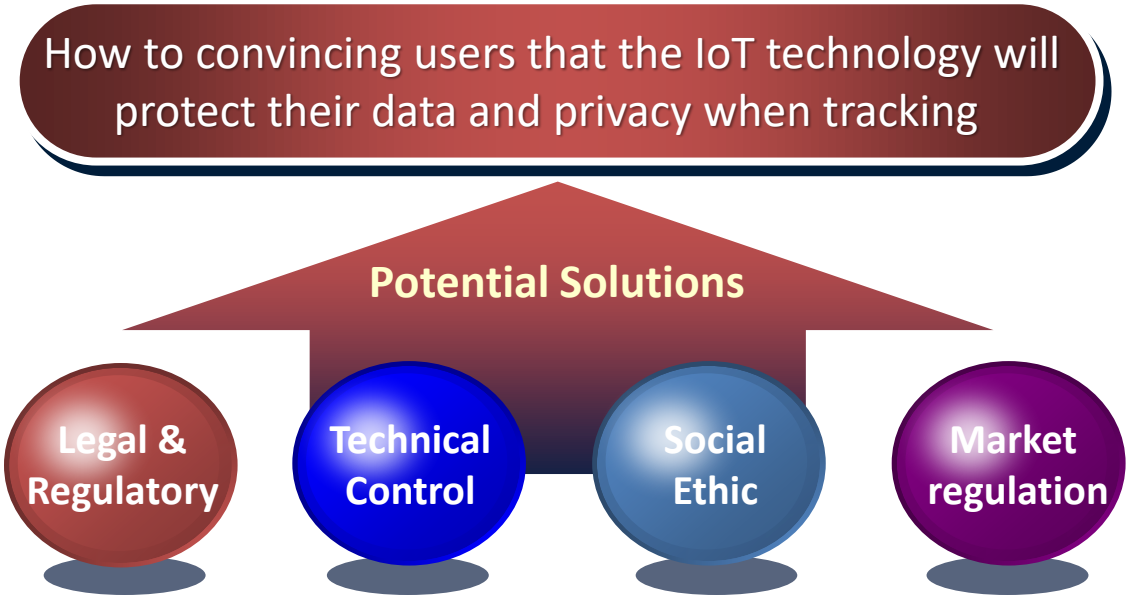


Natural language processing

Decision making

Challenges of IoT

- Social impact
  - Privacy and security
- Governance
  - Technological standardization is now fragmented
  - Managing rapid innovation is challenging to governments



Learning Objectives

- Understand what is urban computing
- Understand the evolution of computing up to IoT computing
- Read IoT applications
- Understand enabling technologies of IoT