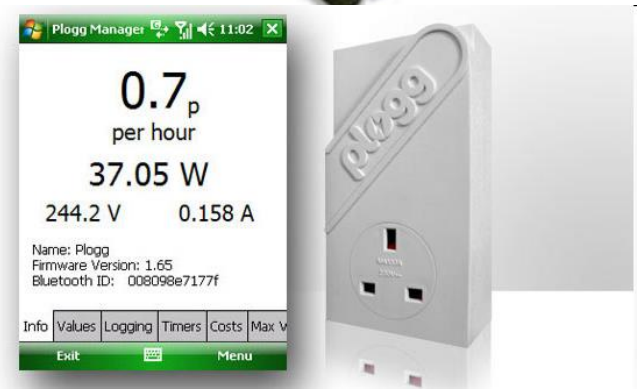
Overview
Internet of Things


IN 60 SECONDS...
1 NEW DEFINITION IS ADDED ON urban
1,600+ READS ON Scribd
13,000+ HOURS MUSIC STREAMING ON PANDORA
12,000+ NEW ADS POSTED ON craigslist
370,000+ MINUTES VOICE CALLS ON skype
98,000+ TWEETS
20,000+ NEW POSTS ON tumblr.
THE LARGEST SOCIAL READING PUBLISHING COMPANY
320+ NEW twitter ACCOUNTS
13,000+ iPhone APPLICATIONS DOWNLOADED
100+ NEW Linked in ACCOUNTS
1 associatedcontent NEW ARTICLE IS PUBLISHED
THE WORLD'S LARGEST COMMUNITY CREATED CONTENT!!
QUESTIONS ASKED ON THE INTERNET...
100+ Answers.com
40+ YAHOO! ANSWERS
600+ NEW VIDEOS
25+ HOURS TOTAL DURATION
70+ DOMAINS REGISTERED
60+ NEW BLOGS
1,500+ BLOG POSTS
168 MILLION EMAILS ARE SENT
694,445 SEARCH QUERIES
Google
Google Search
1,700+ Firefox DOWNLOADS
6,600+ NEW PICTURES ARE UPLOADED ON flickr
50+ WordPress DOWNLOADS
695,000+ facebook STATUS UPDATES
125+ PLUGIN DOWNLOADS
79,364 WALL POSTS
510,040 COMMENTS
GO-Globe.com

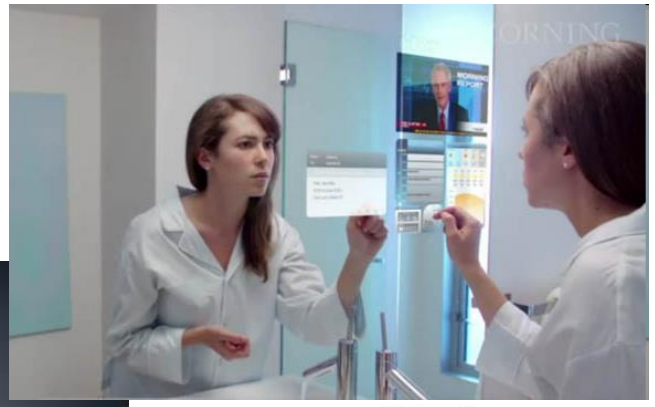
Sensor devices are becoming widely available

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

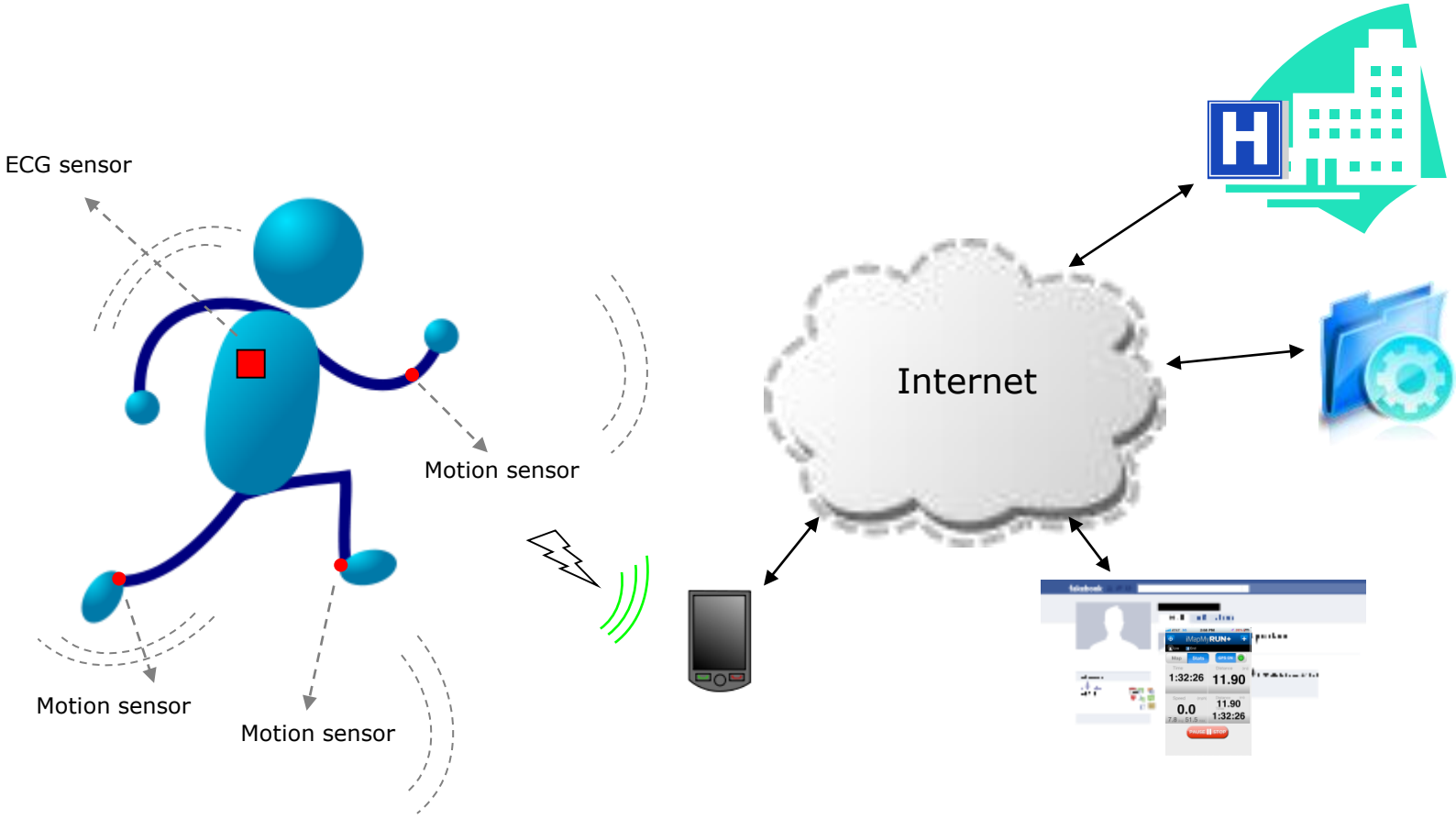


More “Things” are being connected

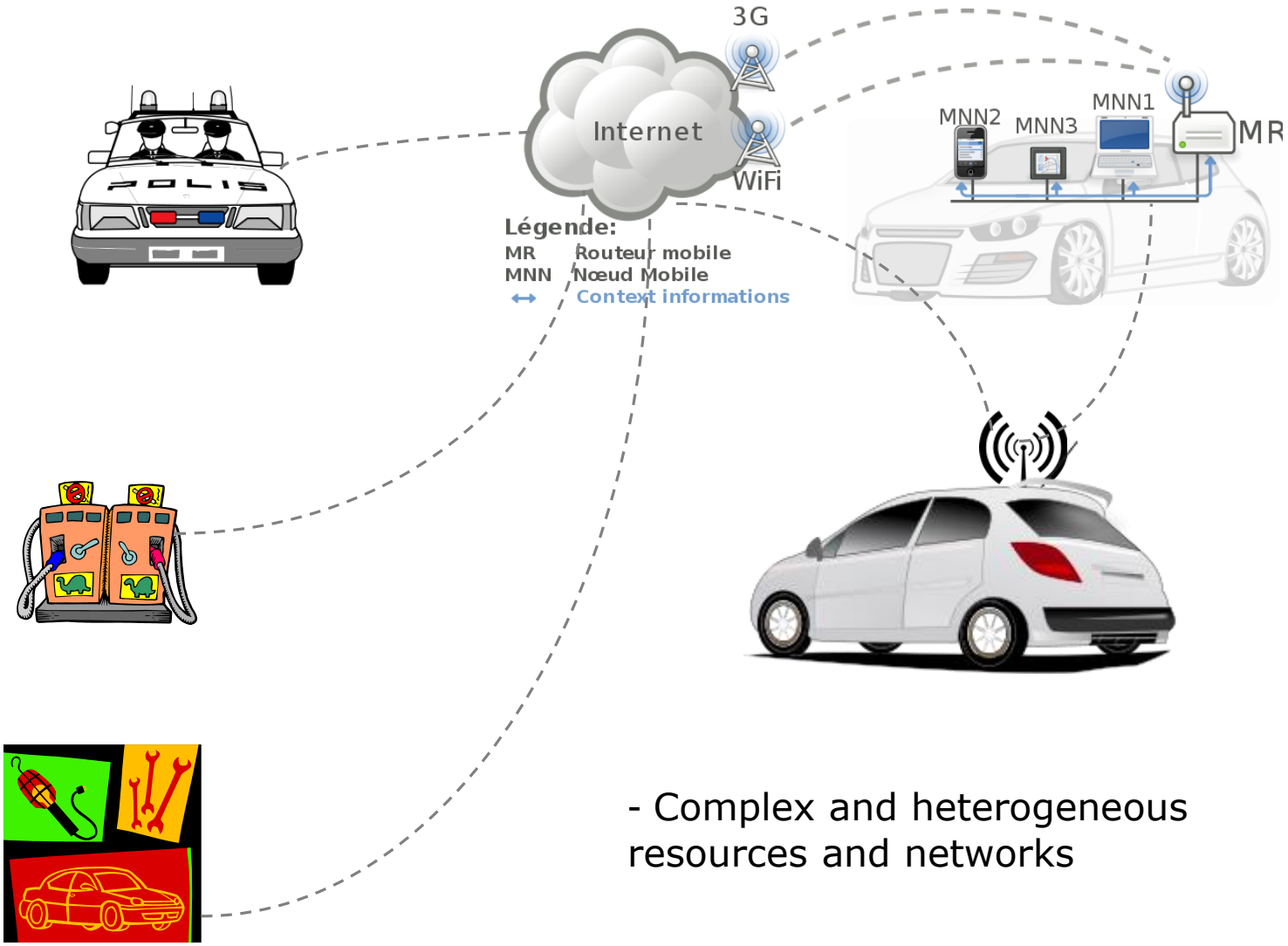
Home/daily-life devices
Business and
Public infrastructure
Health-care
…



People Connecting to Things

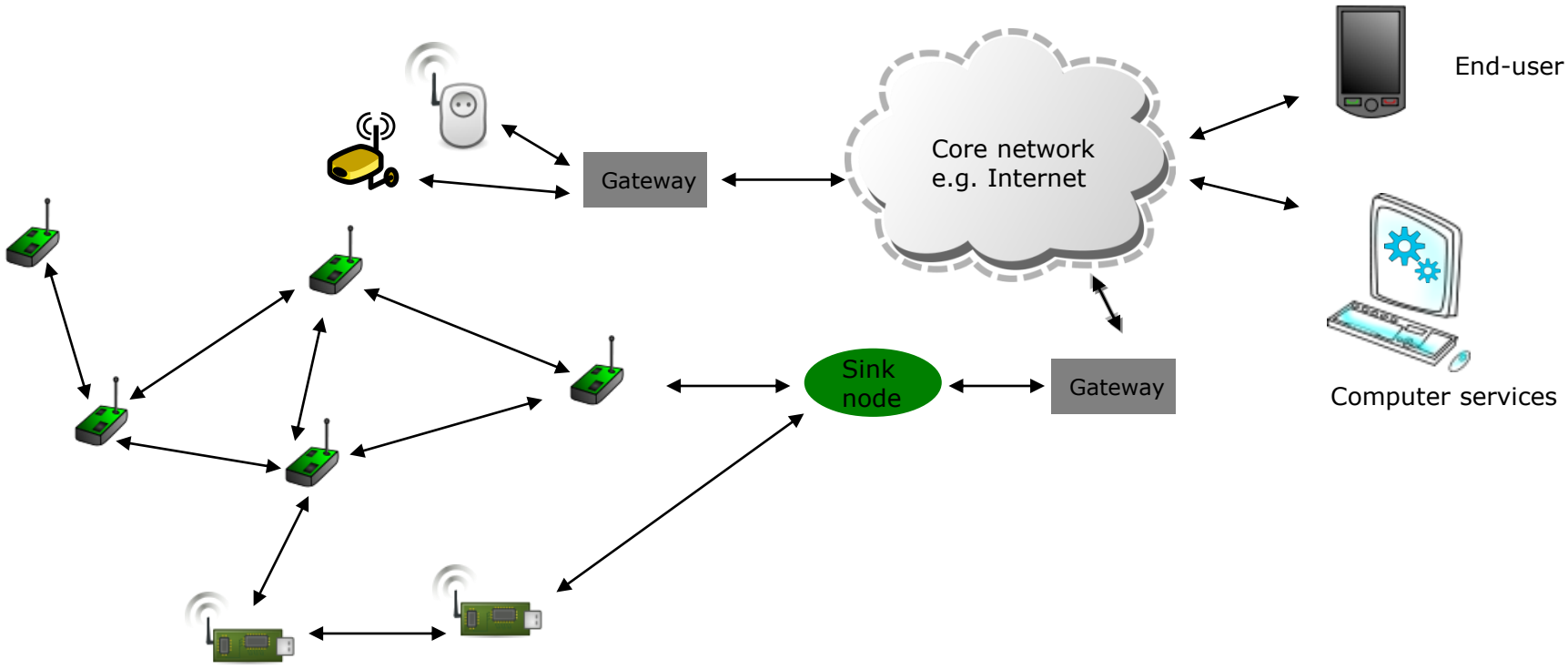


Things Connecting to Things



- Complex and heterogeneous resources and networks

Wireless Sensor Networks (WSN)

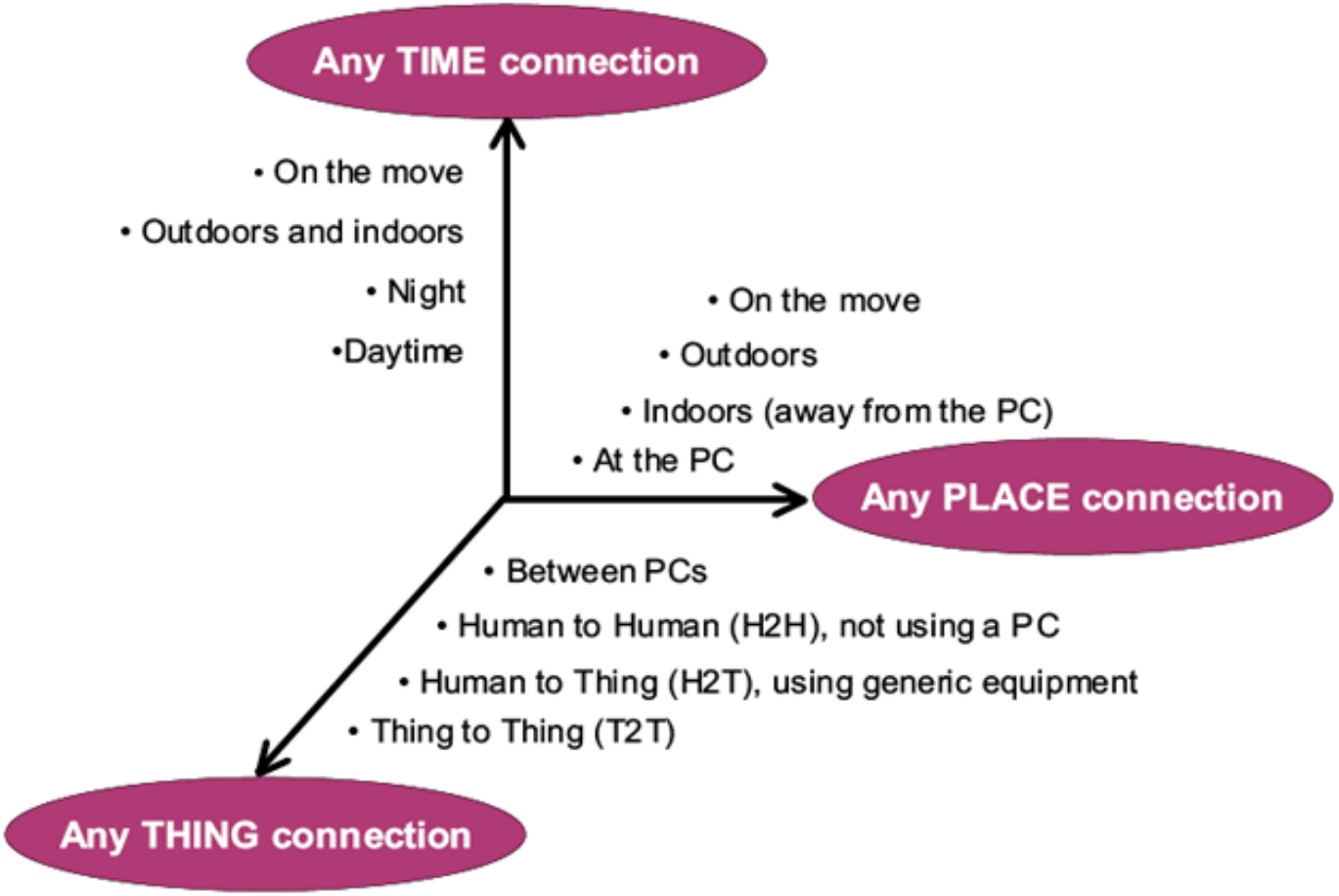


- The networks typically run Low Power Devices
- Consist of one or more sensors, could be different type of sensors (or actuators)

How are the networks changing?

- Extensions
  - More nodes, more connections, IPv6, 6LowPan,...
  - Any TIME, Any PLACE + Any THING
  - M2M, IoT
    - Billions of interconnected devices,
    - Everybody connected.
- Expansions
  - Broadband
- Enhancements
  - Smart networks
  - Data-centric and content-oriented networking
  - Context-aware (autonomous) systems

Future Networks



Source: ITU adapted from Nomura Research Institute

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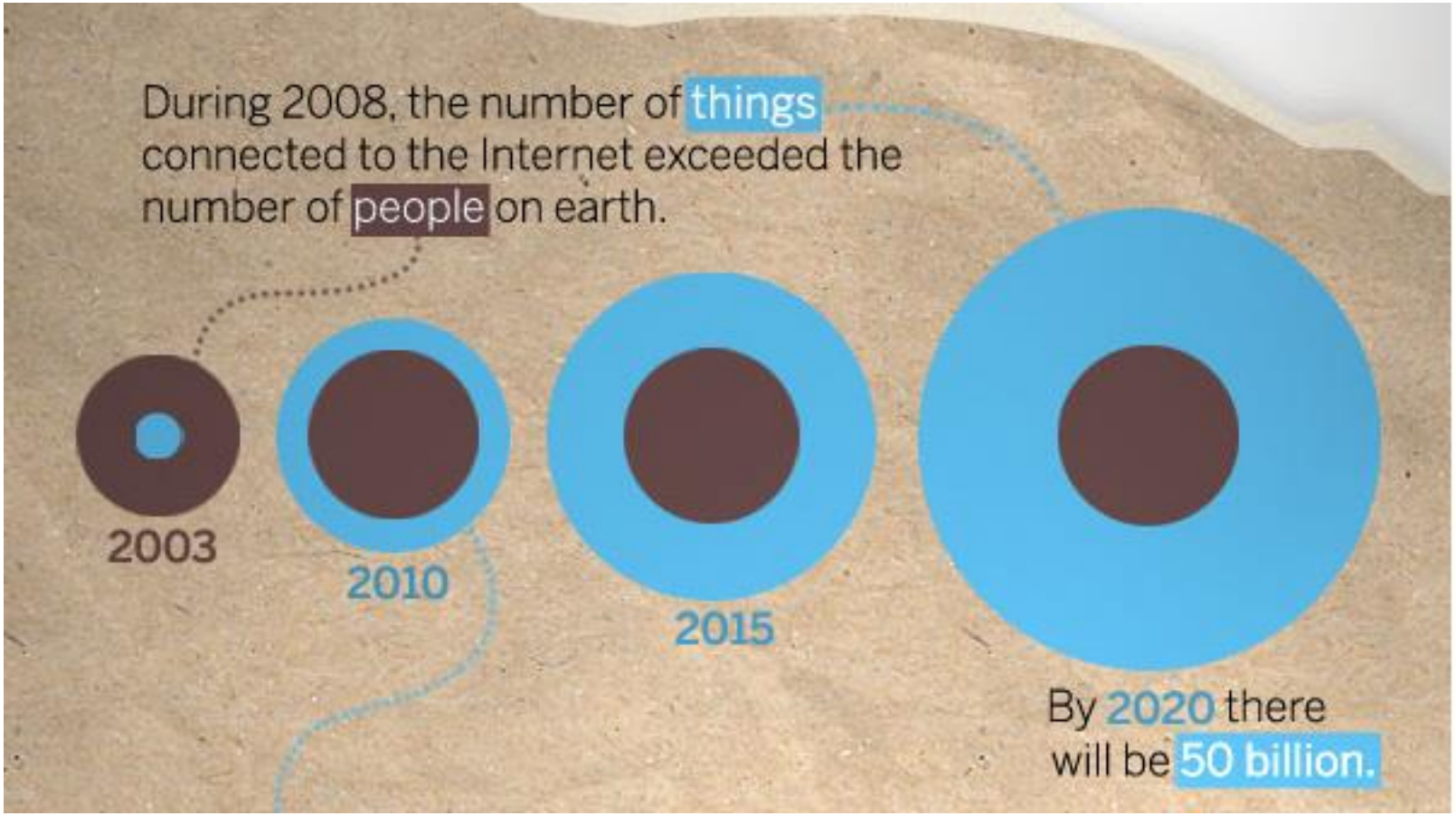
“Thing” connected to the internet



Source: CISCO

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Internet of Things (IoT)

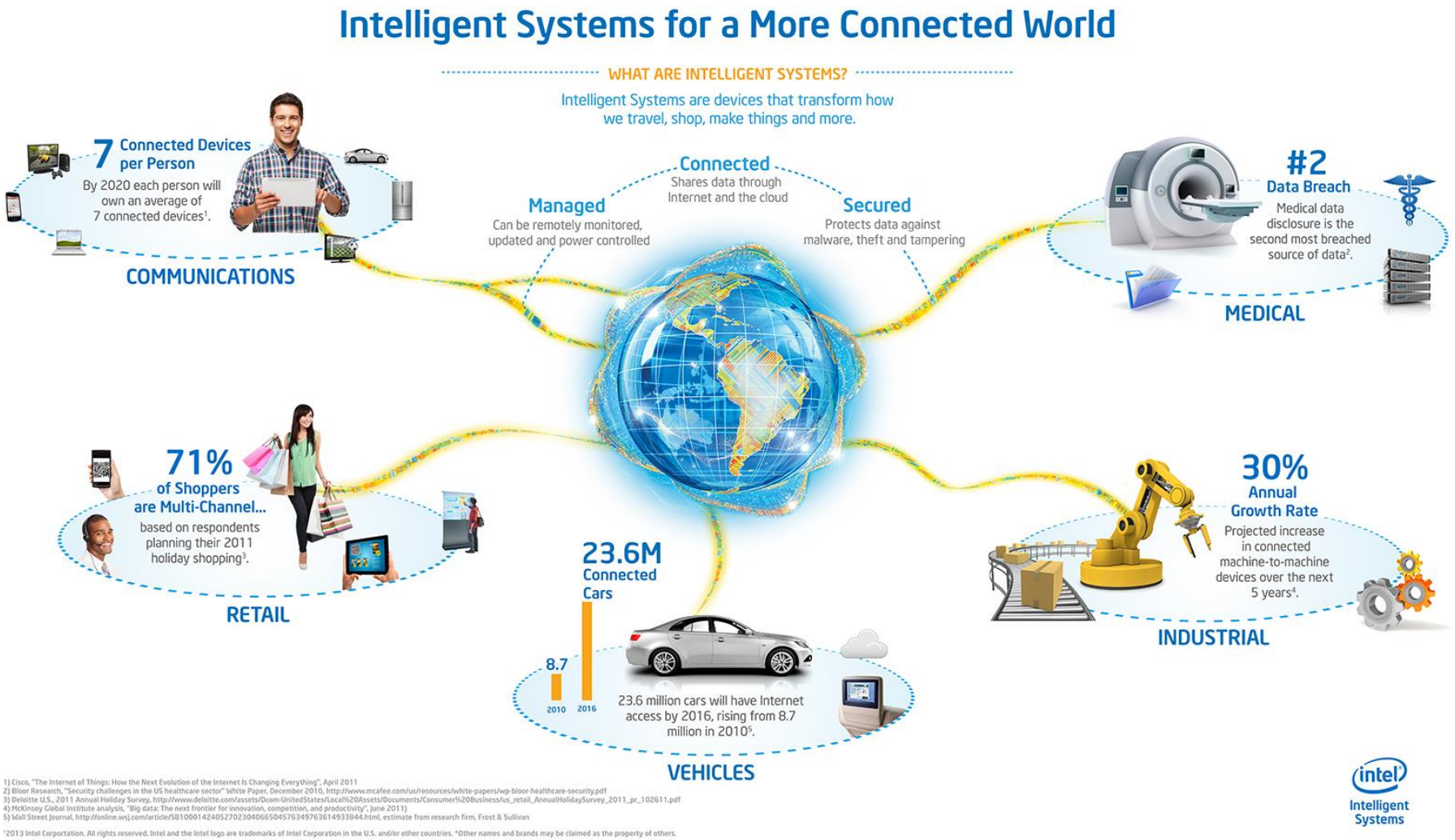
- Extending the current Internet and providing connection, communication, and inter-networking between devices and physical objects, or "Things," is a growing trend that is often referred to as the *Internet of Things*.

- "The technologies and solutions that enable integration of real world data and services into the current information networking technologies are often described under the umbrella term of the Internet of Things (IoT)"

Why should I learn about IoT?

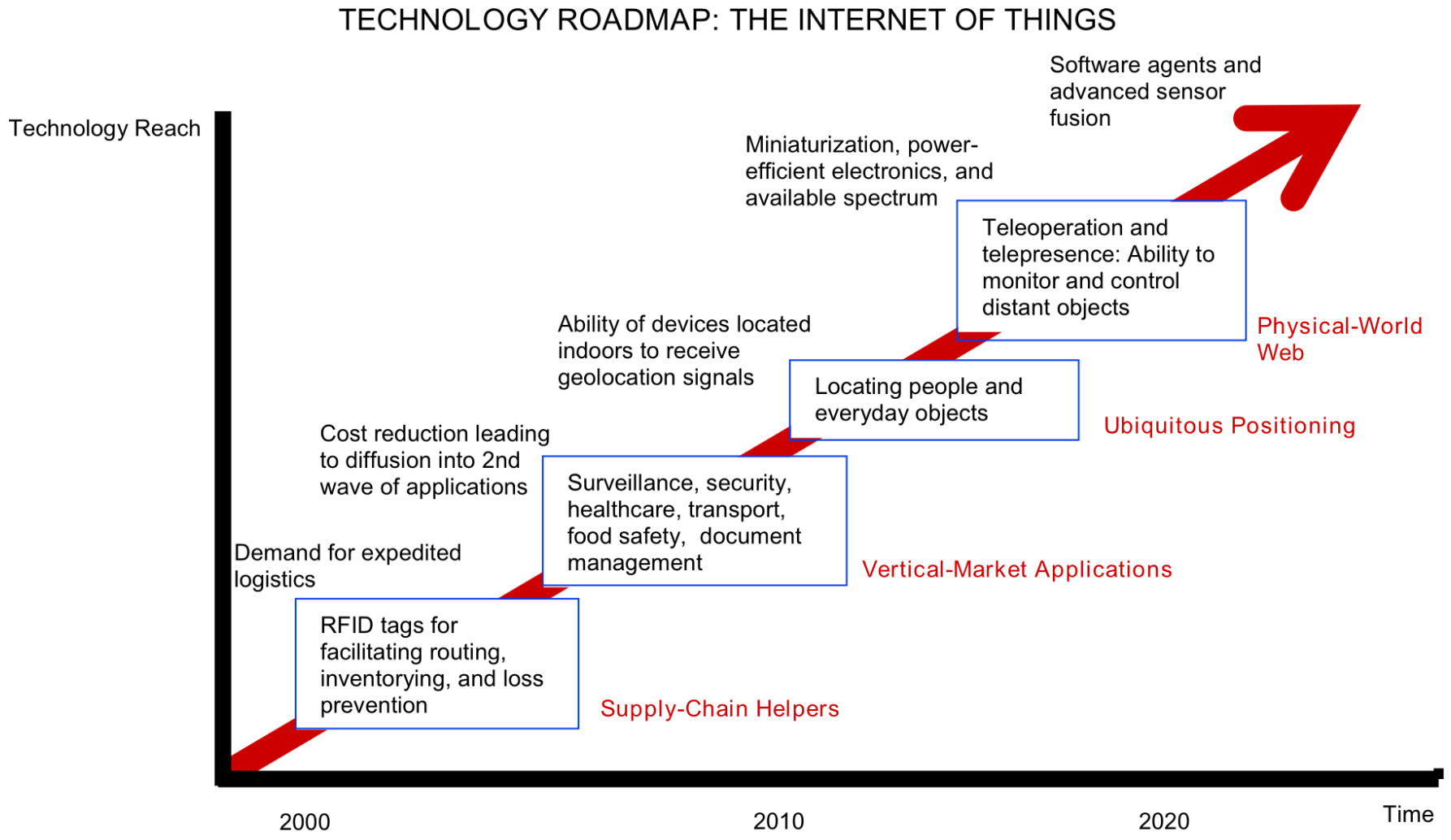
- Business trend
- Emerging technologies
- Growing IoT Services and Application

Opportunities



Source: http://blog.trentonsystems.com/internet-of-things-crosses-business-personal-boundaries/

Technology trend



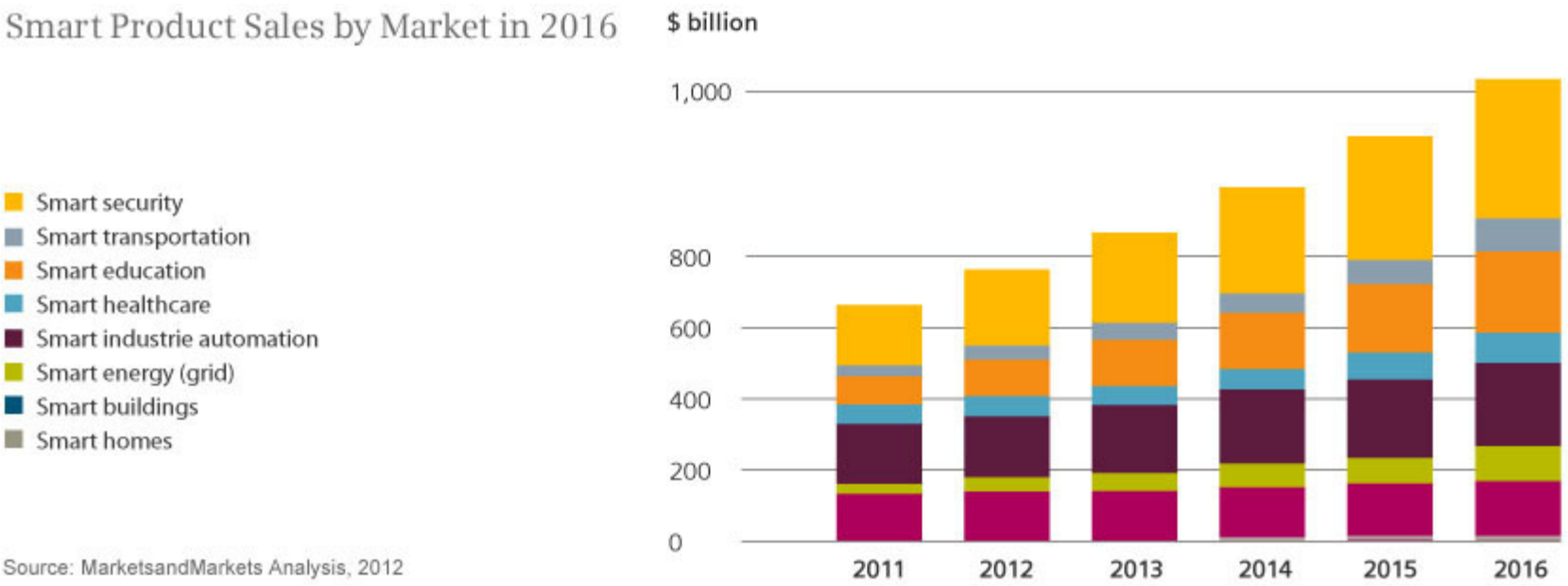
Source: SRI Consulting Business Intelligence

Market growth

- "According to a study conducted by Frost & Sullivan in 2011, the global RFID market of $3 billion to $4 billion (in 2009) will grow by twelve percent per year through 2016 and reach a volume of approximately $6.5 billion to almost $9 billion."
- 80 percent of all households in the European Union are expected to have intelligent power meters by 2020.
- A building's energy management can then be monitored and administered remotely via a smartphone or a PC. Market experts predict that this global market, which represented $5.3 billion in 2010,
- In February 2012 the Chinese government therefore decided to set up a fund of approximately $775 million to support this field in the next five years.will grow to $11 billion by 2015.
- This sector is expected to grow to $116 billion by 2015, according to a report published by the Xinhua News Agency in late 2010.

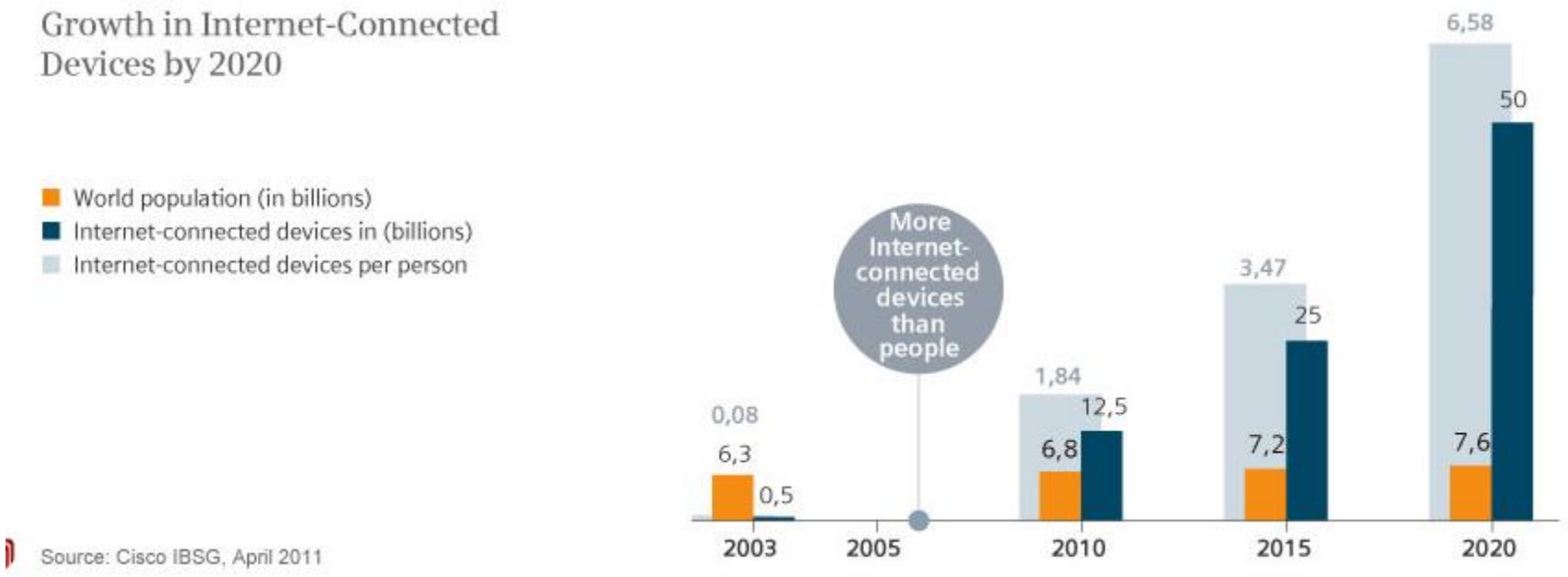
Source: Siemens, http://www.siemens.com/innovation/apps/pof_microsite/_pof-fall-2012/_html_en/facts-and-forecasts-growth-market-of-the-future.html

Smart product sales



Source: Siemens, http://www.siemens.com/innovation/apps/pof_microsite/_pof-fall-2012/_html_en/facts-and-forecasts-growth-market-of-the-future.html

Internet Connected devices



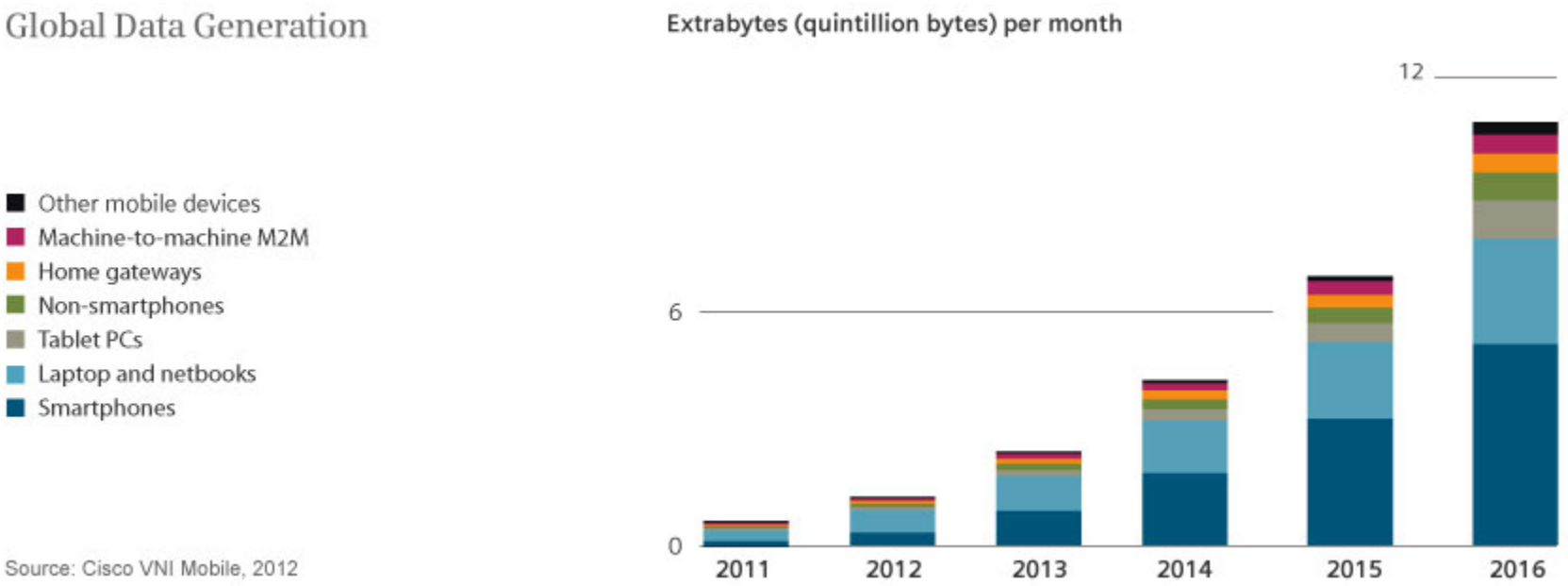
Source: Siemens, http://www.siemens.com/innovation/apps/pof_microsite/_pof-fall-2012/_html_en/facts-and-forecasts-growth-market-of-the-future.html

Global Data Generation

- Everyday around 20 quintillion (10^18) bytes of data are produced (Source: http://www-01.ibm.com/software/data/bigdata/).

- This data includes textual content (unstructured, semi-structured, structured) to multimedia content (images, video and audio), on a variety of platforms (enterprise, social media, and sensors).

Data Generation



Internet of Things Module

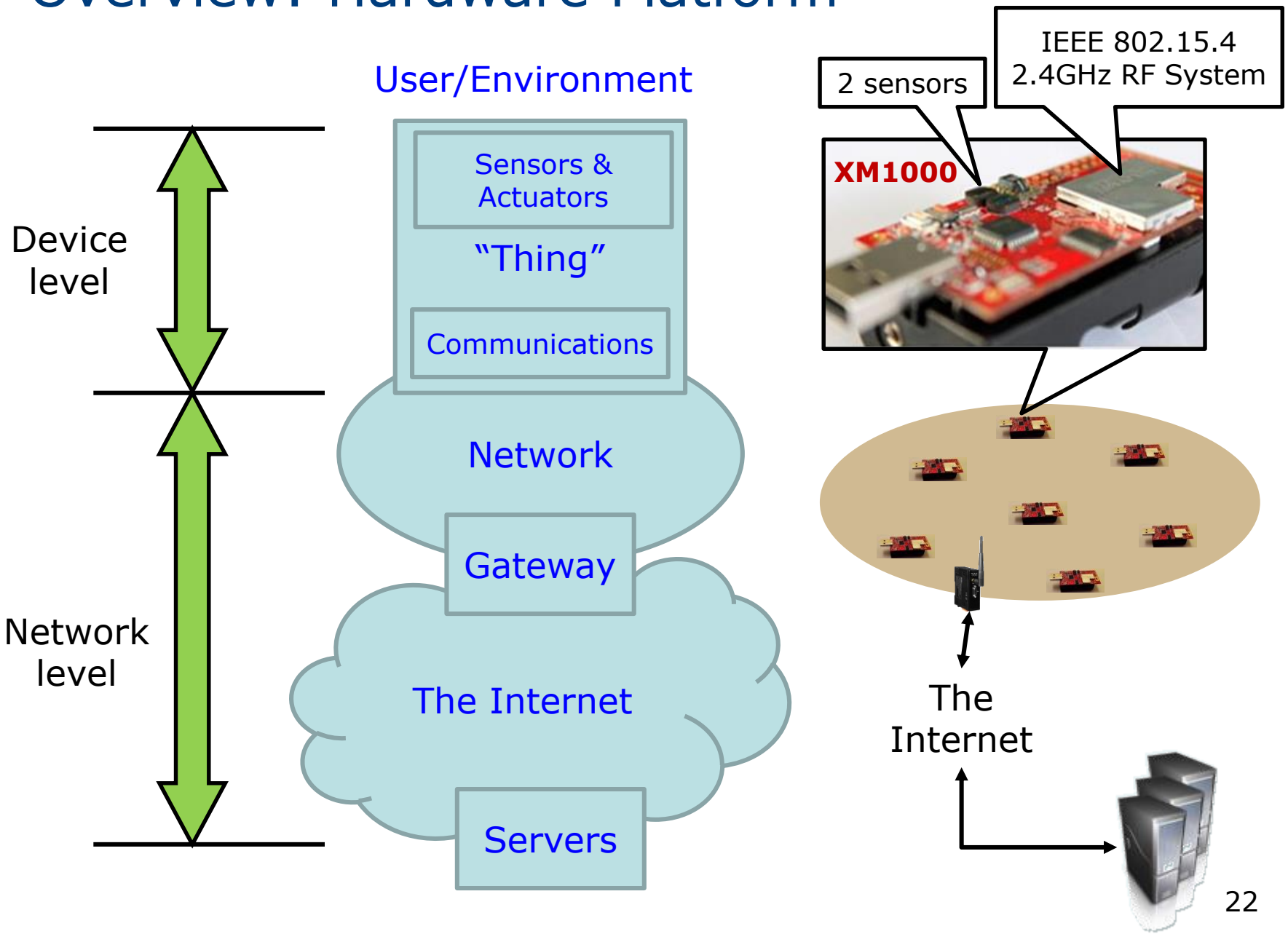
Image courtesy: Wilgengebroed

Topics

- Cyber-Physical systems, smart devices, sensors and actuators
- Key applications, protocols and architectures
- Networks and Communications (Wireless Multi-hop Networks (WMN), Mobile Ad-hoc Networks (MANET), Wireless Sensor Networks (WSN))
- Reliability, Security, Privacy and Trust issues and solutions

- Software platforms and services
- Intelligent Data Processing and Semantic technologies
- Connecting things to the Web
- Applications, system models, Standards, and Physical-Cyber-Social systems

Overview: Hardware Platform



Sensors & Actuators

- Sensors:
  - They are mainly input components
  - They sense and collect surrounding information
  - Basically three types:
    - Passive, omnidirectional (e.g. mic)
    - Passive, narrow-beam sensor (e.g. PIR)
    - Active sensors (e.g. sonar, radar, etc.)

- Actuators:
  - They are mainly output components
  - They alter the surrounding. Some examples:
    - Adding lighting, heat, sound, etc.
    - Controlling motors to move objects
    - Displaying messages
    - and others…

Things

- We can turn almost every object into a “thing”.
- A “thing” still looks much like an embedded system currently.
- A “thing” generally consists of four main parts:
  - Sensors & actuators
  - Microcontroller
  - Communication unit
  - Power supply
- A “thing” has the following properties:
  - It’s usually powered by battery. This implies limited source of energy.
  - It’s generally small in size and low in cost. This limits their computing capability.
  - It doesn’t usually perform complicated tasks.
- Power consumption is the main design issue.

Communications

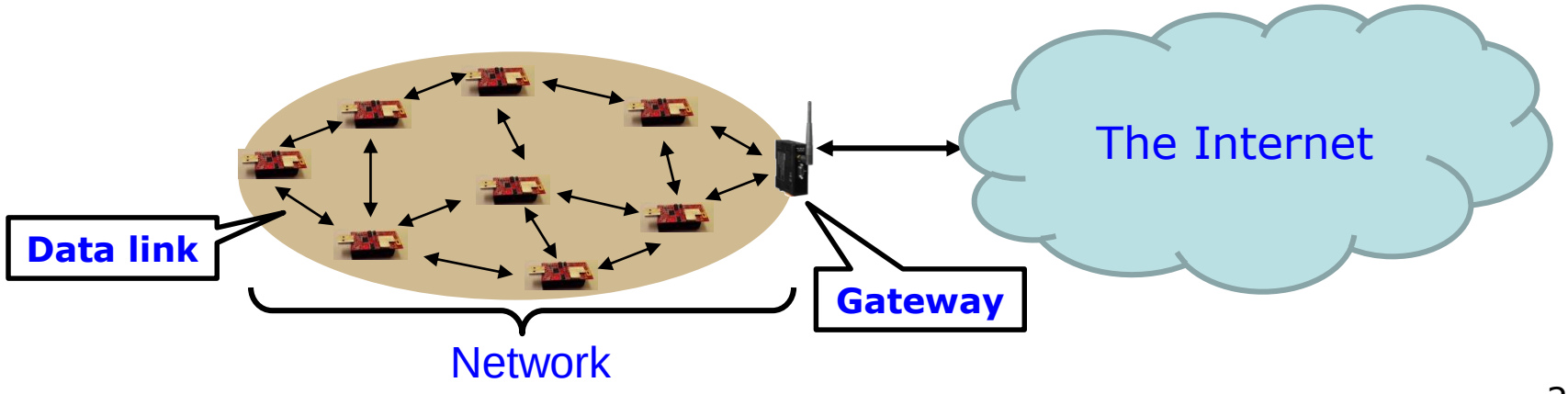
- A “thing” always feature communications for “team working”
- The Role of Communications
  - Providing a data link between two nodes
- Communication type:
  - Wireline (e.g. copper wires, optical fibers)
  - Wireless (e.g. RF, IR). RF-based communication is the most popular choice (and also our focus)
- Popular RF-based communication solutions:
  - IEEE 802.15.4 ← used in XM1000
  - IEEE 802.11 (or Wifi)
  - Bluetooth
  - Near Field Communication (NFC), e.g. RFID

Networks

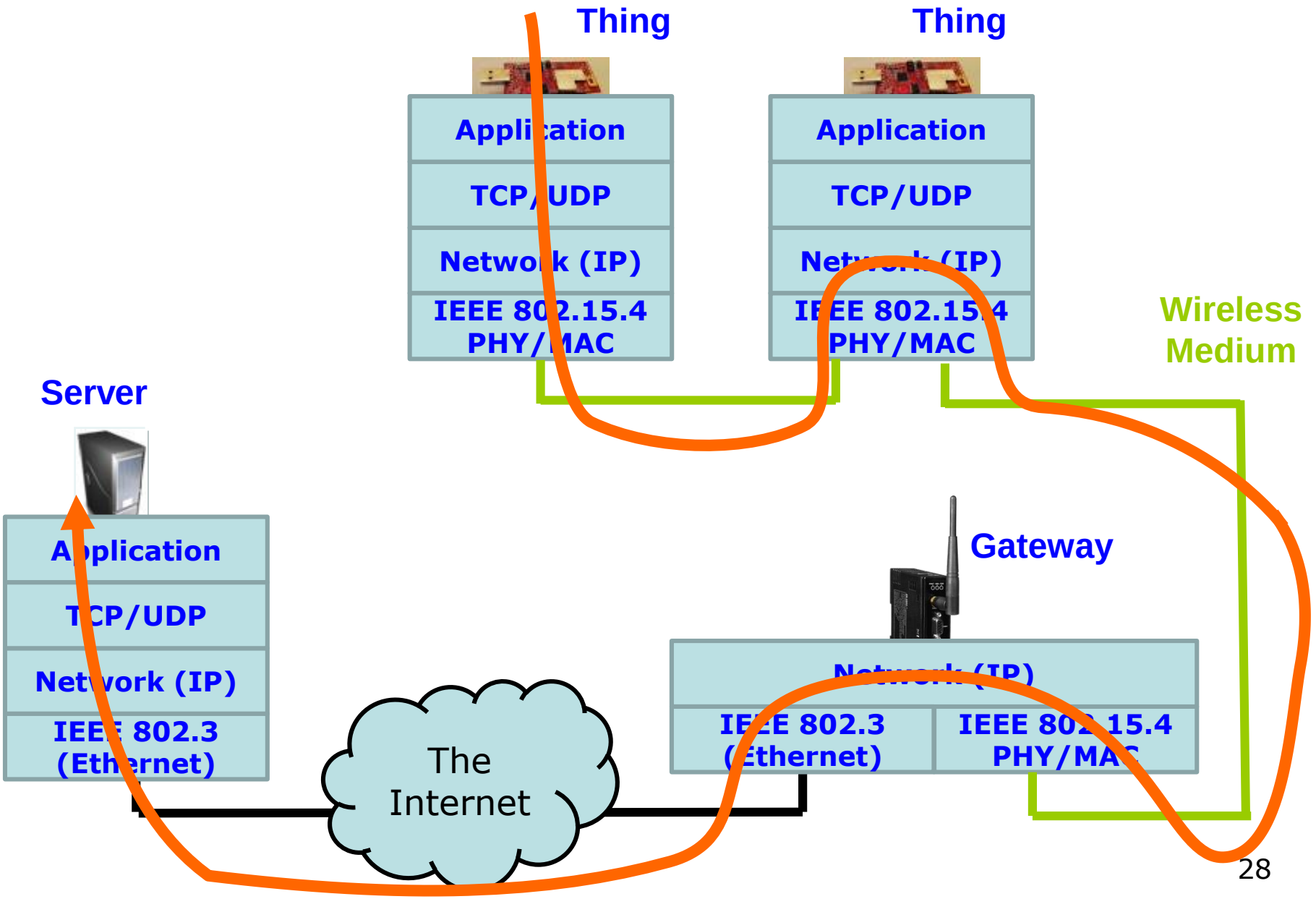
- The Roles of Networks
  - Managing nodes (discovery, join, leave, etc).
  - Relaying data packets from the source to the destination node in the network.
- Networks are a distributed system. All nodes need to perform networking related tasks.
- RF-based Network in IoT is usually a Wireless Multi-hop Network. Some examples:
  - Wireless Sensor Networks (WSNs)
  - Mobile Wireless Ad hoc Networks (MANETs)
  - Wireless Mesh Networks (WMNs)
  - Vehicular Ad Hoc Networks (VANETs)
  - and others...
- Main concern: Reliability & Performance

The Internet

- The Internet serves as a wide area networking for a local network.
- The Internet uses TCP/IP. This implies that things must also support TCP/IP.
- Gateway (or sink)
  - For a practical deployment, a gateway is often needed in a network.
  - It offers relaying packets between the network and the Internet.



Protocol Stack



Security & Privacy

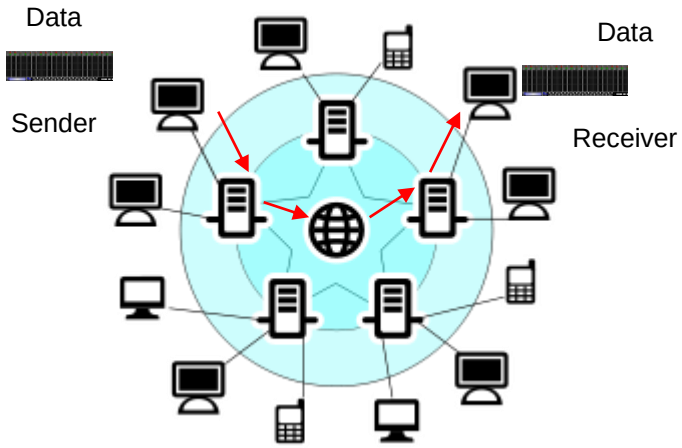
- Are they important?
- What is the risk?
- What are the challenges?
  - Device level
  - Network level
  - System level
  - User level
- Solutions?

Software Platforms and Services

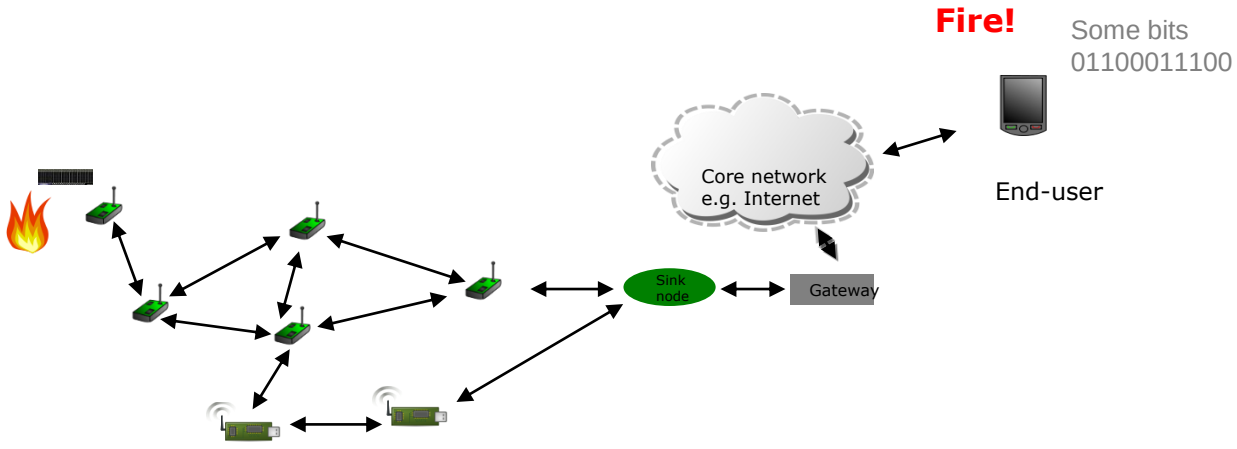
- Operating Systems and execution environments
  - Contiki, TinyOS, TinyDB
- Relevant protocols and standards
  - 6LoWPan, CoAp
- Architecture reference models
- ETSI M2M architecture and components
- Gateway/Middleware

- Types of services
  - In conventional communication networks the target is moving bits from one place to another
  - In IoT moving the data is not the actual goal.
    - IoT is expected to facilitate providing meaningful information/actions.

Example: Type of Services in IoT



A sample data communication in conventional networks



A sample data communication in WSN

Intelligent Data Processing

- Sensing and data collection, sensor data and data-centric networks
- Access, subscription and integration
- Data processing and stream data analysis
- Query and discovery
- Data classification and clustering

Things, Data, and lots of it

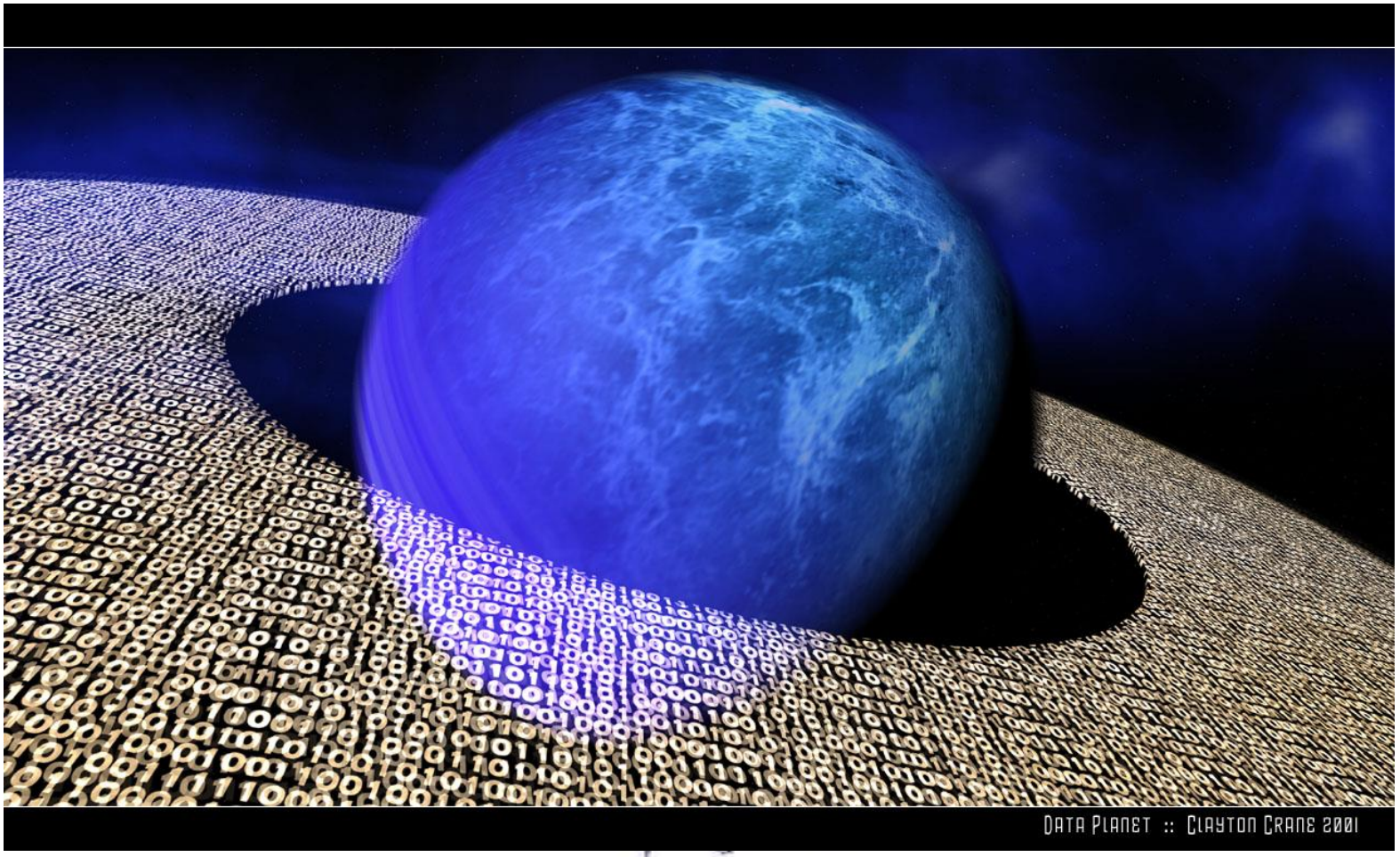
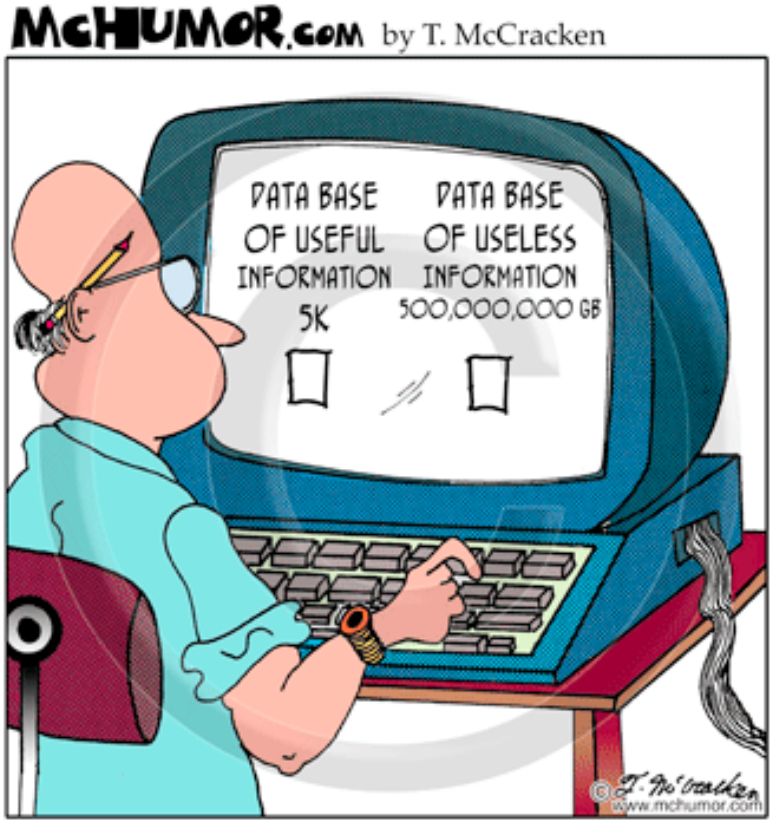


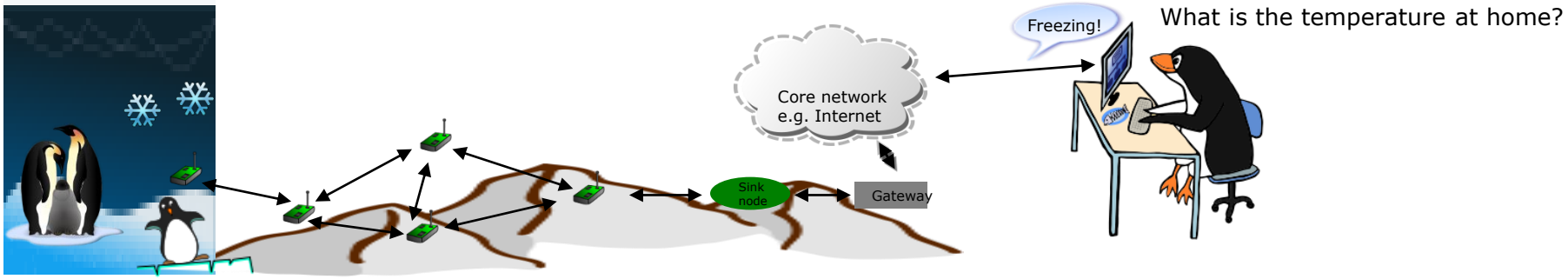
image courtesy: Smarter Data - I.03_C by Gwen Vanhee

Do we need all these data?



“People want answers, not numbers”

(Steven Glaser, UC Berkley)



Storing, Handling and Processing the Data

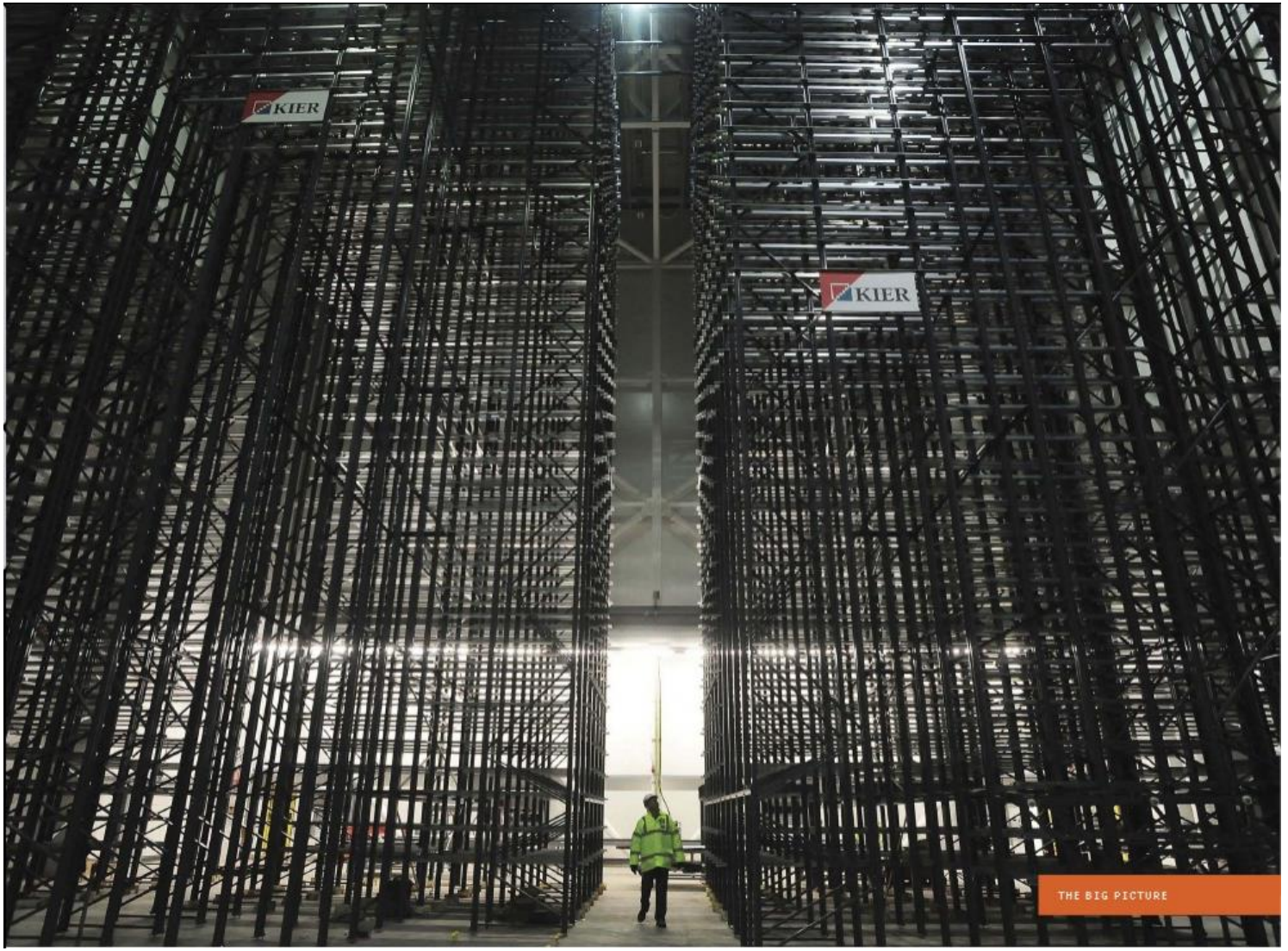


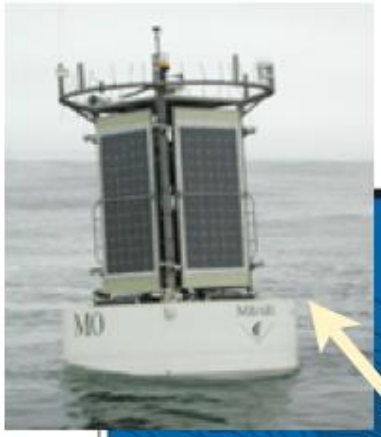
Image courtesy: IEEE Spectrum

Semantic technologies and connecting Things to the Web

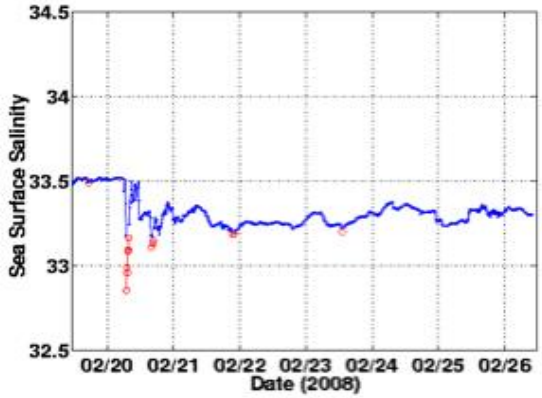
- Meta-data models and schemas
- Linked data and Linked IoT data concepts
- Semantic technologies and semantic sensor networks
- Interoperability issues
- Web of Things

Observation and measurement data

Procedure



Feature of Interest = Monterey Bay



Estimation value of a property

Salinity = property related to the feature of interest

Source: W3C Semantic Sensor Networks, SSN Ontology presentation, Laurent Lefort et al.

System models, Applications and Standards

- Applications: Smart City, Smart Homes, Healthcare, Smart Grid,
- Physical-Cyber-Social Systems
- Machine-to-machine communications
- System models and Standards