BME/TMIT
Budapesti Műszaki és Gazdaságtudományi Egyetem (BME)
Távközlési és Média Informatikai Tanszék (TMIT)

Ambient Networks – Internet of Things (IoT)

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Convergent Networks and Services (VITMM156)

Definition

- Ambient networks and services:
  - The network that surrounds the user
    - Not an „end-user", but part of the network
  - Intelligent environment
  - Personalized services
    - User profiles, based on previous behavior
  - Context-based services
    - Positioning technologies
    - Available networks and devices
  - Connection anywhere, anytime
  - Mobility handling
    - „seamless mobility", vertical handoff
    - „Always best connected"
      - Chooses the best available technology
      - WLAN, Wimax, 3G/4G, etc..
  - Autonomic network and service discovery, configuration and management

Other terms

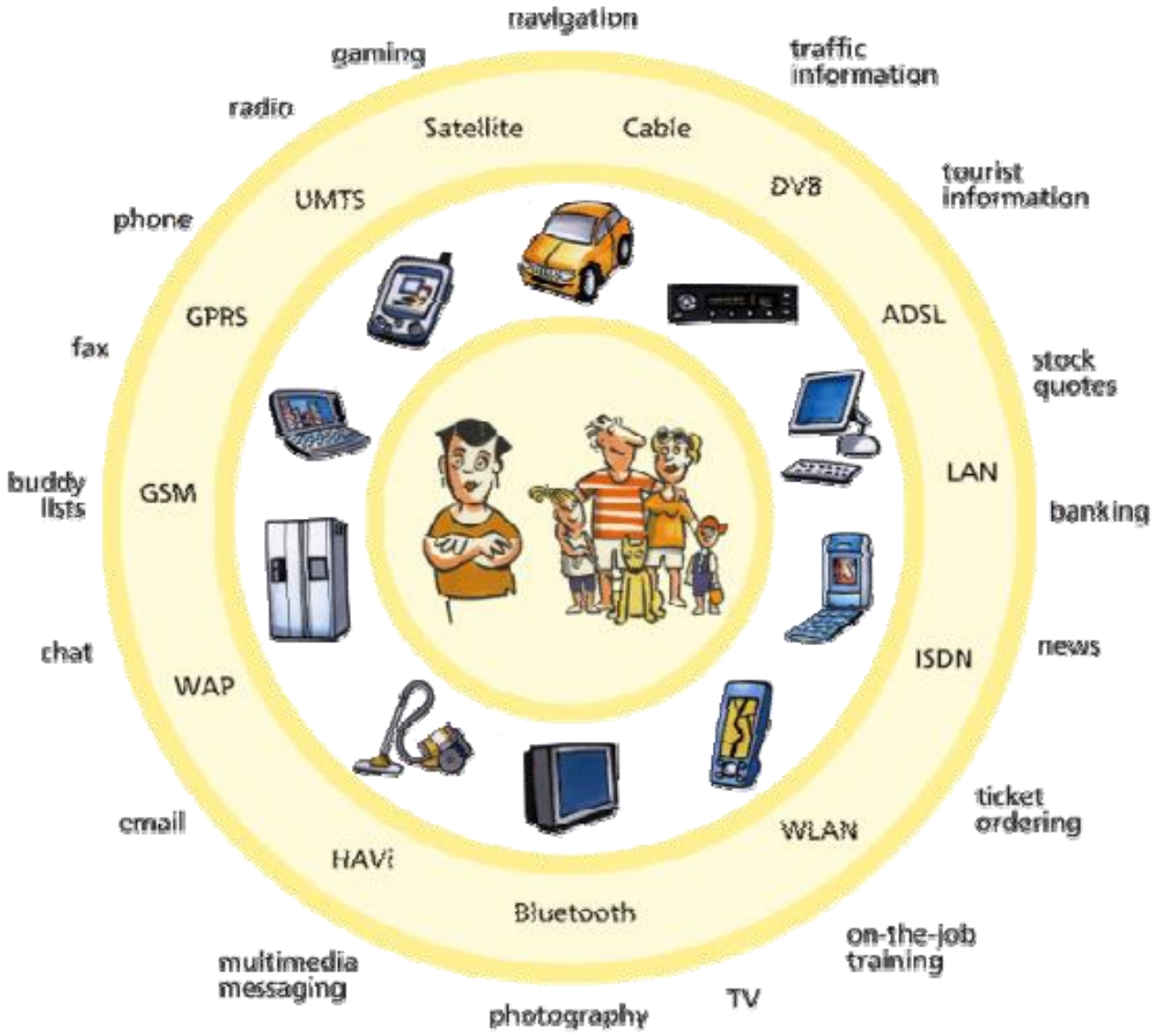
- **Ubiquitous networking/computing**
  - Networks that are present everywhere
- **Pervasive networks**
- Everyware
- **Internet of things**
- Disappearing computing

- Mark Weiser, Xerox Palo Alto Research Center, 1988

Paradigm change

- Desktop computing
  - A given user uses a given device deliberately for a given task
  - Traditional man-machine interface
    - Command line, menus, graphical user interface (GUI)
- Virtual reality
  - Puts the user into a virtual world/environment created by the computer
- Ubiquitous/Pervasive/Ambient networking
  - The computer enters into people's real world
  - New man-machine (human-computer) interface
  - Parallel use of several intelligent devices
    - Often without the user being aware of that

Devices – networks - services



Technological development

- Huge computing capacity
- Huge storage capacity
- Higher and higher network capacity/speed
  - > 5 TBps on optical fiber
  - > 100 Mbps on wireless connections
- Smaller and better quality screens
- Energy efficient devices
  - Perhaps the least visible feature
- Decreasing prices

- Everything is out there to support an intelligent environment and ambient/ubiquitous services

Context-based services

- Definition:
  - **Context** – any information that can be used to describe the situation/position/status of an entity
    - Entity – person, place, device
- **Context categories**
  - Access network
    - The properties of the (wireless) access networks currently available to the user
    - Availability, signal quality/strength, bandwidth, price, etc.
  - Devices and their capabilities
    - Devices that are available to the user
    - Screen size and resolution, memory, CPU, communication interfaces (Bluetooth, GPRS, 3G, WLAN), multimedia codecs, energy supplies
  - User context
    - Space, time, task
    - Emotional status – happy, nervous, etc.
    - Social context – people around
    - Preferred networks and devices

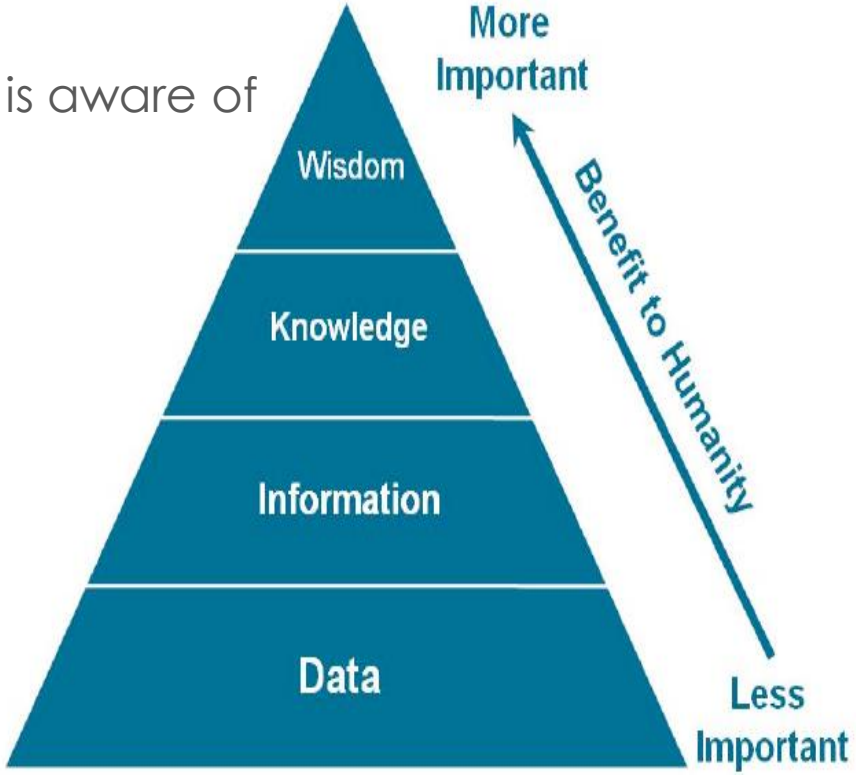
Context categories

- Service platform
  - Security issues
  - Subscription parameters, user rights, business agreements
- Services and applications
  - In the surrounding environment, which are the available services?
- Active connections
  - Information to maintain the current active connections in case of mobility/roaming
  - Parameters of these active connections
    - Communication partner, type of traffic (voice or video), bandwidth requirements

- To support these, we need data…, a lot of data!

From data to human wisdom

- **Raw data** is processed into **information**
  - individual data is not very useful, but volumes of it can identify trends and patterns
- **Information** come together to form **knowledge**
  - knowledge is information someone is aware of
- **Wisdom** is born from **knowledge** plus **experience**
  - knowledge changes but wisdom is timeless
- **...and it all begins with the acquisition of data!**



Source: Cisco IBSG, April 2011

From data to human evolution (cont'd)

- Humans evolve because they communicate
  - Once fire was discovered and shared, it didn't need to be rediscovered, only **communicated**
- The more data is created, the more knowledge and wisdom people can obtain!
- **Internet of things (IoT)**
  - dramatically increases the amount of data available for us.

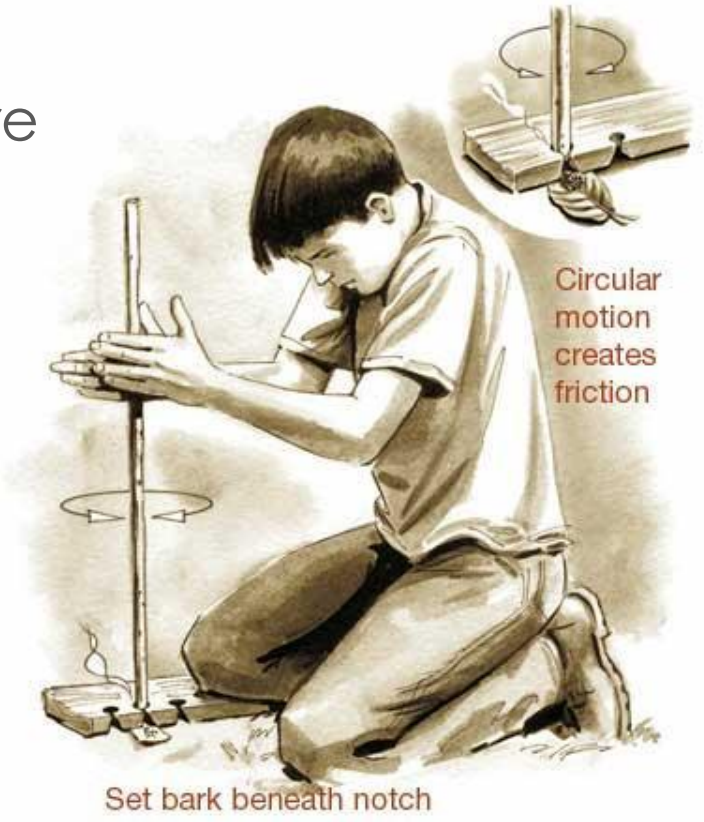


Photo Gallery by Field & Stream Online Editors.

„About a rabbit...” – on the Internet

> **Look for a rabbit!**
> searching... found
>
> **Where is the rabbit?**
> http://auntiemoon.files.wordpress.com/2011/02/tiger-rabbit.jpeg
>
> **Show me the rabbit!**
>
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„About a rabbit...” – in real world

> **Look for a rabbit!**
> searching... found
>
> **Where is the rabbit?**
> 47°31’07.46’’ N 19°04’39.22’’ E elev 109 m
>
> **Show me the rabbit!**
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Real world vs. digital/virtual world

- *"With a trillion sensors embedded in the environment—all connected by computing systems, software, and services—it will be possible to hear the heartbeat of the Earth, impacting human interaction with the globe as profoundly as the Internet has revolutionized communication."*

Peter Hartwell

Senior Researcher, HP Labs

Media break

- A real world vs. virtual world **media break** occurs when information is transferred from one carrier medium (e.g., bar code) to another (e.g., database).

- Humans are not very good at dealing with media breaks!
  - boring and tiring task (e.g., typing in data thousand times)

- **IoT technology** *automates the bridging* of the last mile between the Internet and the physical world, i.e., *dissolves the transaction costs* of real world-virtual world media breaks.

IoT - (kind of) definitions

- The basic idea of the IoT is that virtually every physical thing in this world can also become a computer that is connected to the Internet. [ITU, 2005]
  - at least they can *feature* tiny computers
  - they are often called **smart things**

- *But do things really have to feature computers to become smart?*

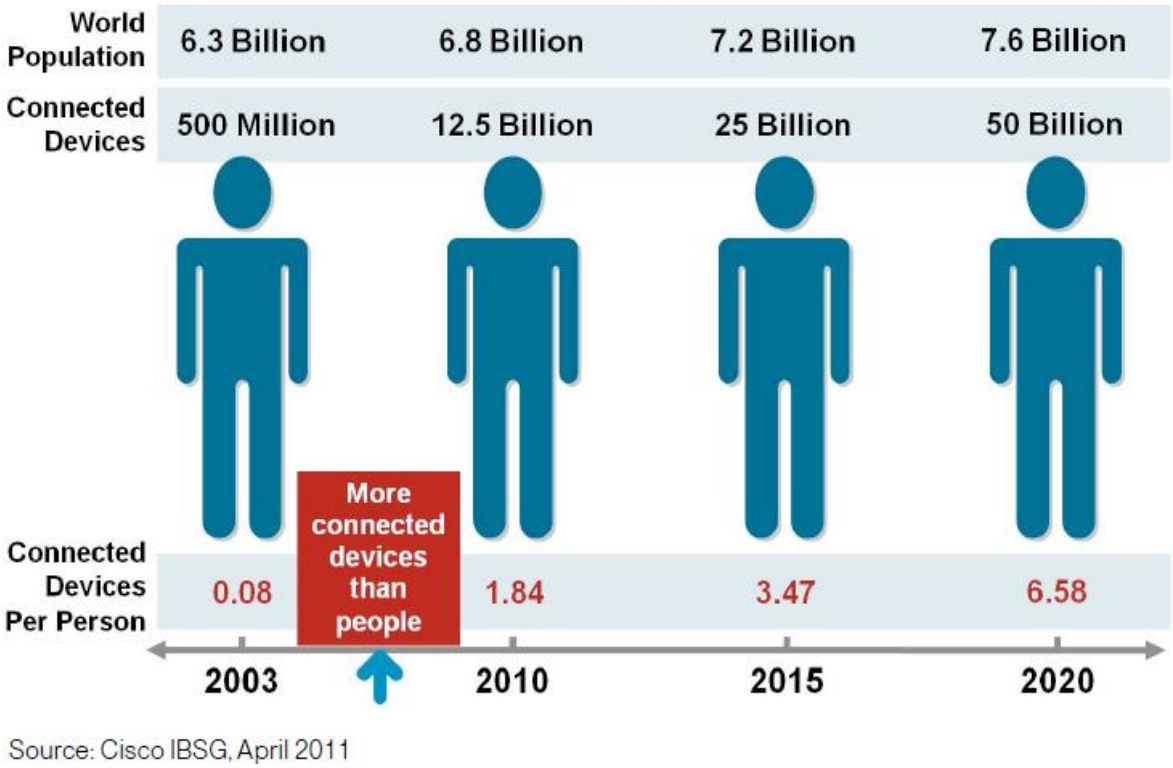
Smart objects

- **Smart** objects...
  - are able to *perceive their context* (using sensors), and
  - are able to *communicate* with each other,
  - *access the Internet* services and
  - *interact with people* (via built in networking capabilities)

- „**Digitally upgrading**" conventional objects enhances their physical function by adding the capabilities of a smart object.

IoT - (kind of) definitions

- *„IoT is simply the point in time when more „things or objects" were connected to the Internet than people"* (Cisco, 2011)
  - ...so **IoT was „born" sometime between 2008 and 2009**



Source: Cisco IBSG, April 2011

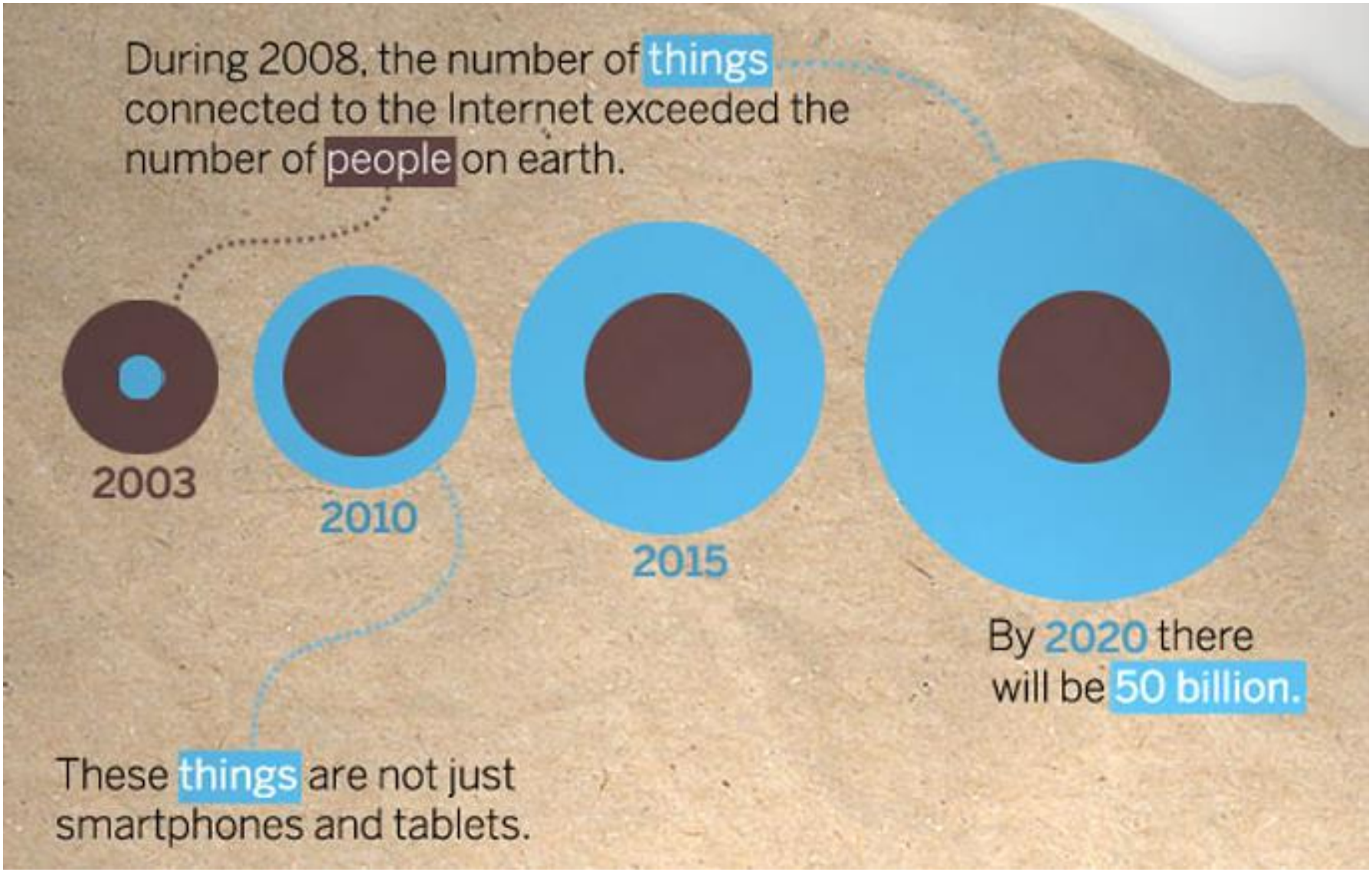
IoT in numbers

- „*There will be 25 billion devices connected to the Internet by 2015 and **50 billion by 2020***" (Cisco)

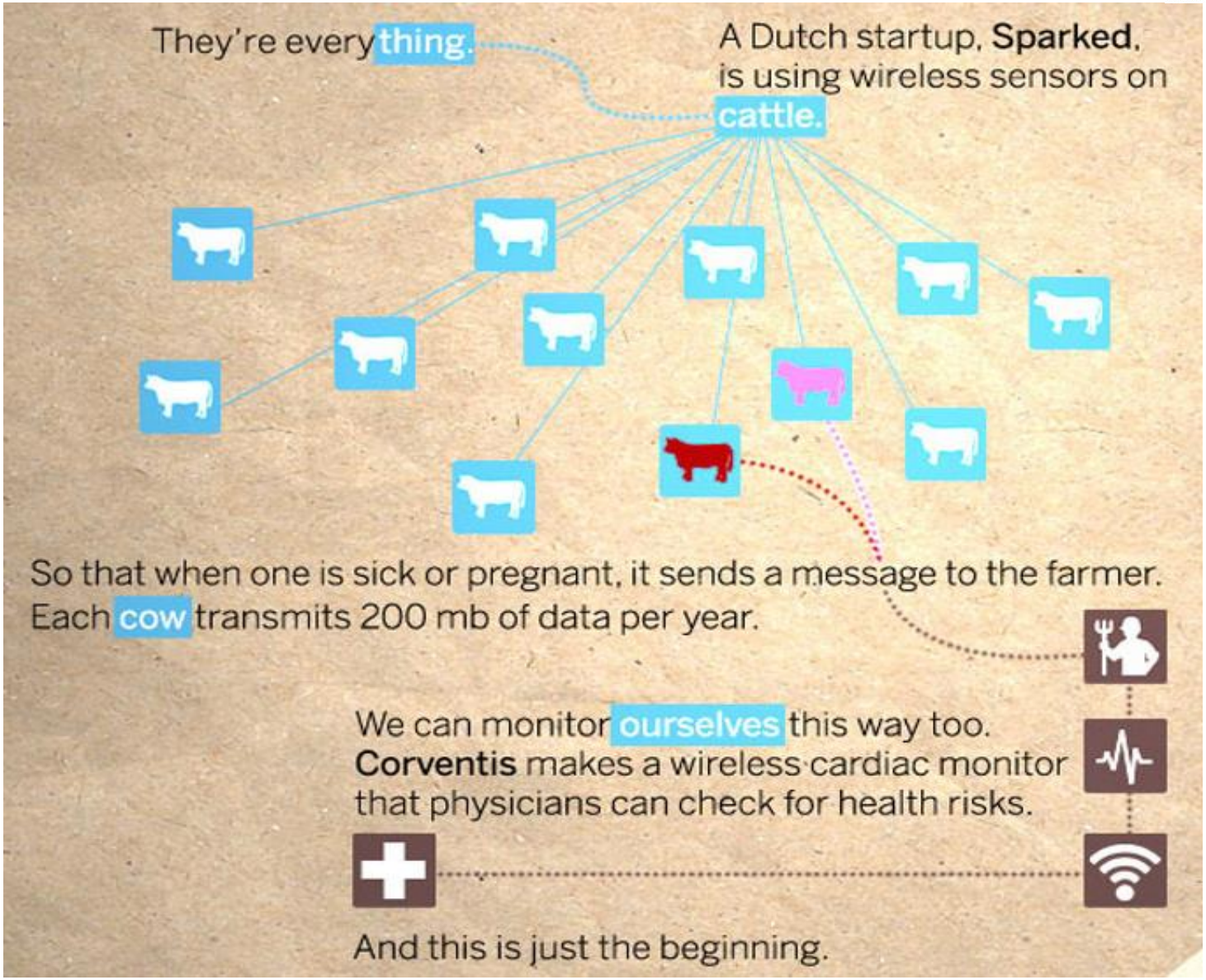
- „*By 2020, there will be 4 billion people online, and **31 billion** Internet-connected devices*" (Intel, June 2011)

- „*More than **50 billion** connected devices by 2020*" (Ericsson, 2011)

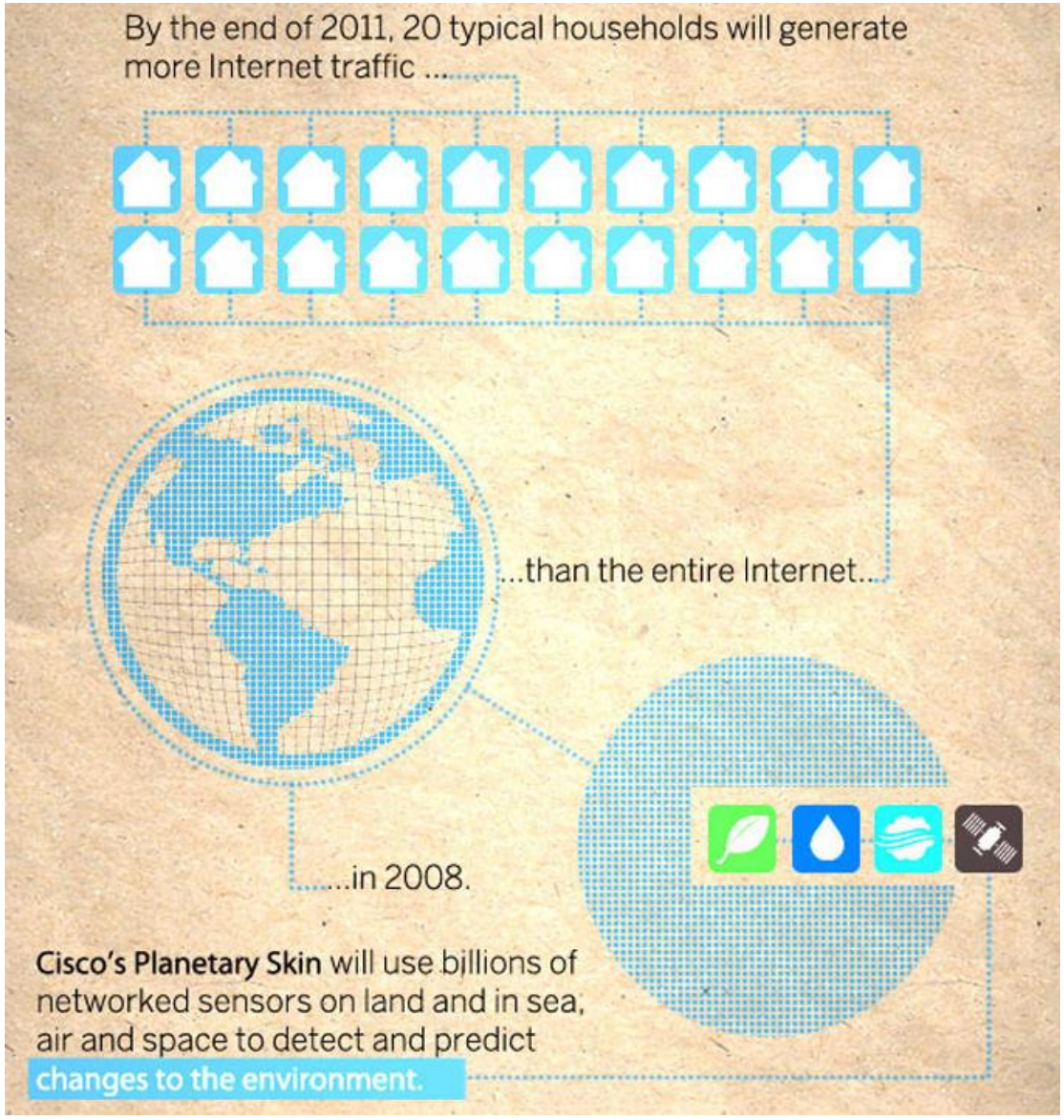
IoT CISCO vision



IoT CISCO vision



IoT CISCO vision

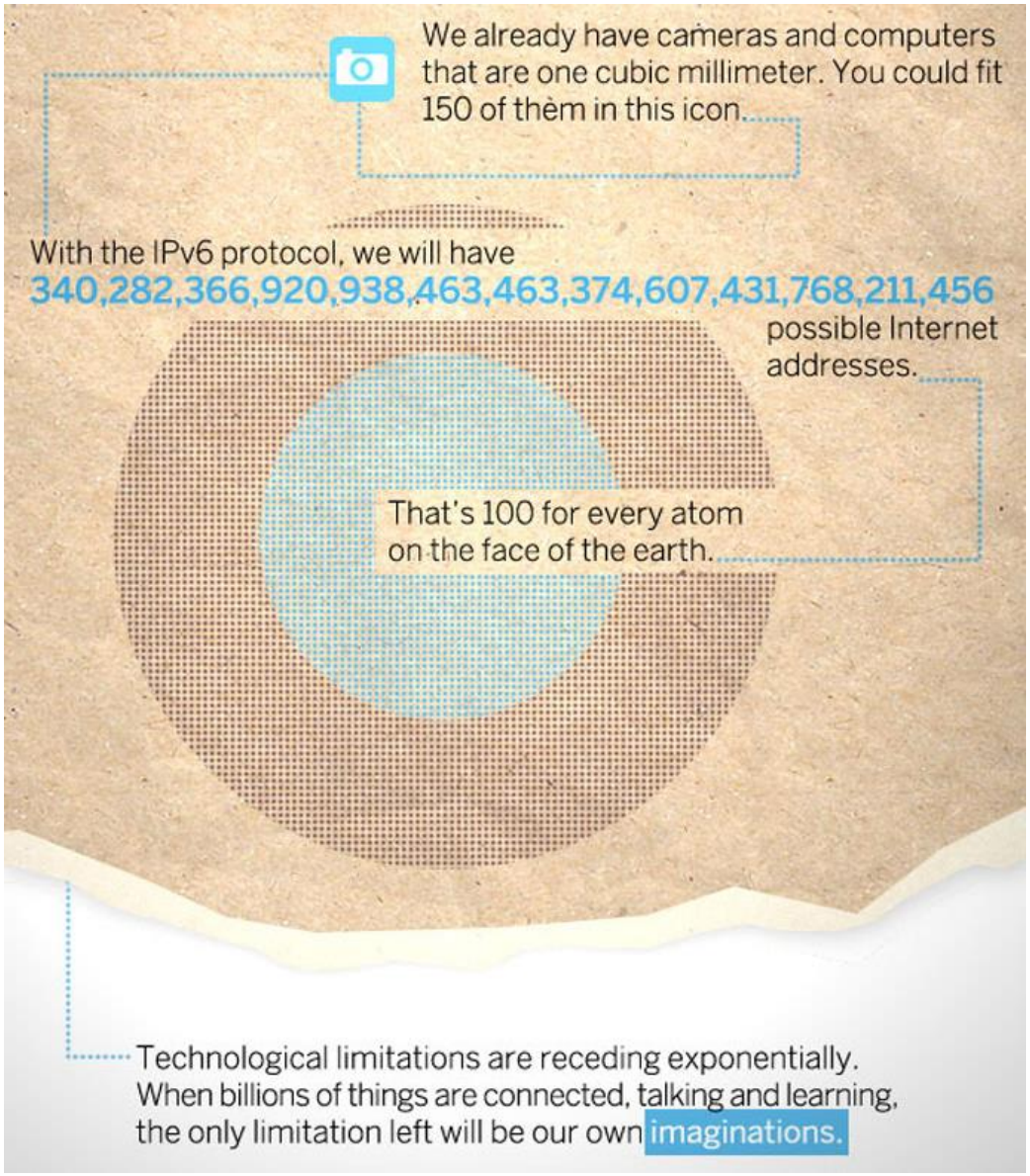


Planetary Skin Institute

- Common project of Cisco and NASA (2009)
  - 100 million USD
  - Sensors on earth, in water, in air
  - Data is collected in a central databse
    - It will be good for „something, sometime"

http://www.planetaryskin.org/

IoT CISCO vision



IoT capabilities

- IoT is not the result of a single novel technology.

- Instead, several technical developments provide *capabilities to bridge the gap* between the *virtual* and *physical* world.

- IoT **capabilities** include:
  - Communication and cooperation
  - Identification and addressing
  - Sensing and actuation
  - Localization

IoT – communication and cooperation

- Objects have the ability to network...
  - with each other, and
  - with Internet resources

- Technologies:
  - Wireless technologies (e.g., IEEE 802.15.4 and ZigBee, UMTS, WiFi)
    - E.g., range of 10 to 100 m for 1 mW transmission power, with transmission rate of 250 kbps
  - 6LoWPAN – IPv6 over Low Power Wireless Area Networks IETF Working Group: IPv6 using 802.15.4
    - E.g., TCP/IPv6 stack with 4 kB RAM and 24 kB flash memory

IoT – identification and addressability

- Objects can be located (in the network) and addressed.
- Objects are uniquely identifiable.
- Identification enables objects to be linked to information associated with the particular object that can be retreived via the Internet
- Technologies:
  - RFID, NFC (Near Field Communication), optical bar codes

IoT – sensing and actuation

- Objects collect information about their surroundings using **sensors**, record it, forward it or react directly to it.
- Object can contain **actuators** to manipulate their environment.
- Actuators can be used to remotely control real-world processes via the Internet.

IoT – localization

- Smart objects are aware of their physical location, or can be located.

- Technologies:
  - GPS or cellular mobile networks (if complexity permits)
  - WiFi-based, UWB, acoustic or optical
  - RFID readers

IoT challenges and barriers

- Biggest challenges for the development of IoT
  - **Deployment of IPv6**
    - IPv4 addresses ran out in February 2010
  - **Sensor energy**
    - Sensors need to be self-sustaining.
    - Method would be needed to generate electricity from environmental elements (e.g., vibrations, light, ...)
  - **Standards**
    - More standardization activities are needed in the areas of security, privacy, architecture and communications

Social and political issues

- Trust
  - Hard to define, but its mechanisms can be described
    - Context-based
    - Directed
    - Measurable
    - Changes in time
    - Can be handed over

- **Trusted data** is data that is difficult to influence because it is quietly and continuously collected by machines all the time.

- The price of this „silent monitoring" is *loss of privacy*.

Privacy

People usually do not like the „big brother”

But if you offer them useful services, they rapidly forget about privacy

Social and political issues

- „***security*** *vs.* ***freedom***" and „***comfort*** *vs.* ***data privacy***"
- Threats:
  - Automatically collected personal data could be used by third parties without people's agreement or knowledge for unknown and potentially damaging purposes.
  - We can never be entirely sure whether we are being „observed".
- *Who would own* the masses of automatically captured and interpreted real world data, which could be of significant commercial or social value, and who would be entitled to use it and within what ethical and legal framework?
- Willingness to share
  - Sharing resources, context information
  - Users cannot be forced to do so
  - The technology provides more and more secure solutions
    - It is the decision of the user whether it trusts and uses them, or not
    - Without sharing, many applications will not work

Social and political issues (cont'd)

- Dependence on technology
  - Just think of how dependent we are on the general availability of electricity!
  - If everyday objects only worked with an Internet connection, it would lead to even greater **dependence on the underlying technology**.
  - Remotely controlled objects could cause us to become dependent and **loose our supremacy** on a personal level.

Internet vs. IoT - hardware

- **Powerful**
- Internet end hosts are full blown computers (workstations, laptops, smart phones, etc.)
- Require regular access to the power grid
- Humans interact with them

- **Invisible**
  - Things are very small, even invisible, low-end computers
    - With low energy consumption
  - Limited functionality, often including sensing
  - Communicating a limited amount of information
    - Cannot directly interact with humans

(Fleisch, 2010)

Internet vs. IoT - #nodes

- **Billions**
- About five billion devices (mobile phones, PCs, PDAs, data servers, etc.) serve about 1.5 billion Internet users

- **Trillions**
- There are MANY computer-enabled things around us that *people are not* able and *will not be willing to* directly communicate with them
- A new *network infrastructure* might be required

Internet vs. IoT– last mile

- **Broadband**
- The last mile in the Internet has been increasing tremendously (cable based at least 1 Mbps, optical based up to 50-100 Mbps and beyond...)

- **Bottleneck**
  - The speed towards a low energy consuming radio (of sensor motes) is around 100 kbps.

Internet vs. IoT– addressing

- **Global identification**
- IP – as simple as that

- **Babylon**
- IP-based identification and addressing schemes require too much capacity to become part of low-end smart things
  - New solutions such as IPv6 and 6LoWPAN are required

Internet vs. IoT – humans and machines

- **User-centric**
- Vast majority of Internet-based services are targeted towards human beings as users (WWW, e-mail, file sharing, telephony, shopping, ...)

- **Machine-centric**
  - Humans are basically excluded from direct intervention!
  - paradigm shift towards *human-out-of-the-loop-computing* (Mattern, 2004)
  - Smart things communicate amongst each other and with computers in the Internet in a machine-to-machine way

Internet vs. IoT – focus

- **Communication**
- Economic success story of the Internet: **WWW** – reaching out to a global customer base at *very* low cost!
  (e.g., advertising – Google, shopping – eBay, Amazon, ...)
- The ability to deal with user-generated content: **Web 2.0**
  (Wikipedia, Facebook, YouTube, ...)

- **Sensing**
  - It allows the *physical world*, things and places, to generate data automatically.
    - IoT is about **sensing the physical world**

IoT enablers

- The IoT idea is not new
  - It is the technology that now allows the manufacturing of small and inexpensive low-end computers.

- Due to their diminishing size, falling price and declining energy consumption, processors, communications modules and other electronic components (sensors) are being increasingly integrated into everyday objects.

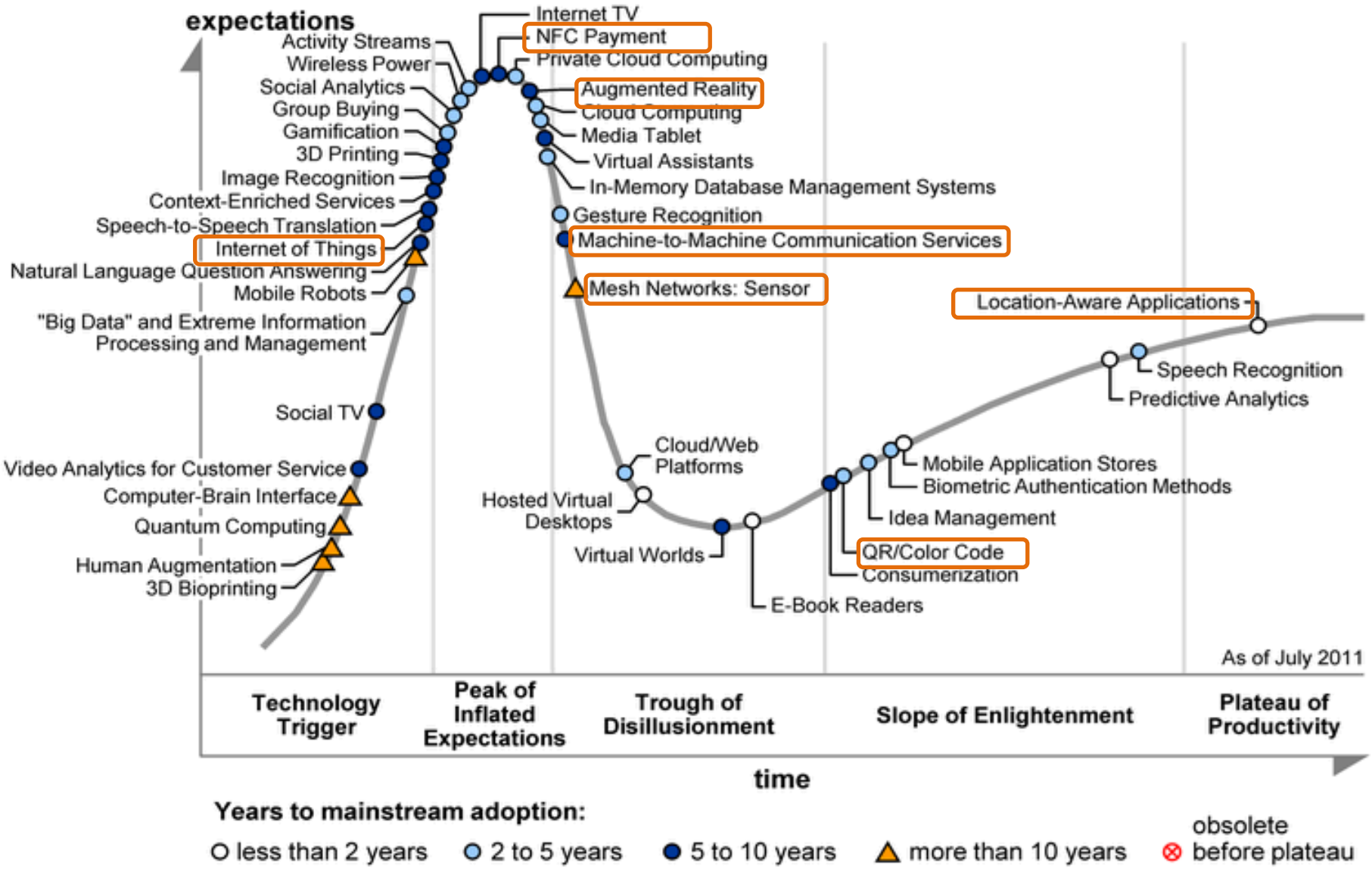
- Mass adoption of these tiny networked computers becomes a real option.

Gartner's Top 10 Strategic Technologies for 2014

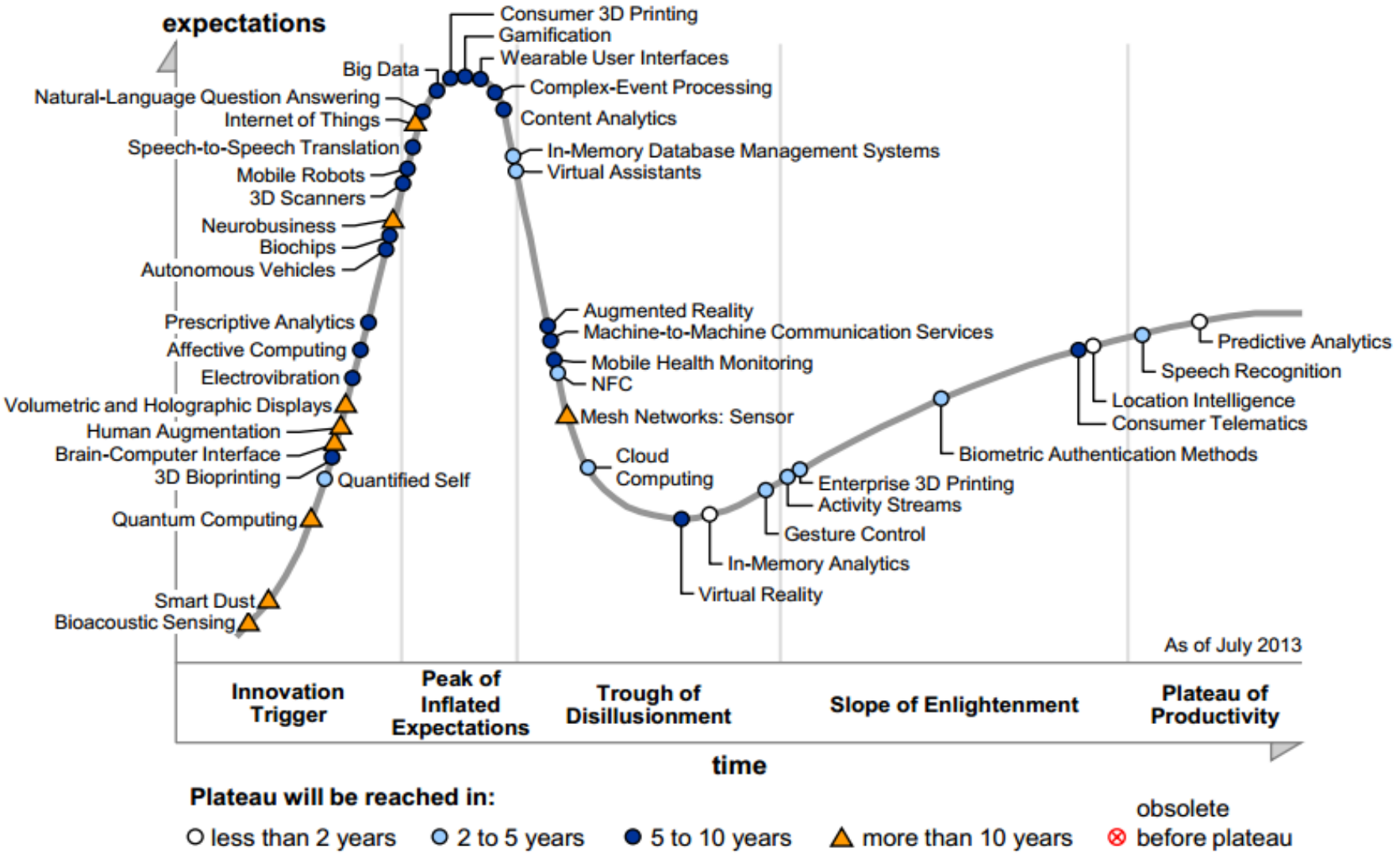
- Mobile Device Diversity
- Mobile Apps and Applications
- **Internet of Everything**
- Hybrid Cloud
- Cloud-Client Architecture
- Personal Cloud
- Software Defined Anything
- Web-Scale IT
- Smart Machines
- 3D Printing

http://www.gartner.com/newsroom/id/2603623

Gartner's Hype Cycle for 2011



Emerging Technologies Hype Cycle, 2013



Gartner