Networking technologies and applications

May 11, 2015

4G - LTE

- **LTE – Long Term Evolution**
  - Developed by the 3GPP (Third Generation PartnerShip Project)
  - Release 8 (2008)
  - First publicly available service launched by TeliaSonera in Oslo and Stockholm in December 2009

- LTE-Advanced (LTE-A, Release 10, 2011)
  - „True 4G"

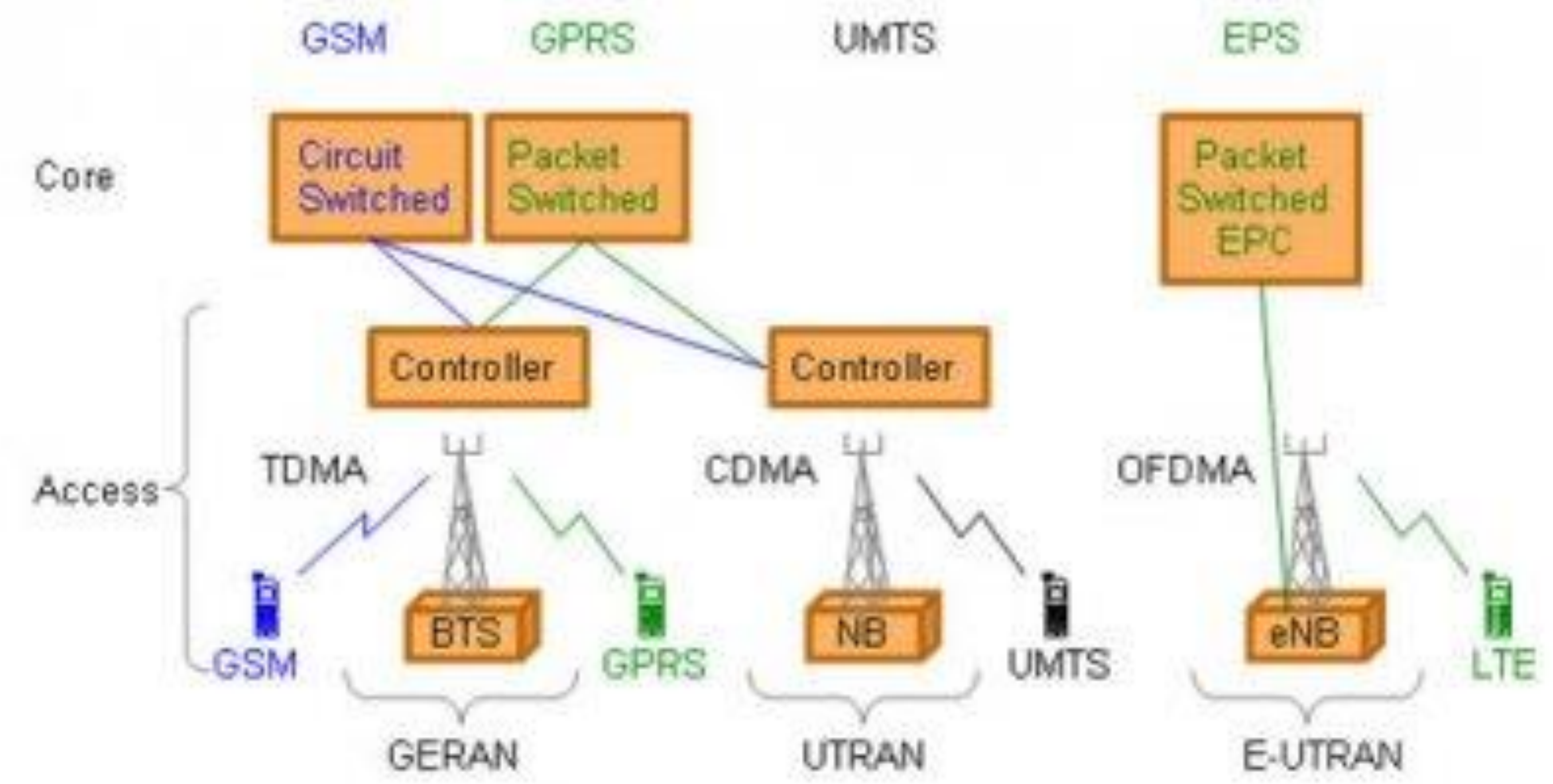
- LTE-M (Release 12, to be comercially deployed in 2016)
  - Support for the Internet of Things (IoT)
  - Introduction of Power Saving Mode in Idle state

LTE

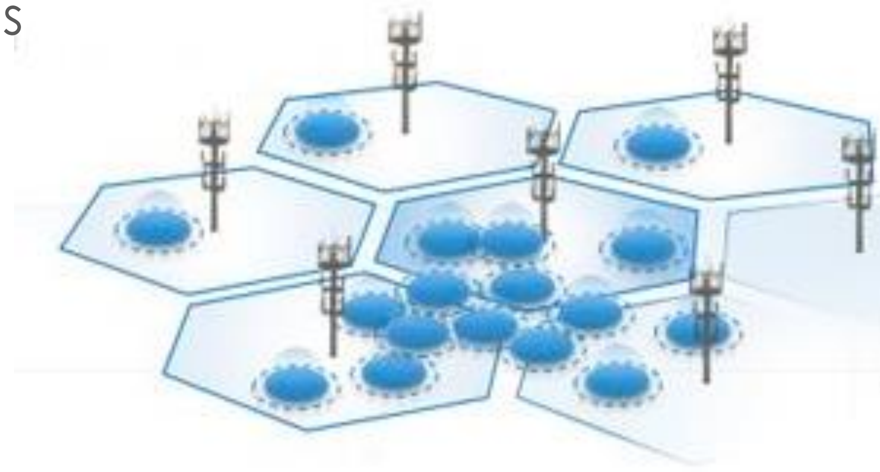
- Increased speeds
  - Downlink speed – 300 Mbit/s
  - Uplink speed – 75 Mbit/s
- Transfer latency below 5 ms in the RAN
  - Radio Access Network
- Support for both FDD and TDD
- Increased spectrum flexibility
  - 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells
  - Only 5 MHz cells in W-CDMA
- Support for different cell sizes
  - Femtocells and picocells – tens of meters
  - Macrocells – 100 km
- All-IP network, support only for packet-switching

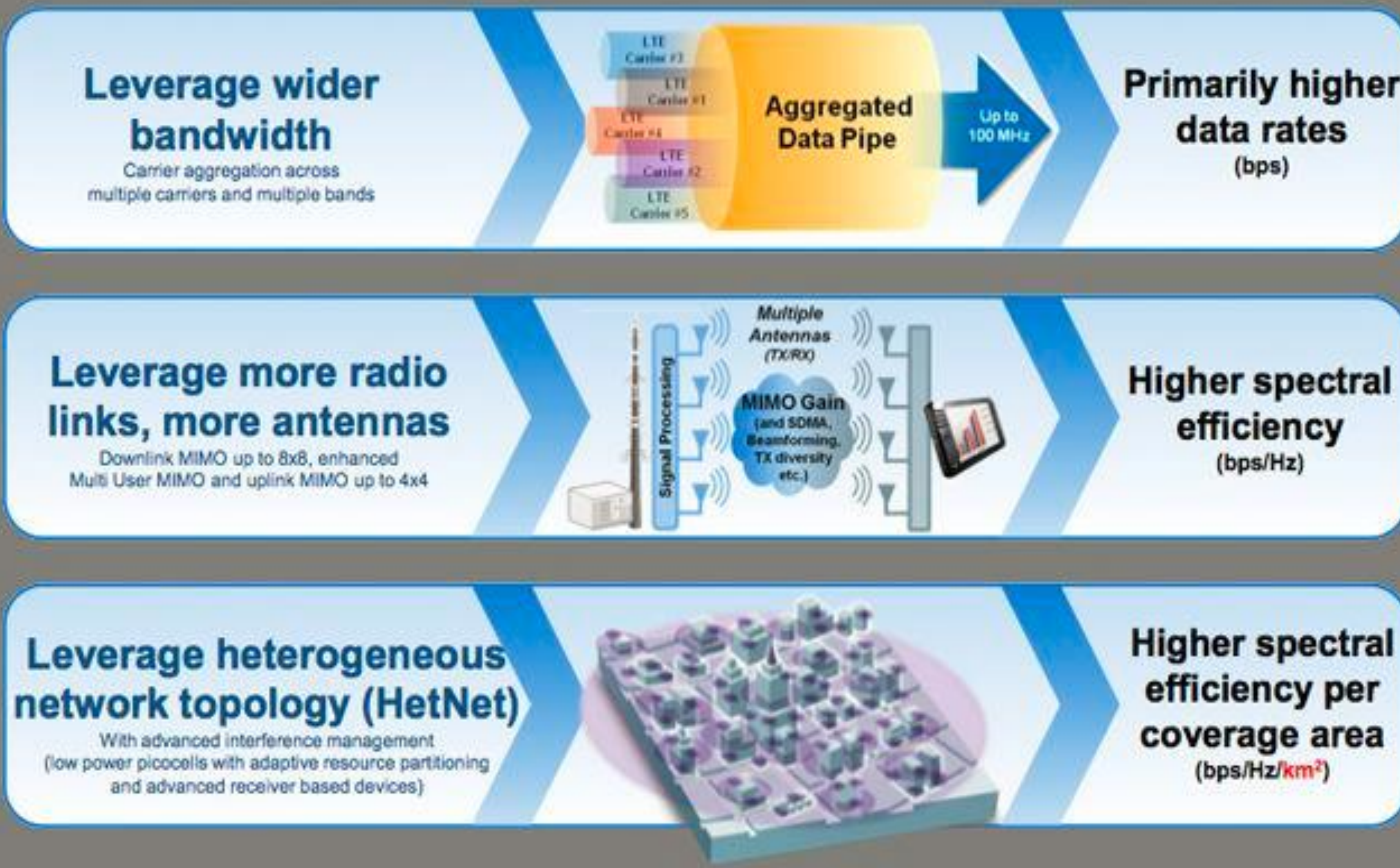
E-UTRAN

Evolved Universal Terrestrial Radio Access Network



- Speeds up to 1 Gbit/s for downlink
- Ultra wide bandwidth – up to 100 MHz
- MIMO (Multiple Input Multiple Output)
    - multiple antennas on the same device
- Carrier aggregation
- Optimized heterogenous networks (Hetnets)
    - Macrocells, picocells, femtocells

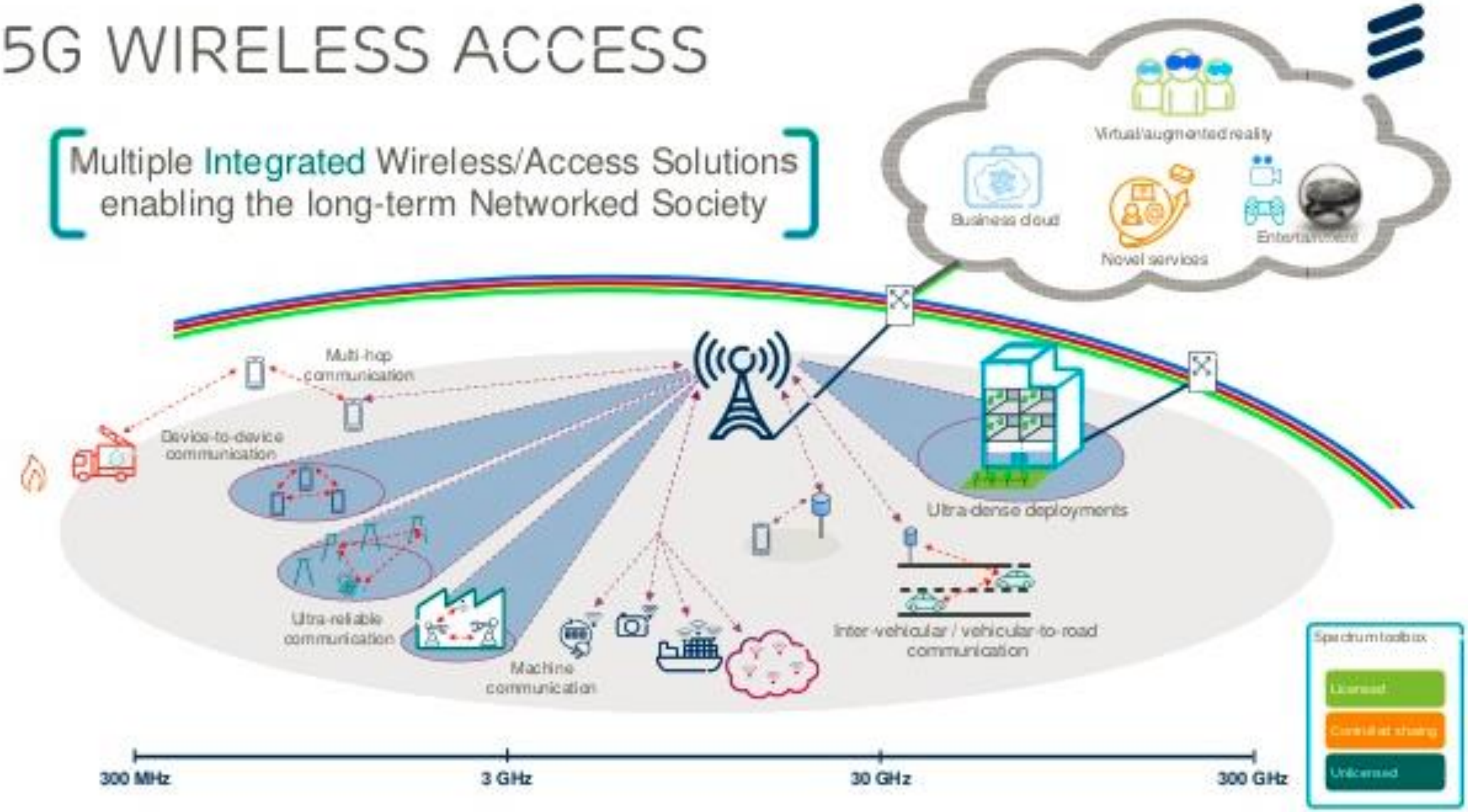



Leverage wider bandwidth
Carrier aggregation across multiple carriers and multiple bands
LTE Carrier #3
LTE Carrier #1
LTE Carrier #4
LTE Carrier #2
LTE Carrier #5
Aggregated Data Pipe
Up to 100 MHz
Primarily higher data rates
(bps)
Leverage more radio links, more antennas
Downlink MIMO up to 8x8, enhanced Multi User MIMO and uplink MIMO up to 4x4
Signal Processing
Multiple Antennas
(TX/RX)
MIMO Gain
(and SDMA, Beamforming, TX diversity etc.)
Higher spectral efficiency
(bps/Hz)
Leverage heterogeneous network topology (HetNet)
With advanced interference management (low power picocells with adaptive resource partitioning and advanced receiver based devices)
Higher spectral efficiency per coverage area
(bps/Hz/km²)

5G

- Expected for 2020
- No clear definition
- Not a novel radio technology, but rather a combination of all the others
  - User simultaneously connected to several different access technologies, and move seamlessly among them
    - 4G, WLAN, IEEE 802.15.4, etc
- Offloading the cellular mobile network
- Support for the Internet of Things (IoT)

5G WIRELESS ACCESS



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?*

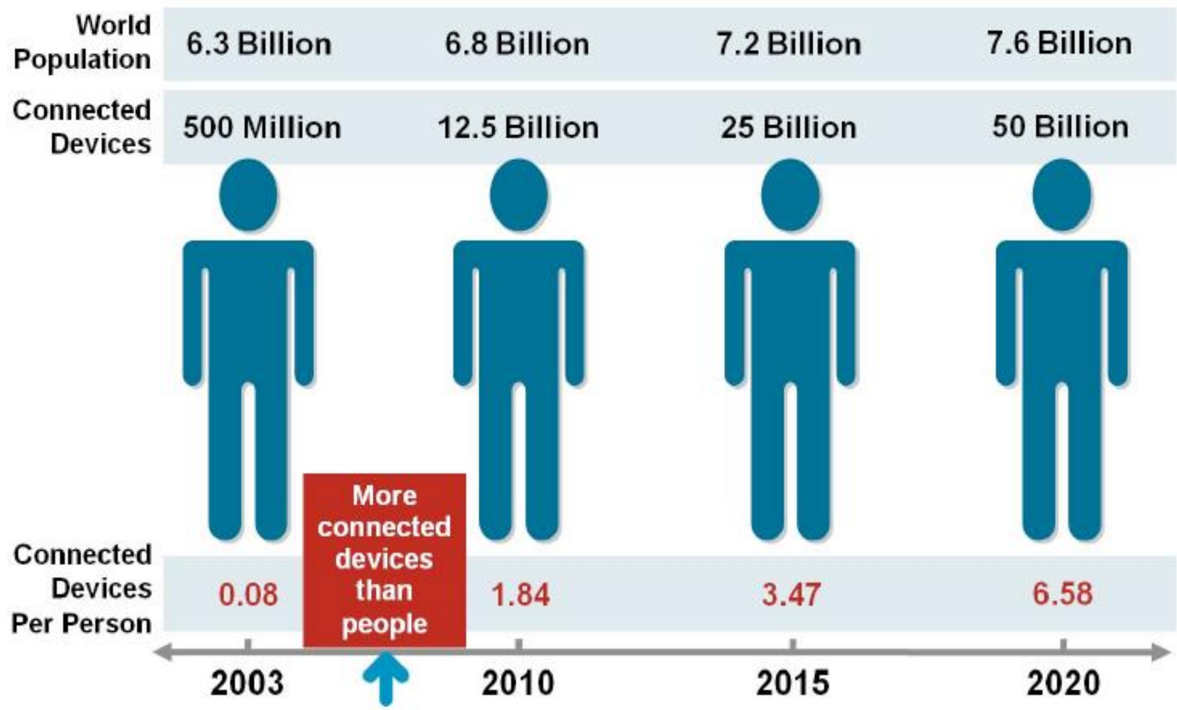
Smart objects

- **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

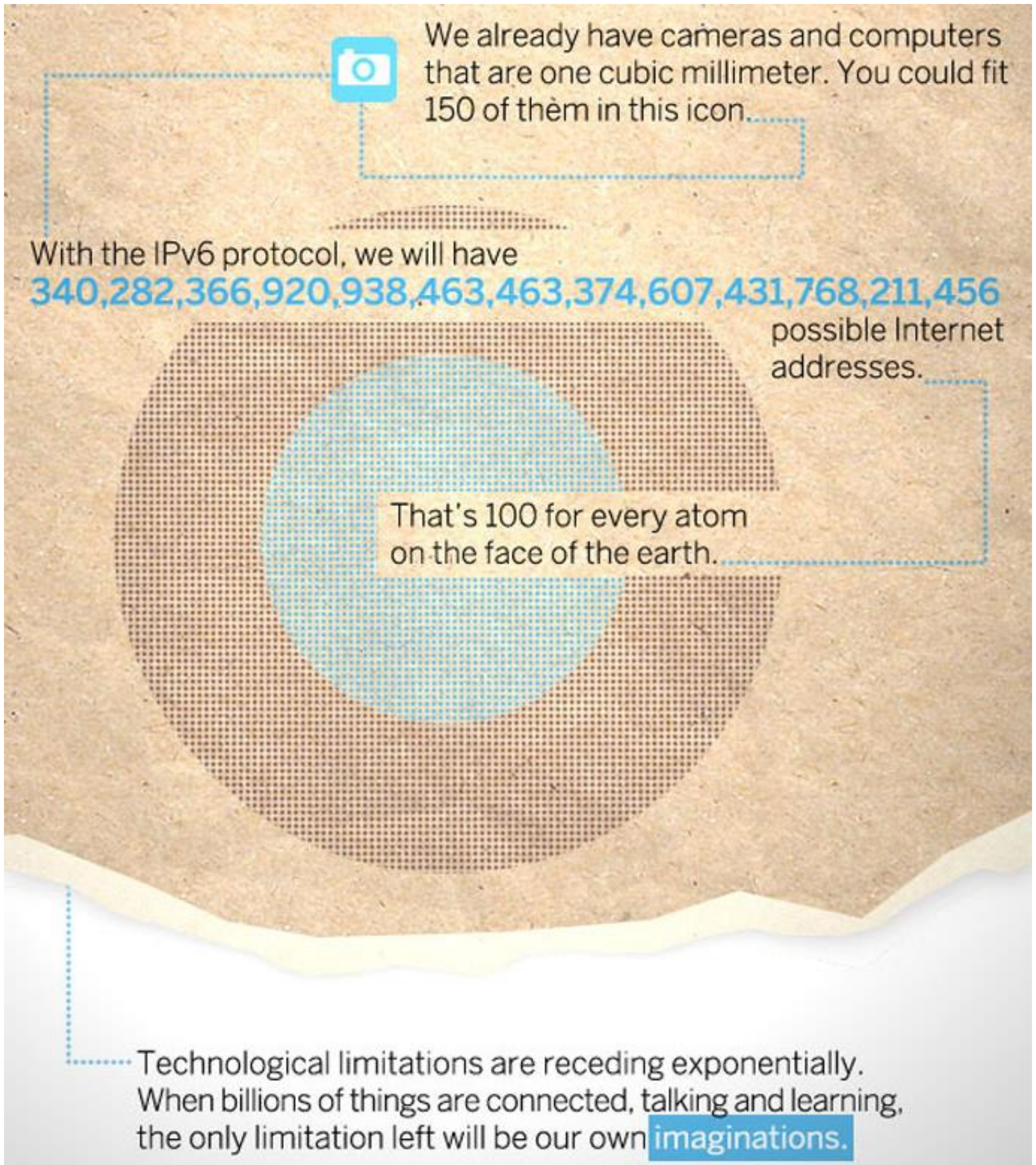
IoT in numbers

- *„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



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 database
    - It will be good for „something, sometime"

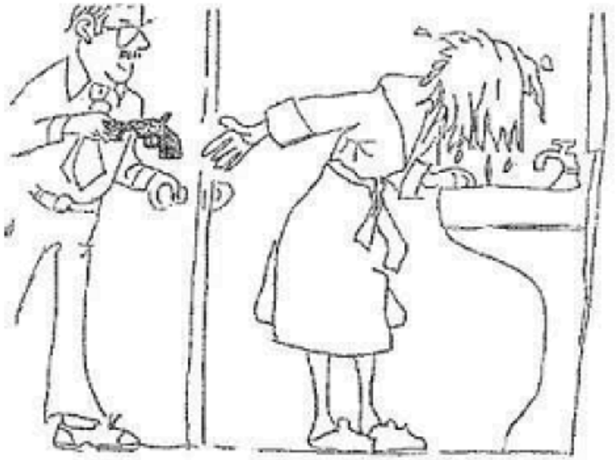
http://www.planetaryskin.org/

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



"Hand me the Hairdryer"

- **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 <u>and</u> 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, ...)

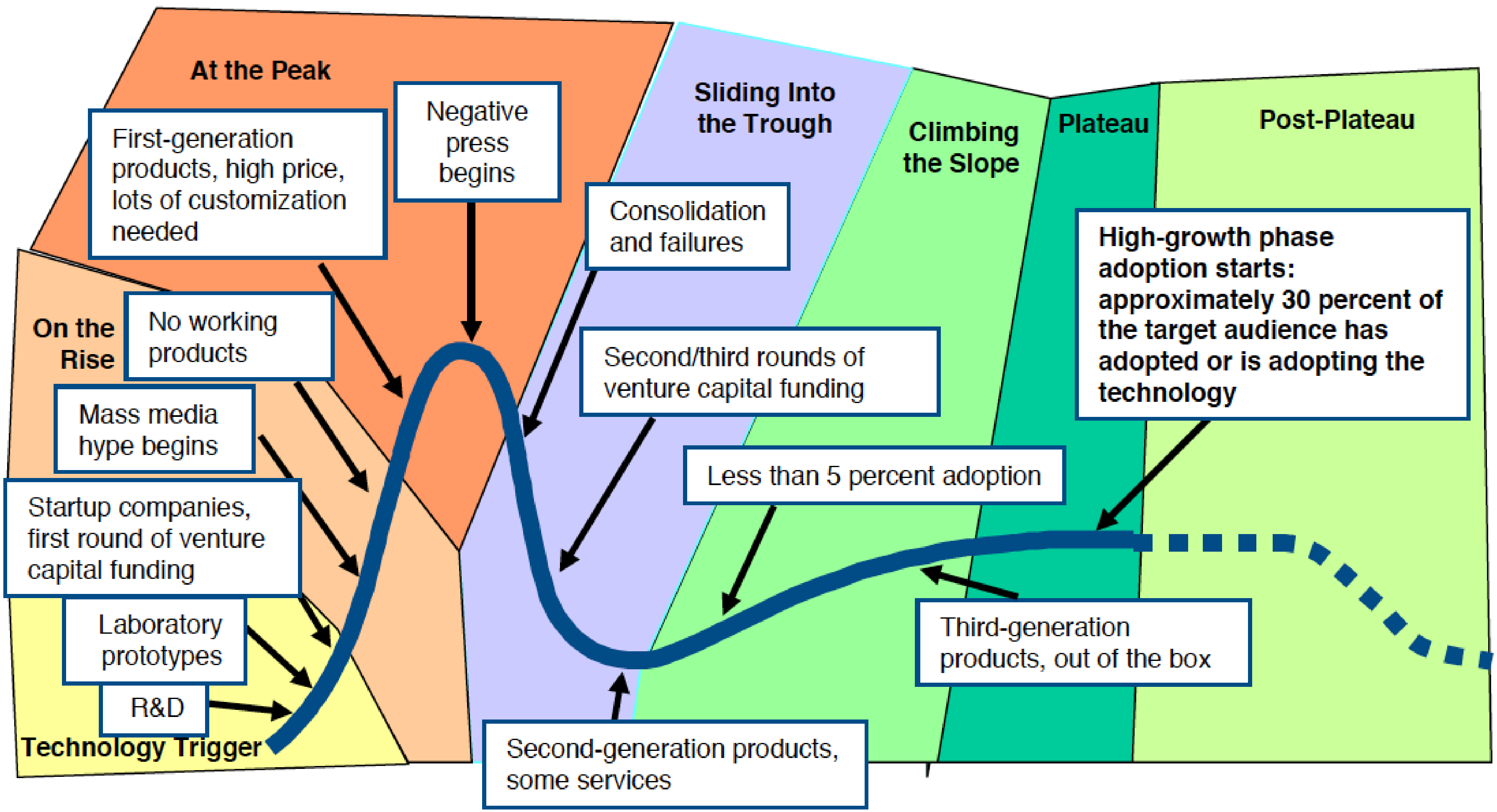
- **Sensing**
- It allows the *physical world*, things and places, to generate data automatically.
- IoT is about **sensing the physical world**

Gartner's Top 10 Strategic Technologies for 2014

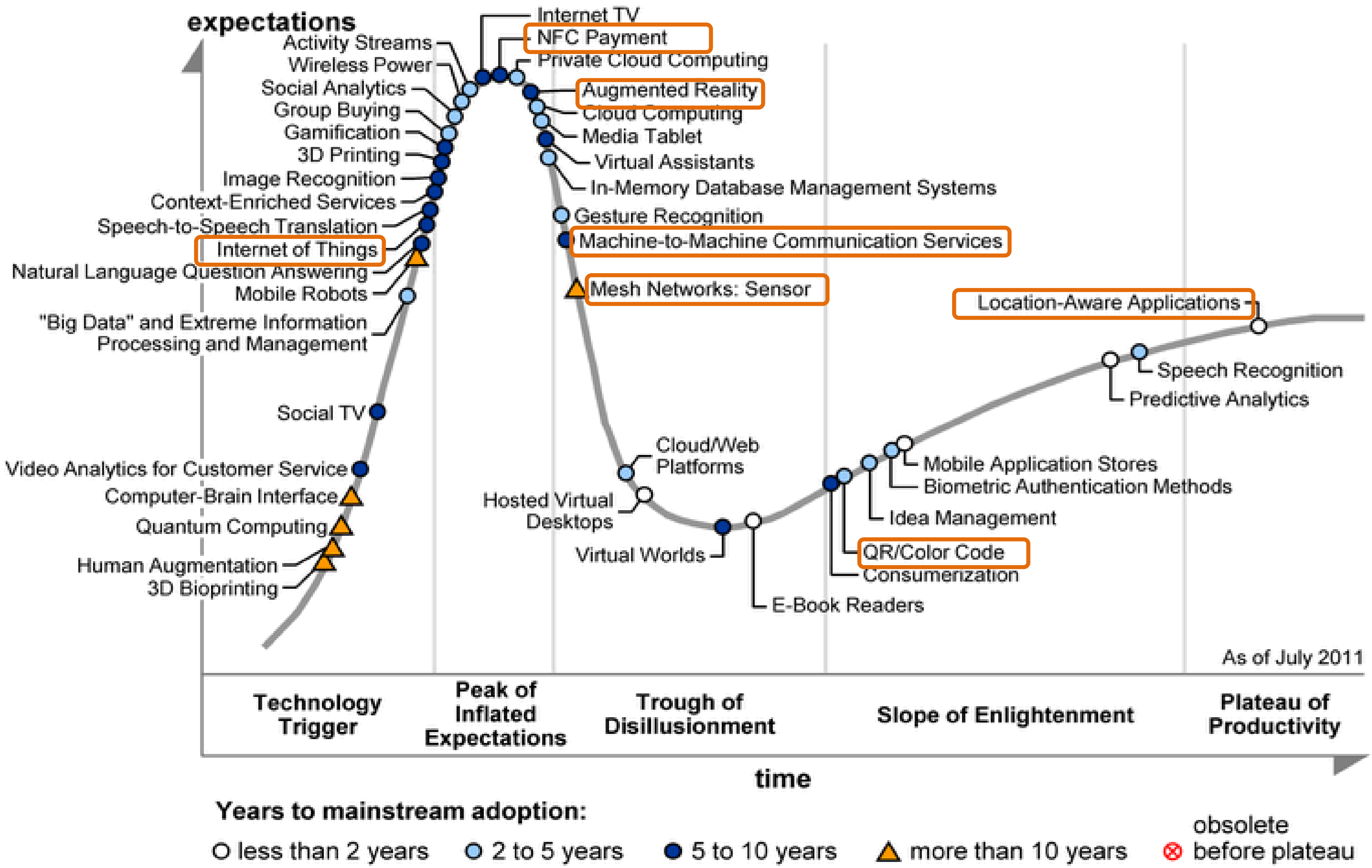
- Mobile Device Diversity
- Mobile Apps and Applications
- **Internet of Everything**
- Hybrid Cloud
- Cloud-Client Architecture
- Personal Cloud
- Software Defined Anything
- Web-Scale IT
- Smart Machines
- 3D Printing

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

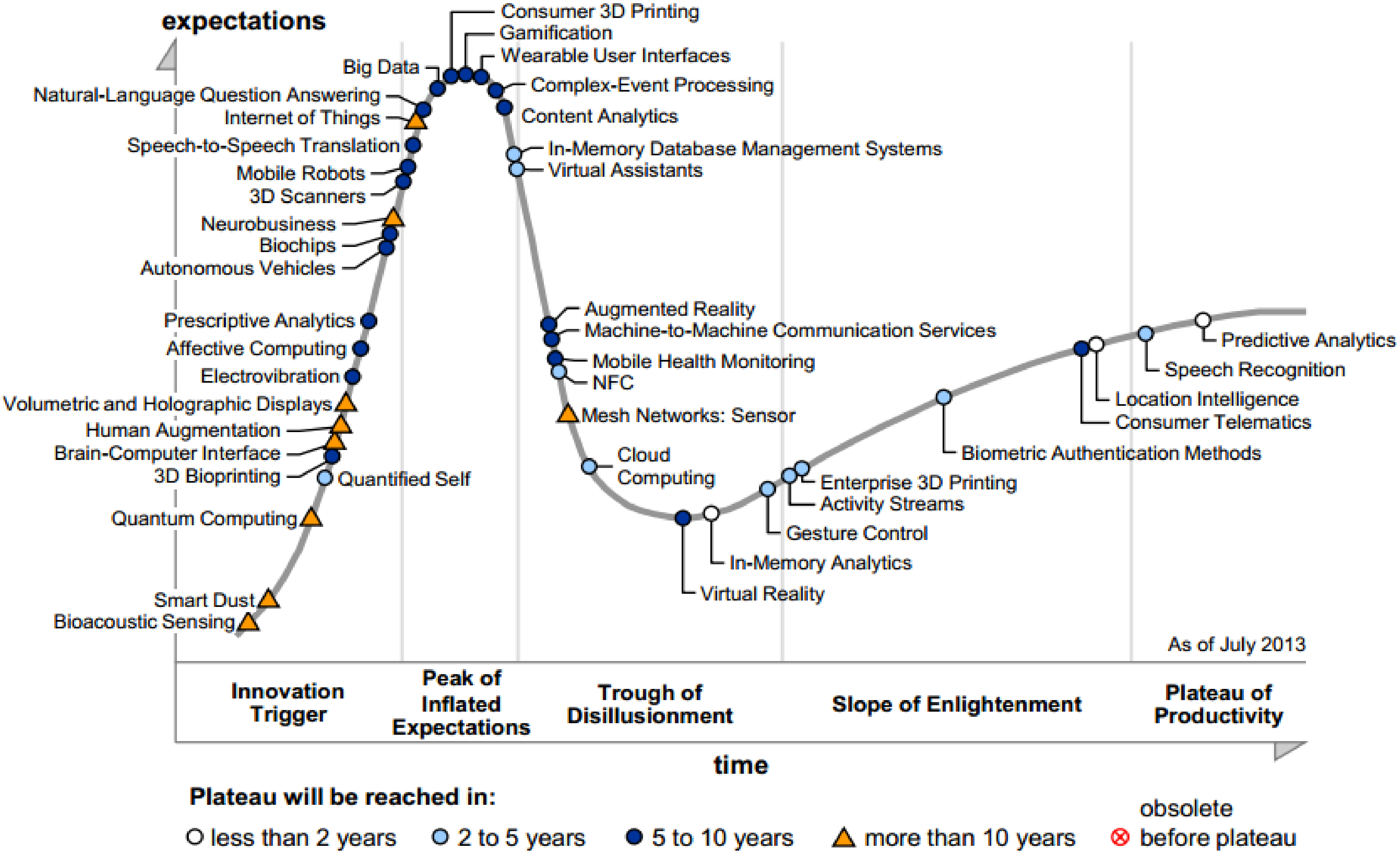
Gartner's Hype Cycle



Gartner's Hype Cycle for 2011



Emerging Technologies Hype Cycle, 2013



Gartner

Gartner's Hype Cycle for 2014