TELECOM ParisTech

INSTITUT Mines-Télécom

Core building blocks of technologies for IoT

Overview

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Lecture slides for

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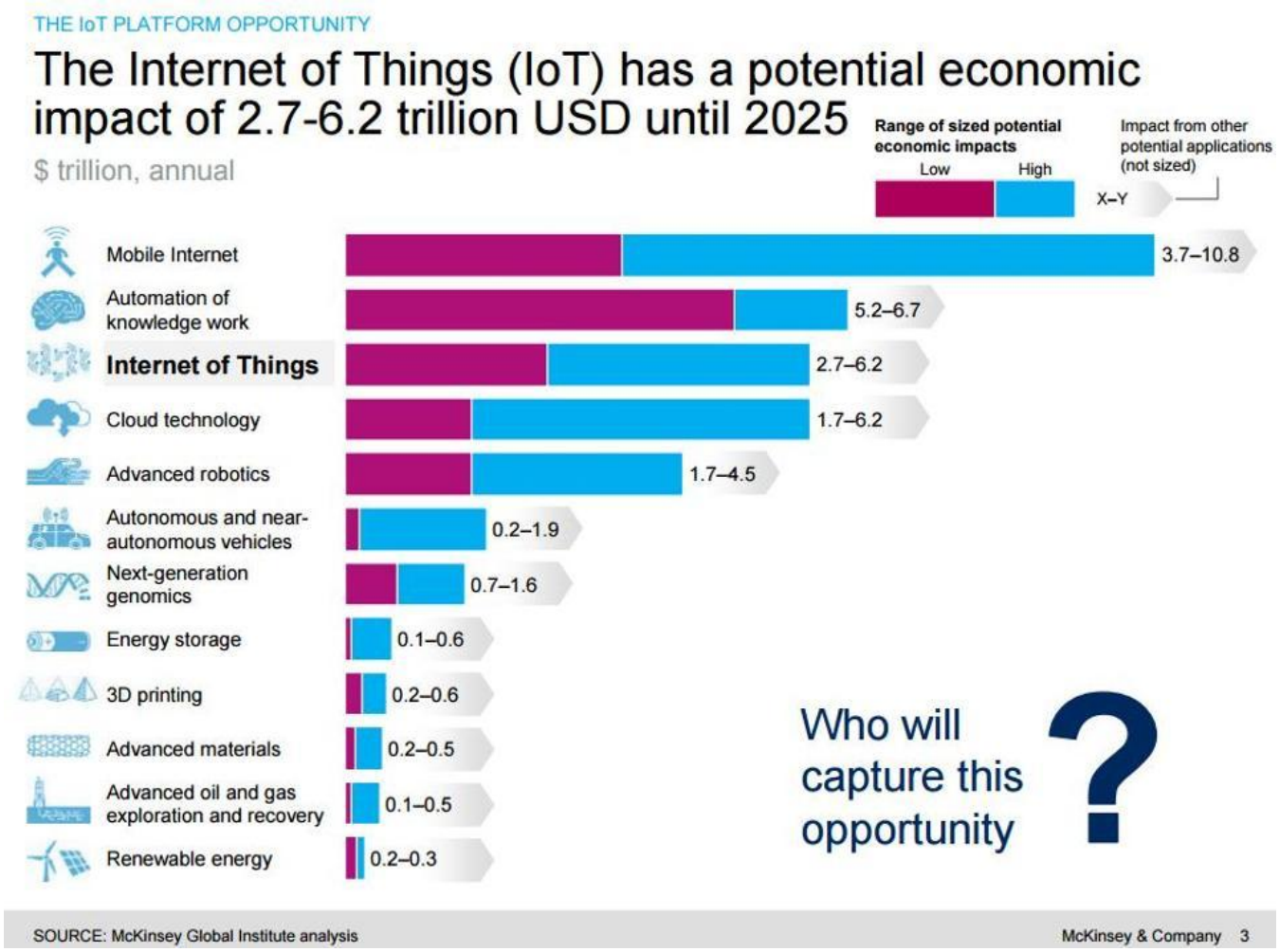
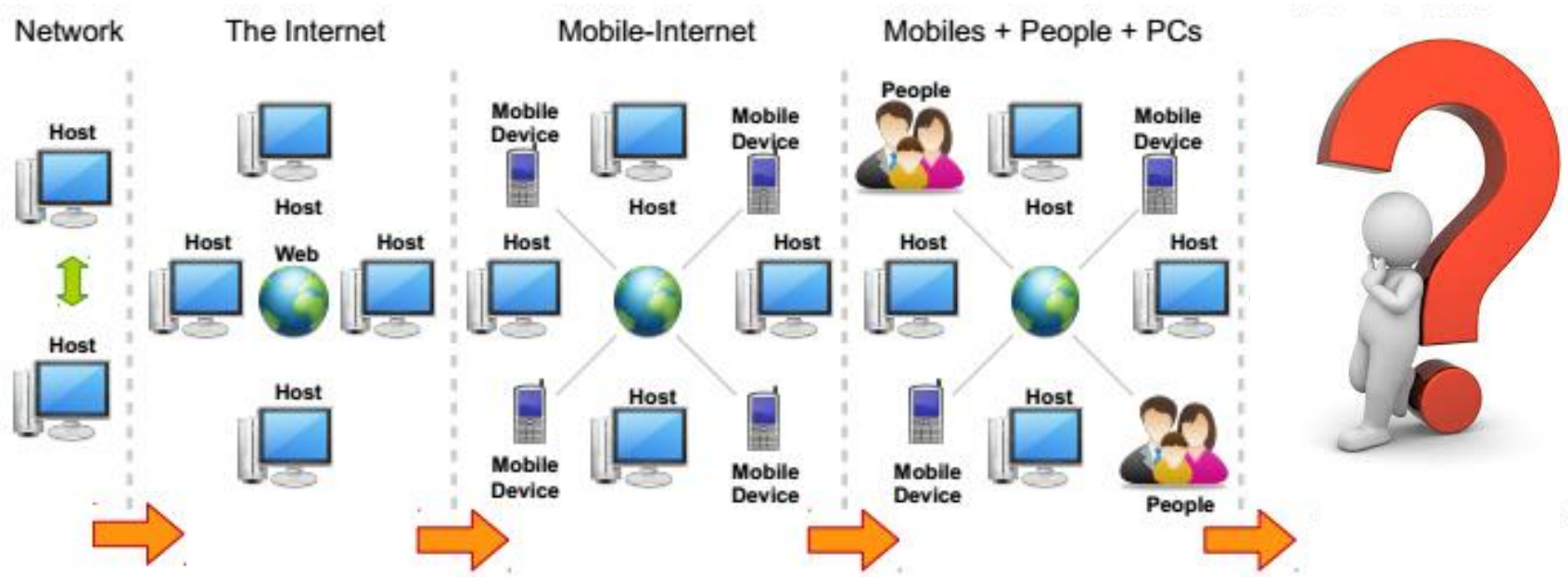
université PARIS-SACLAY

Another look at power of IoT



Evolution of the Internet (1/2)

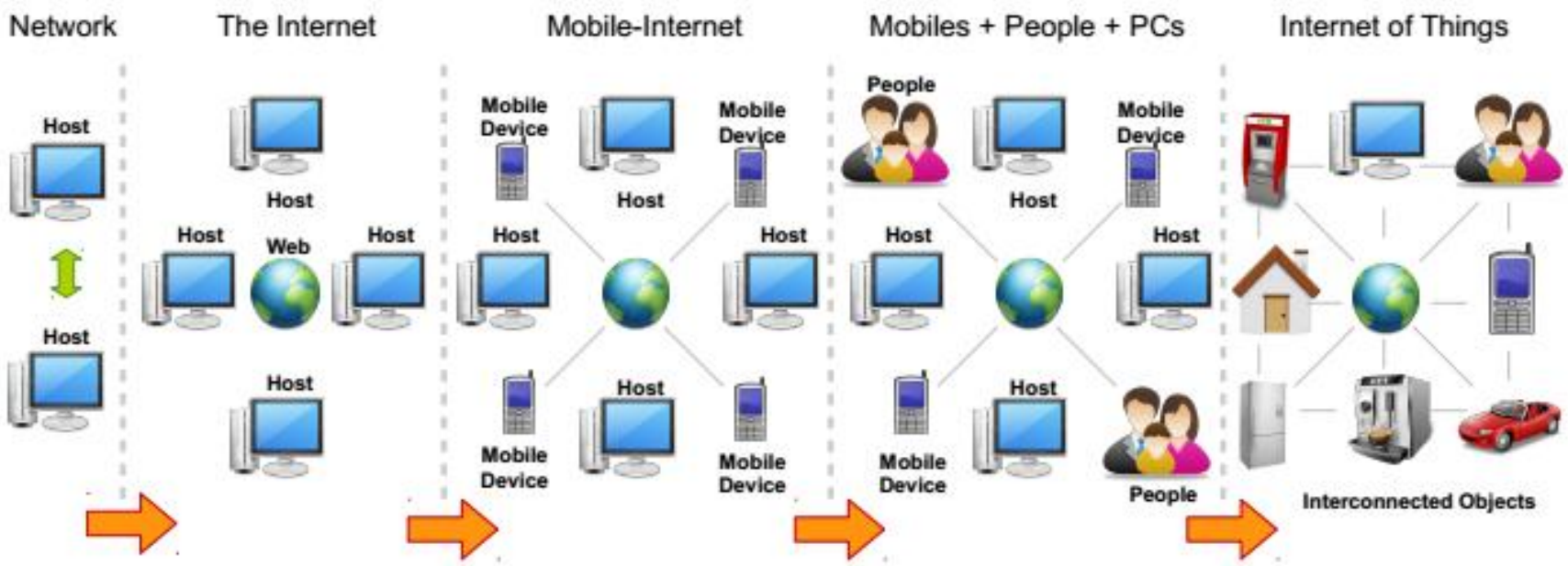
- **The evolution of internet begins with connecting two computers and then moved toward creating**
  - The next wave in the era of computing will be outside the realm of the traditional desktop



Evolution of the Internet in five phases. [1]

Evolution of the Internet (2/2)

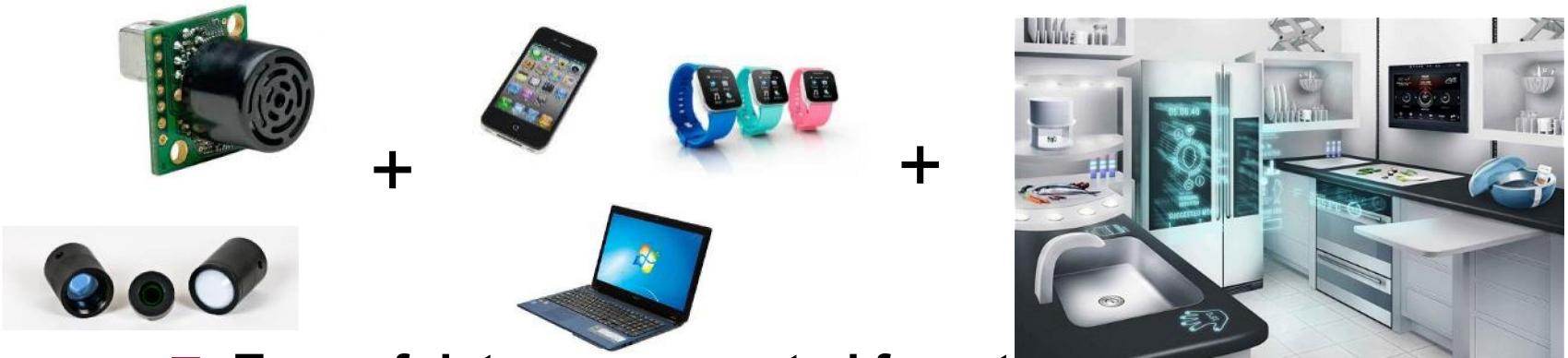
- **Internet of Things by connecting every objects to the internet**
  - Many of the objects that surround us will be on the network



Evolution of the Internet in five phases. [1]

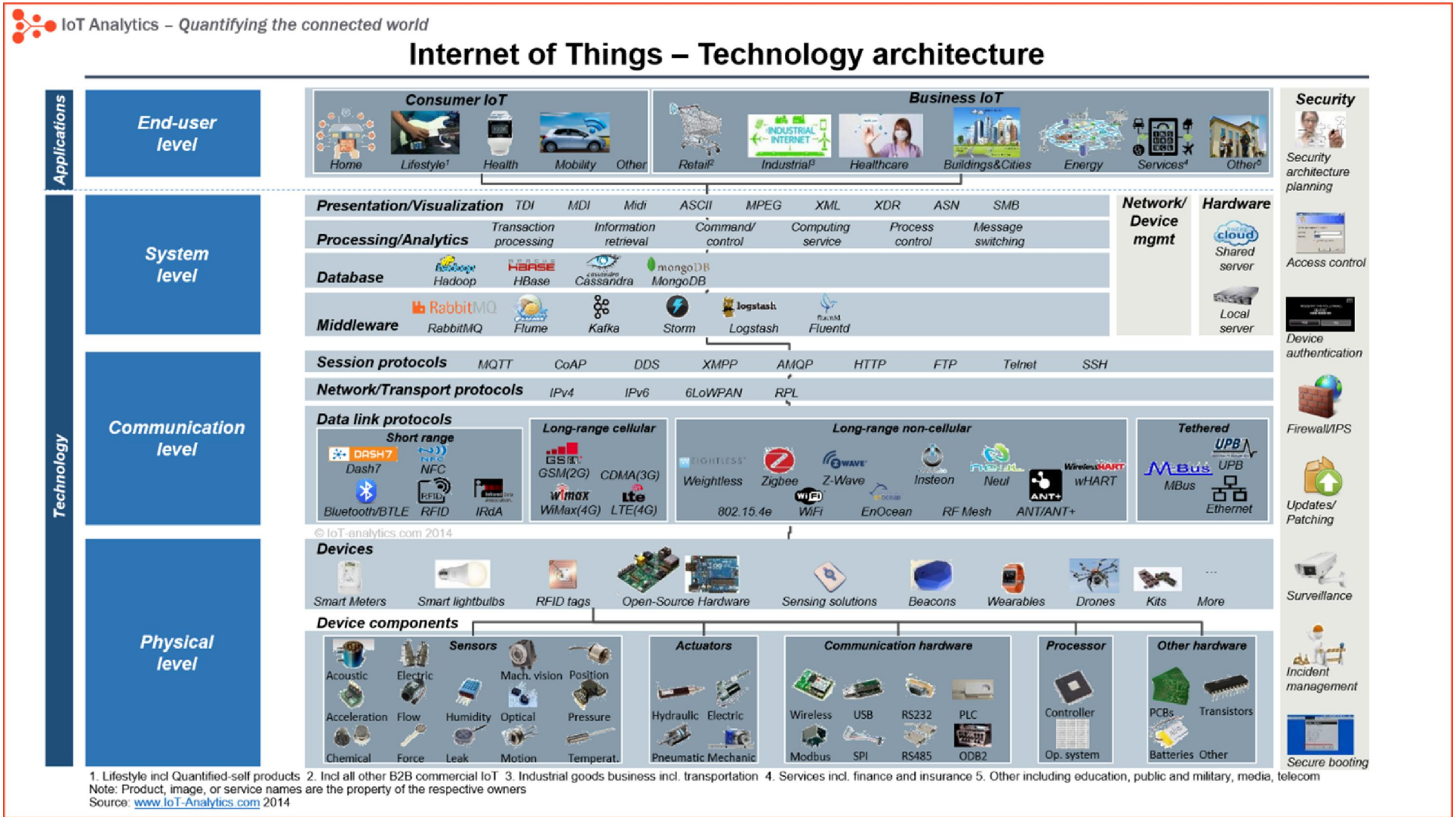
The “Things”

- **Various electronic devices that can generate data**
  - Sensors
  - Embedded Devices
  - General Appliances
  - Even household utensils!!



- **Tons of data are generated from these devices**
  - Sensing data
  - Location data
  - Status, Information, etc.

More general IoT environment



1. Lifestyle incl Quantified-self products 2. Incl all other B2B commercial IoT 3. Industrial goods business incl. transportation 4. Services incl. finance and insurance 5. Other including education, public and military, media, telecom
Note: Product, image, or service names are the property of the respective owners
Source: www.IoT-Analytics.com 2014

Key components

- **Platform development**
  - OS
  - Software
  - Hardware
- **Standardization efforts in**
  - Communication
  - Networks
- **Applications**
  - Requirements

Before we go on…

- **What does this all have to do with data science?**
  - New trend of IoT data!
  - Different compared to the existing data

- **IoT data?**
  - The hardware platforms CREATE the data
  - The software platforms PROCESS the data
  - And they are TRANSFERRED through communication

IoT Platforms

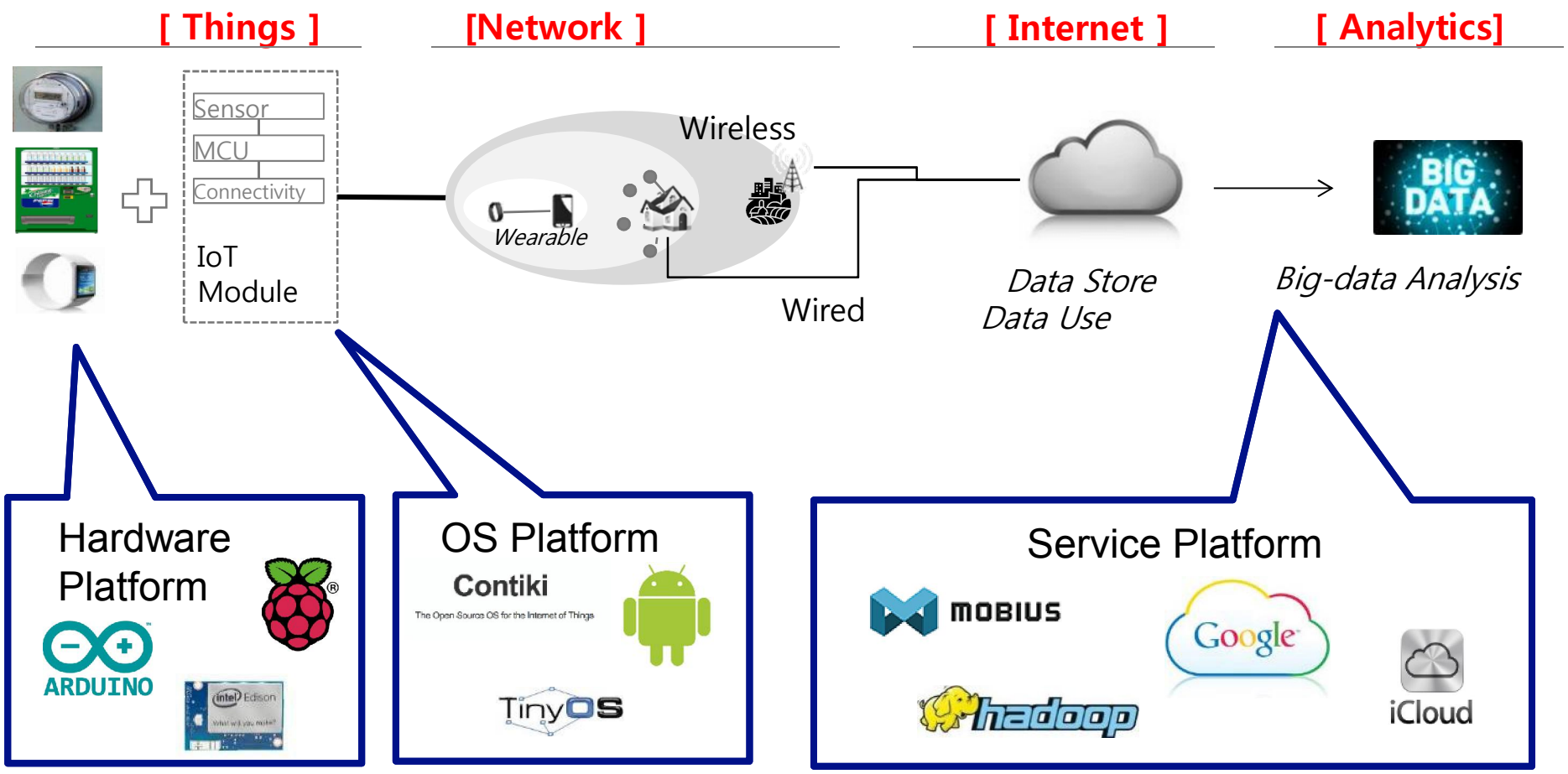
IoT Platform

- **Why is it needed?**
  - Easy to implement and manage in a common method (Convenience / Efficiency)
  - Widely-used platforms can speed up growth of IoT dramatically (Compatibility)

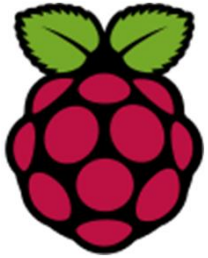
- **Requirements?**
  - Easy to access and contribute
  - Reliable and marketable

- **What kinds of technologies are considered?**
  - Embedded hardware platforms – for things
  - OS platforms – for things and connectivity
  - Service platforms – for Internet management and servicing

How are platforms applied?

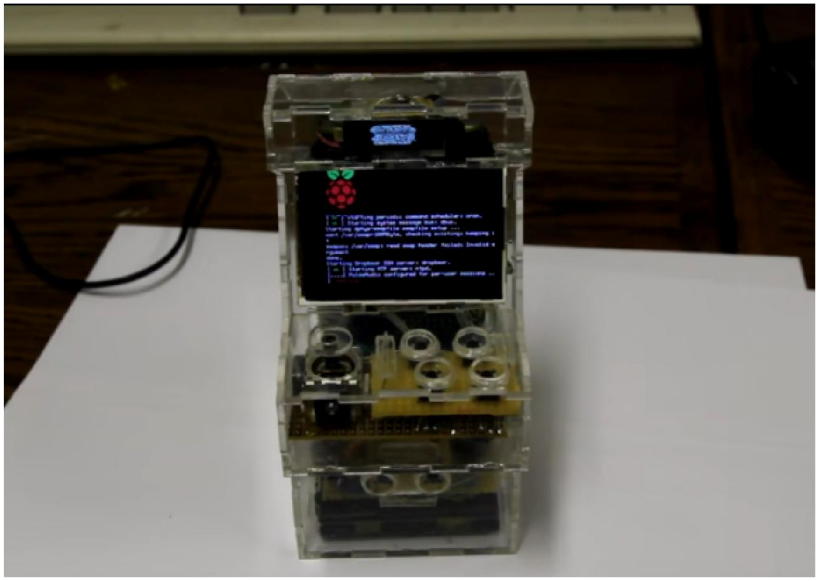


Hardware platform – Raspberry-pi



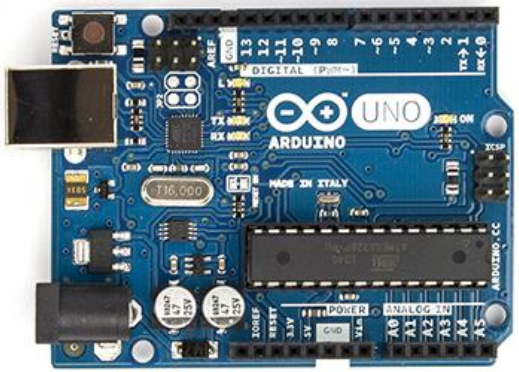
- **Single-board embedded computer**
  - Good for education, testbeds…
- **Specification (ver.3):**
  - 1.2GHz 64-bit quad-core CPU (ARM)
  - 802.11n Wi-Fi
  - 1GB RAM
  - 40 GPIO
  - USB / HDMI / ethernet
- **Runs on**
  - Raspbian (Linux variant)

Project examples in R-Pi



Arduino

- **Simple circuit board with programming capabilities**
  - Additional modules
  - Design of drivers
- **Spec: (Arduino due)**
  - ARM Cortax-M3 SAM3E8X
  - 512KB Flash MEM
  - 96KB SRAM
  - 84Mhz Clock



- **Used for education**
  - Can run on Linux / Microcontroller

Intel platforms

- **Platforms used for such purposes**
  - Galileo – Arduino certified, runs on Linux
  - Edison – Computer-on-module for wearable devices
    - Can be used on Arduino

Sensor platforms

- **Very small embedded boards designed for sensor motes**
  - Multiple sensors – temperature / luminosity / etc.
  - Communication module – 802.15.4 / ZigBee

Sensor kits for Arduino / Rpi

- **GPIO sensors designed to be wired with hardware platform**

Note

- **Many companies would develop their own versions of hardware platforms**
  - To fit to their requirements of the service
- **Most devices I have mentioned are:**
  - Open-source devices used for training, development, and tutorial

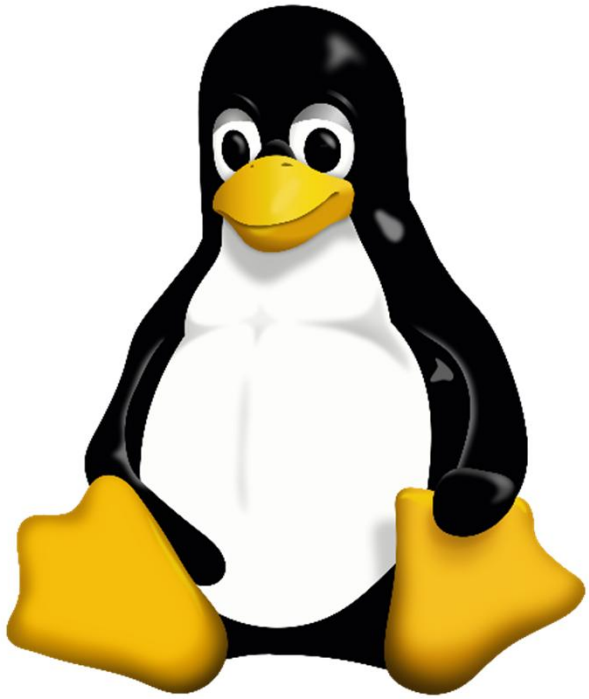
Challenge question

- **I have probably been only talking about devices that you have never heard of.**
- **Why can't we use things like:**
  - Pentium?
  - Laptops?
  - Super computers??
- **HINT**
  - Embedded
  - Tailor-made

What allows the devices to act intelligently?

- Well, devices are all good, but aren't we missing something?

- Hint:



Software Platforms

- **Software platforms are used to control every aspect of an IoT device and its network**
  - Enabling/disabling sensing
  - Enabling/disabling communication
  - Turning on/off device
  - Software commands

  - Etc,etc.

Why are platforms important?

- **There are many types of platforms available**
  - Embedded linux
  - TinyOS
  - Contiki
  - RIOT
  - Etc.

- **But why do they make these platforms???**
  - Better performance
  - Better compatibility

Some people say….

- **The most important research in future IoT is:**
  - Not the network algorithms
  - Not the improvement in hardware devices

  - The **compatibility** of numerous devices through efficient management of PLATFORM
    - Embedded platforms!!!!!

TinyOS

- **Sensor network OS developed by UC Berkeley**
- **Very small coding size (Based on components)**
- **Usage of nesC programming language**
  - Good or bad?
- **Event-driven**
  - With usage of tasks
- **Large community**

Contiki

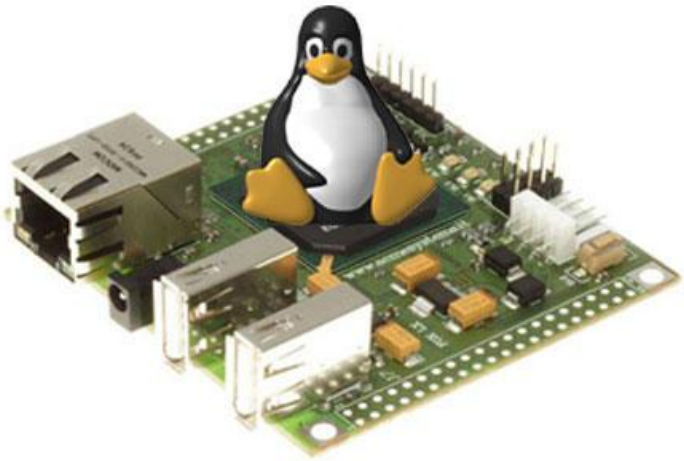
- **Created by Adam Dunkels – Sweden**
- **Allowed multitasking through multithreading**
  - Preemption
  - Strong GUI – Cooja
- **Heavier than TinyOS but also more powerful!**
  - Smallest IPv6 stack when first developed
- **Strong community**

RIOT

- **Joint OS production in Europe**
  - France, Germany..
- **Known to be more powerful + flexible compared to TinyOS and Contiki**
  - Created later too
- **However, smaller community**
  - Less supported popular devices too

Embedded Linux

- **Not really exclusively created for sensor networks**
  - However, still gaining very much popularity!!
  - Why?
- **Recently, many devices are being developed with embedded linux in mind**
- **Largest community**



Why so popular?

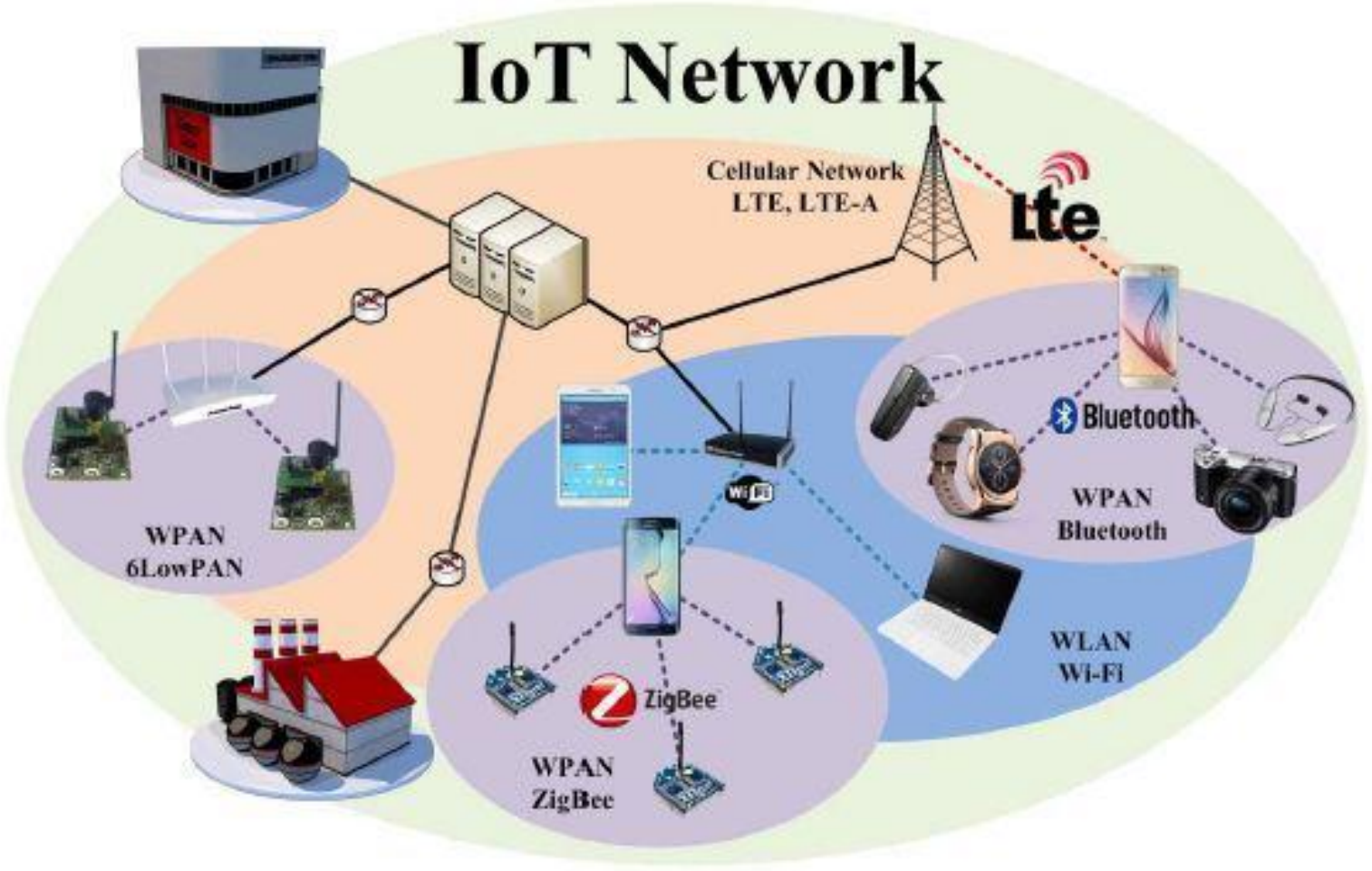
- **Multi-purpose**
- **Powerful!**
- **Becoming less and less power consuming!**
- **Many custom sources distribution of embedded Linux!! (Tailor-made / Framework based)**
  - Raspbian
  - Yocto
  - Android

Communication Platforms

Why do we need communication tech?

- **Can't we just use Mobile technology???**
- **Why do we have to use non-cellular technologies?**
  - Like Wi-Fi?
  - Or Bluetooth?
  - Or IEEE 802.15.4?

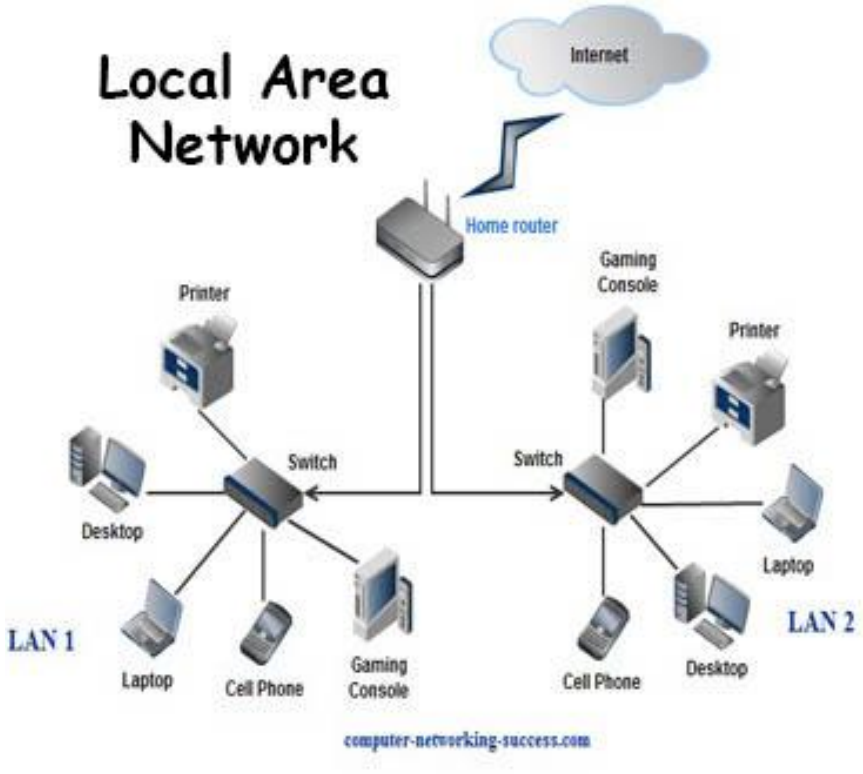
Network concept in IoT



LAN (Local Area Networks)

- **Typically restricted in their diameter to buildings, a campus, single rooms**

- **IEEE 802.3 Ethernet**
  - Specification for CSMA/CD
  - High capacity
  - Broadcast capability
  - Full connectivity among stations

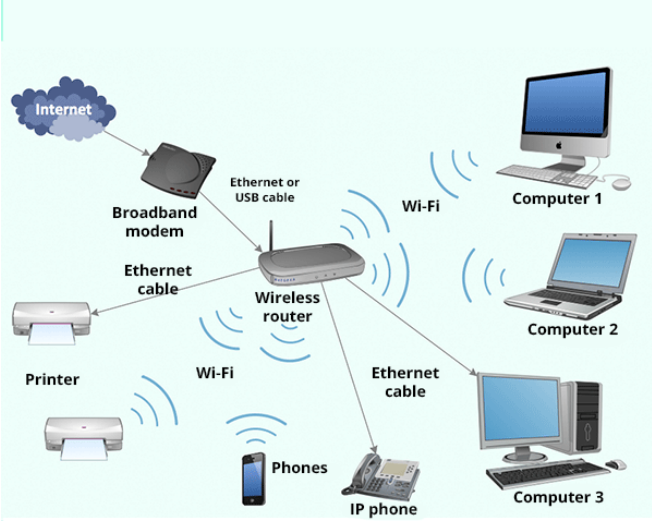


Wireless Extension for LAN

- **Why Wireless? … good for mobility, flexibility, and cost**

- **WLAN vs LAN?**
  - Unprotected, less reliable wireless shared media
  - Lack of full connectivity
  - Dynamic propagation & topologies

- **IEEE 802.3's CSMA/CD not applicable!**
  - Utilizes concept of CSMA/CA



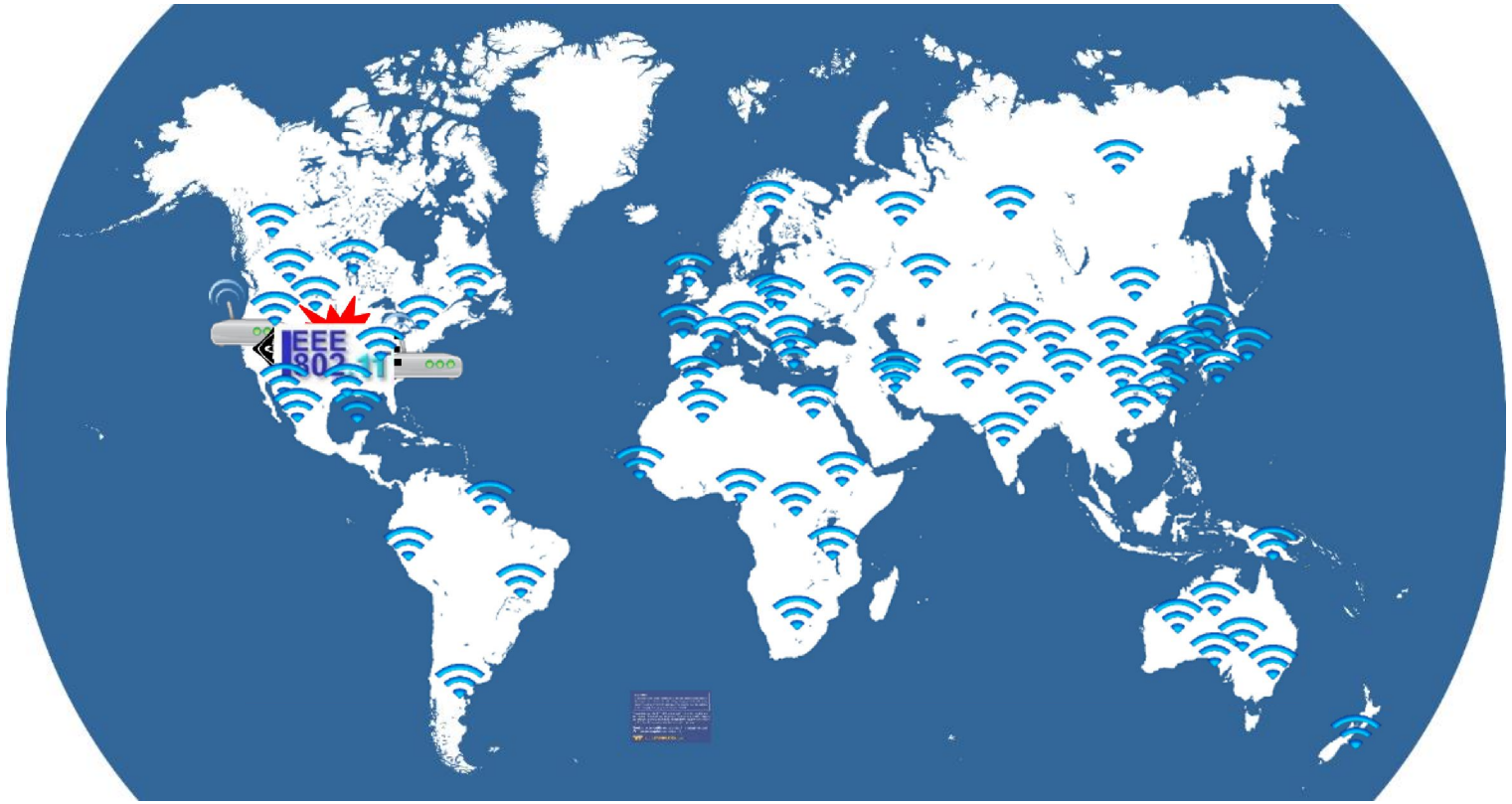
WLAN Network Diagram

Wi-Fi?

- **What does it stand for?**
  - Wireless fidelity???
  - Misconception!

- **What is it exactly?**
  - The line of devices that is based on the IEEE 802.11 WLAN standard & technology

Brief History of Wi-Fi Evolution



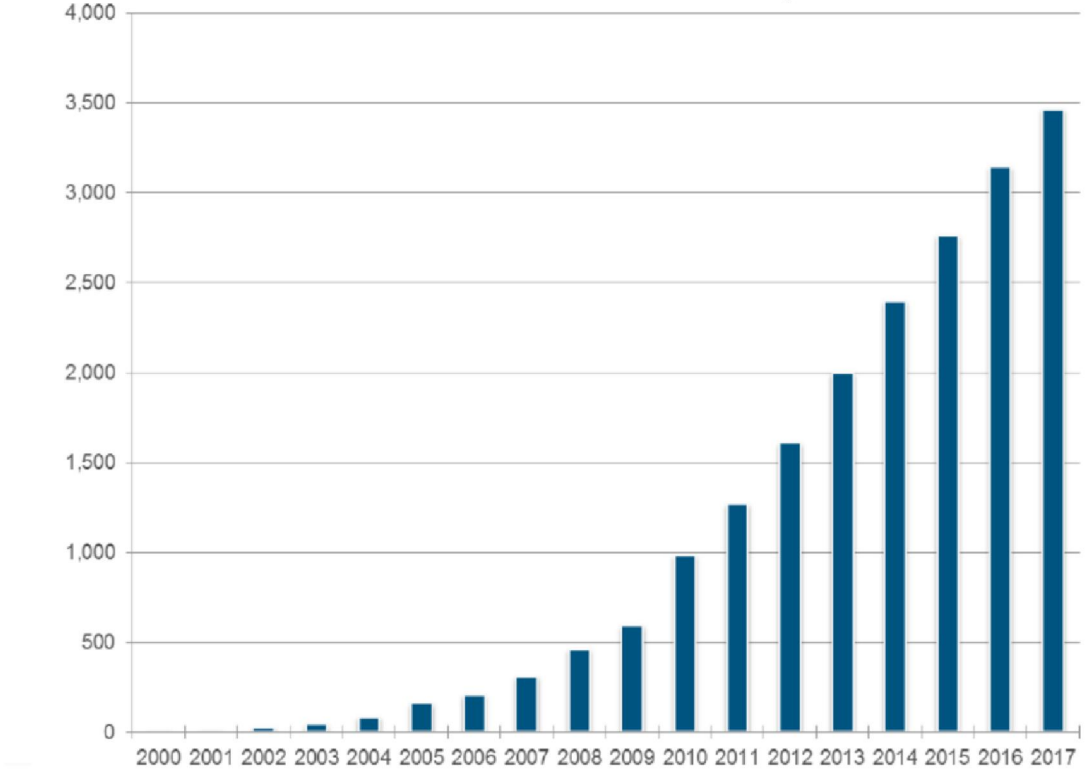
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

1997: [illegible] was not compatible with each other (why?)

To create a consumer-friendly trademark, the name "Wi-Fi" was taken (beat FlankSpeed and DragonFly)

Global Wi-Fi Market

- **Wi-Fi Chipset Shipments (Millions of units)**
  - 2017: More than 9 million devices a day!



https://www.abiresearch.com/market-research/service/wi-fi/

WPAN

- **Wireless Personal Area Networking technology**
  - Short-range (Not anymore, but intended)
  - Low-power (WHY?)
  - Multi-node network (Not like RFID / NFC)

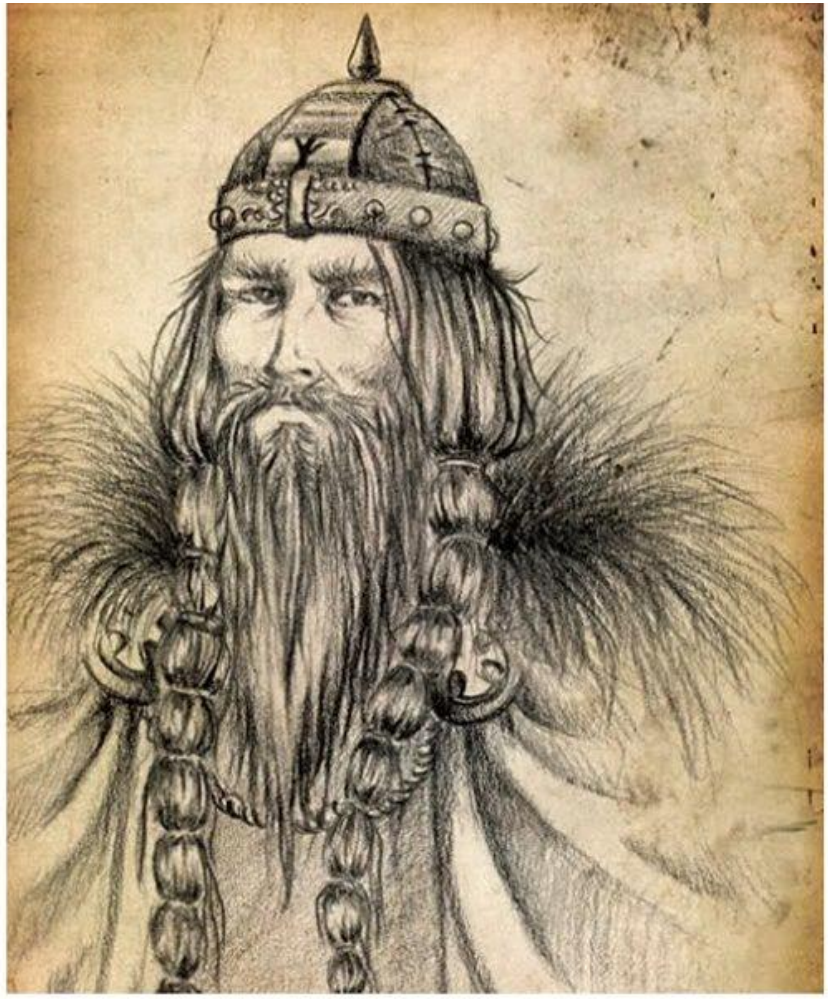
- **WPAN technologies?**
  - Bluetooth
  - Infra-red
  - 802.15.4-based (Zigbee, 6LoWPAN)
  - Visible light communication
  - Z-wave
  - Etc.

WPAN design challenges

- **Embedded**
  - Power limitation
  - Low-cost
- **Dynamicity**
  - Co-existence
  - Mobility

Bluetooth

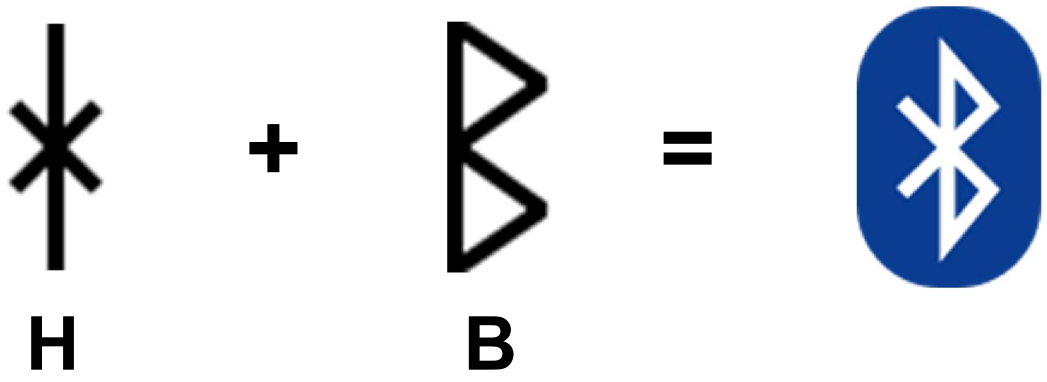
- **Harald "Blåtand" Gormsson**
  - King of Denmark and Norway
  - Reign 958 - 986
- "**Blåtand**" = Bluetooth
- **Why?**
  - 1) bad tooth?
  - 2) Blueberries!
  - 3) Fashion?



Origin of Bluetooth

- **As Harald Bluetooth unified Denmark and Norway,**
  - Bluetooth technology had the goal of unifying wireless computers and phones

- **In Nordic runes,**



What exactly is Bluetooth?

- **As the developers say, it was:**
  - An alternative to data cables
  - First used for connecting keyboards, earphones, etc.

- **Now, we can conceive it as:**
  - A wireless technology for short-distance, low-power communications
  - Now targeted for low-power connection of everything!

  - A part of WPAN technology

List of Bluetooth specifications

- **Classic Bluetooth**
  - Bluetooth V1.0 and its family
  - 2.0 + EDR and its family
  - 3.0 + HS

- **Bluetooth Low Energy (LE)**
  - 4.0 + LE and its family
  - **5!**

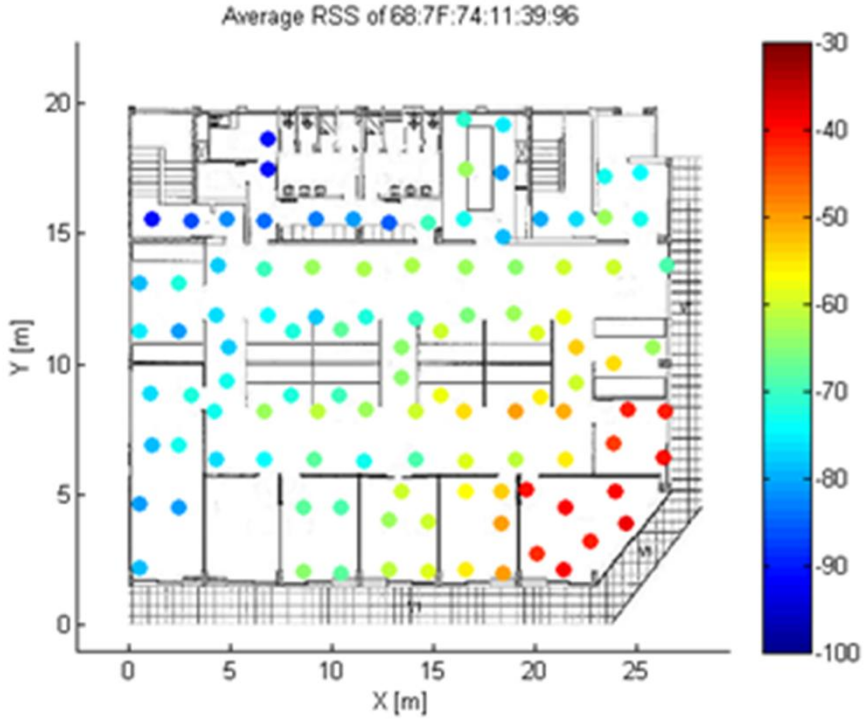
Localization using BLE?

- **Beacons in BLE (advertisement)**
  - Low-power / low-cost
  - Acceptable range
  - Potentials to be in many quantities
  - Can be used to localize!

- **Target**
  - Indoor positioning (indoor GPS)
  - But via what methods?

Location Fingerprinting?

- **Estimating a location depending on the signal strengths of various signals received**
  - Based on past databases of wireless fingerprints



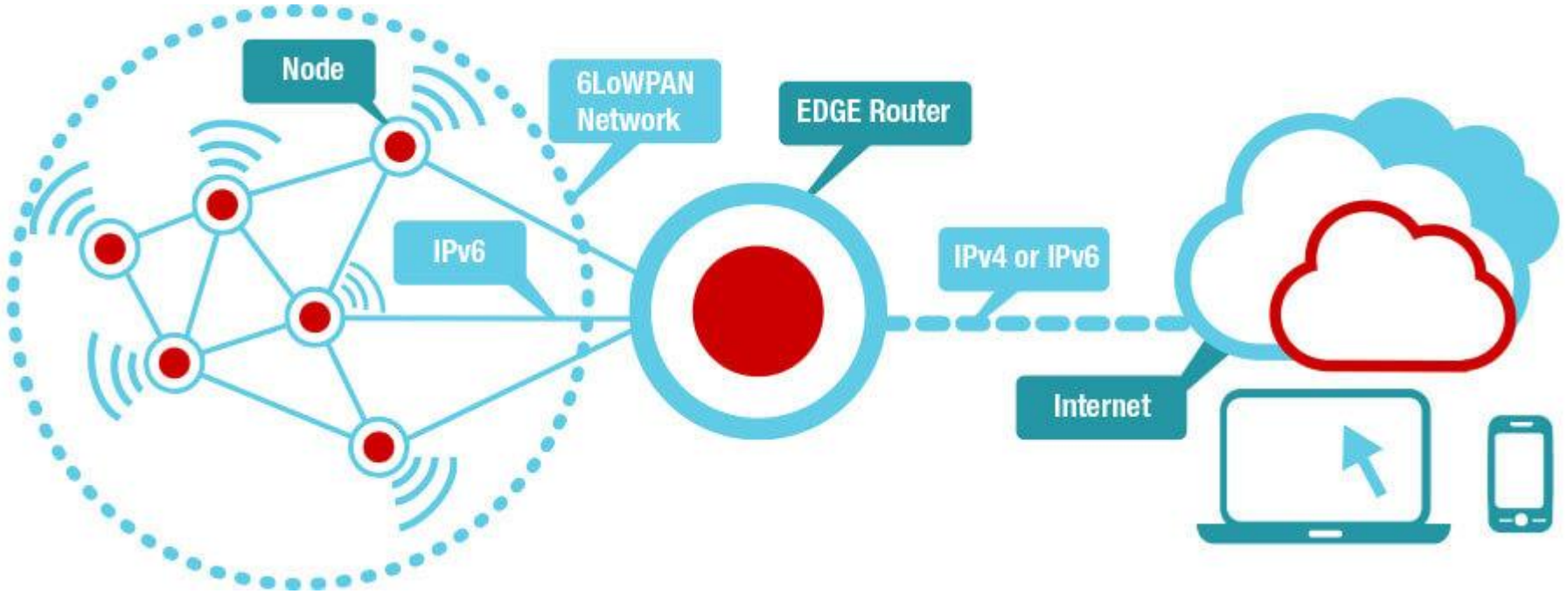
6LoWPAN

- **Another WPAN standardization project**
  - To provide IPv6 addressing in IoT/sensor networks
  - Why?

* IPv6 address has 128 bits
  * $2^{128} = 3.4 \times 10^{38}$ addresses!!!!
* 340,282,366,920,938,463,463,374,607,431,768,211,456
* 4.3x1020 addresses per square inch on earth
* Enough address for every grain of sand on earth!

6LoWPAN Concept

- Try not to go too deep here



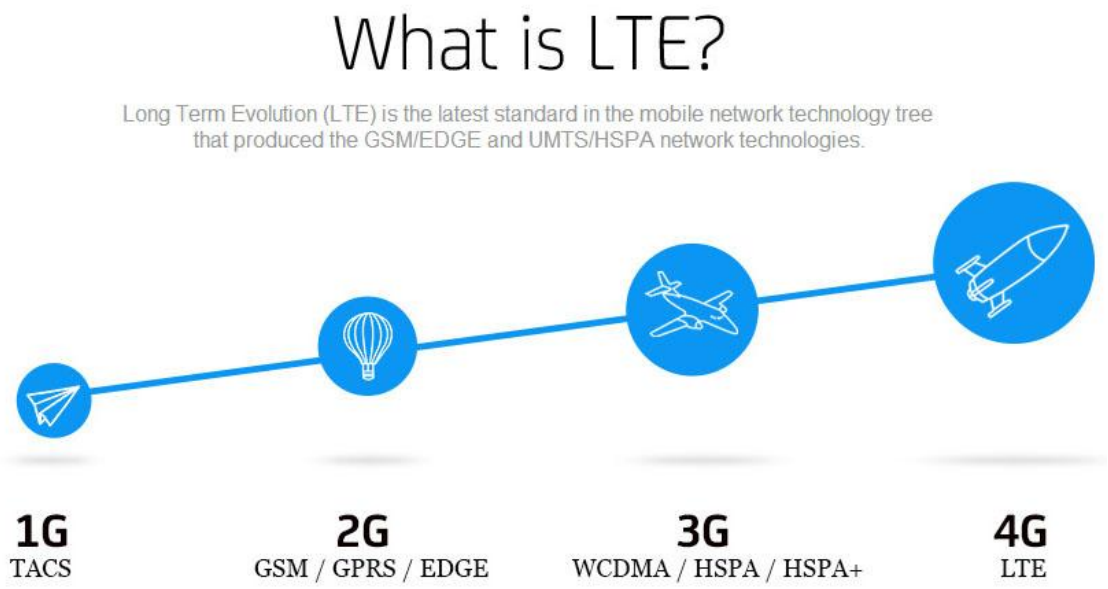
Wide area Networks?

- **Low-Rate WAN is another possible technology of the future**
  - Slow enough to save energy
  - But wide! (about 15km)

- **You heard of…**
  - SigFox?
  - LoRa?

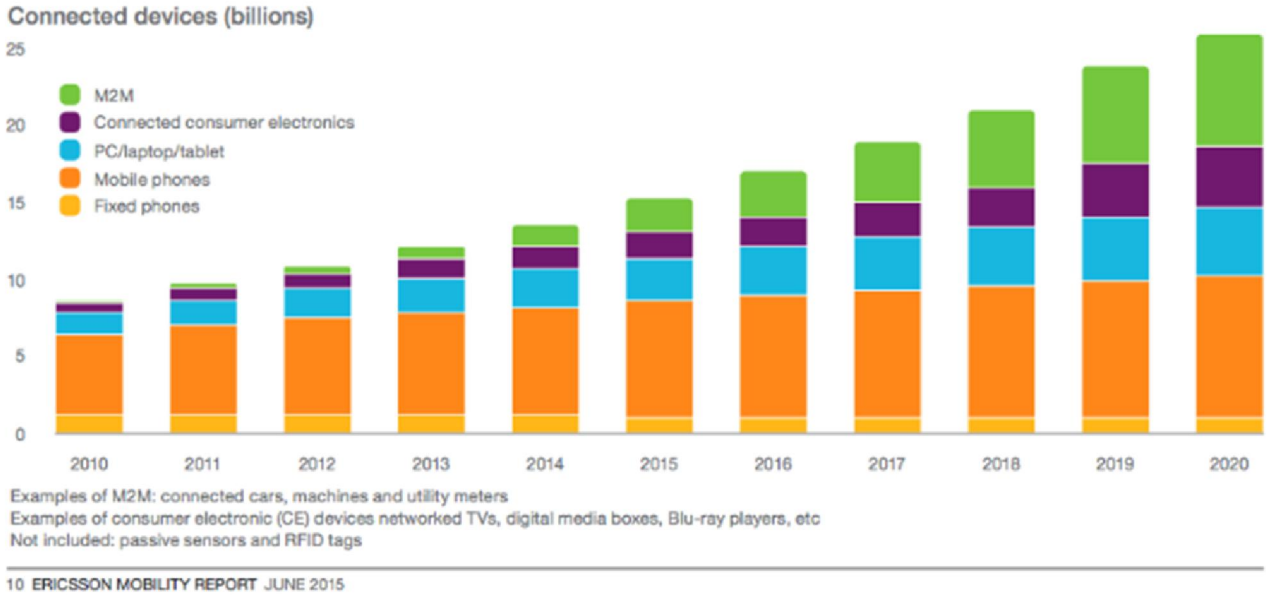
Mobile networks

- **Means to connect people to a network anywhere**
- **Via what technologies?**
  - CELLULAR



Predicted future

- **Ever-growing usage of mobile networks**



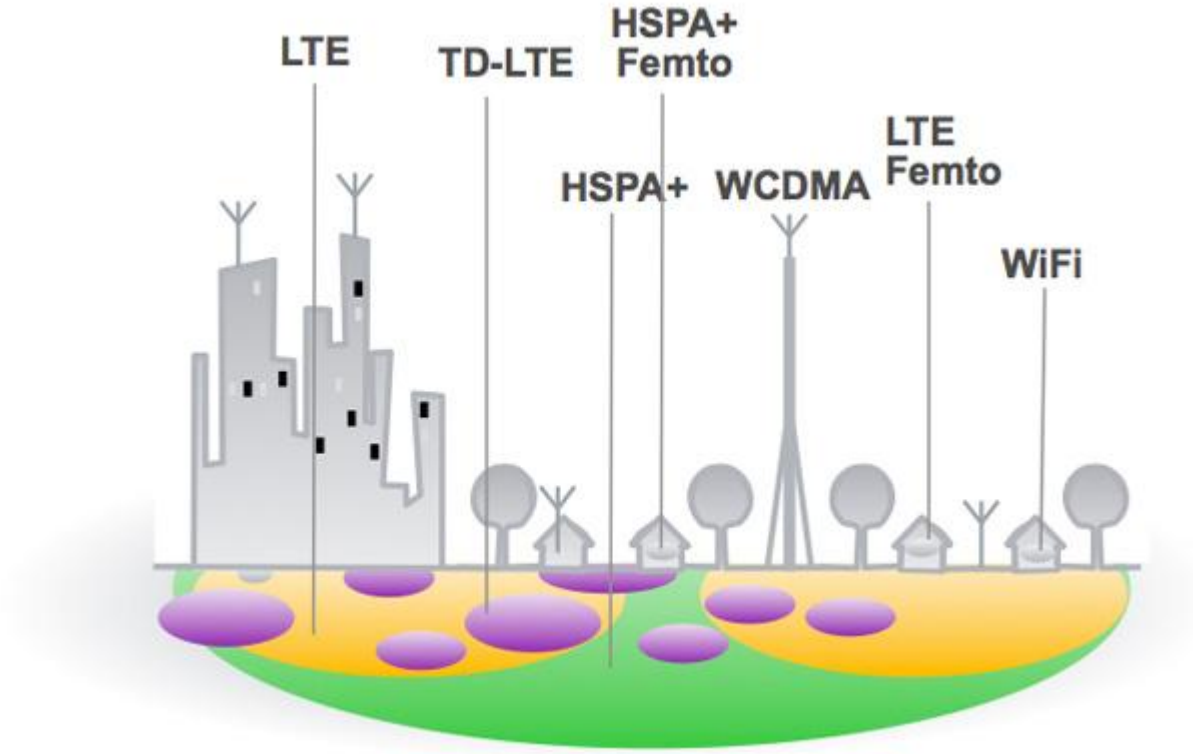
5G

- **They are already looking into advancement!**

- Data rates of tens of megabits per second for tens of thousands of users
- Data rates of 100 megabits per second for metropolitan areas
- 1 Gb per second simultaneously to many workers on the same office floor
- **Better coverage**

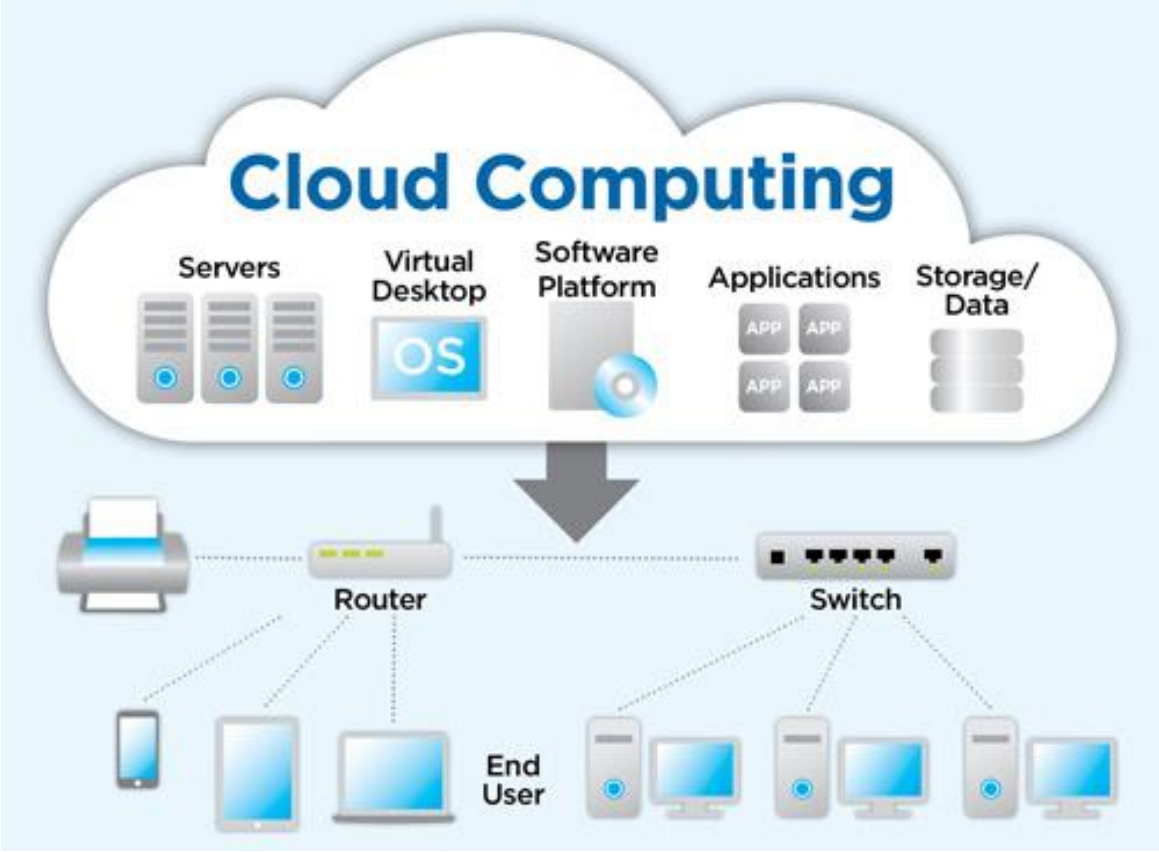
Hetnets

- **HETerogeneous NETworks**
  - All can be operated under same service set
  - Without the user having to configure anything



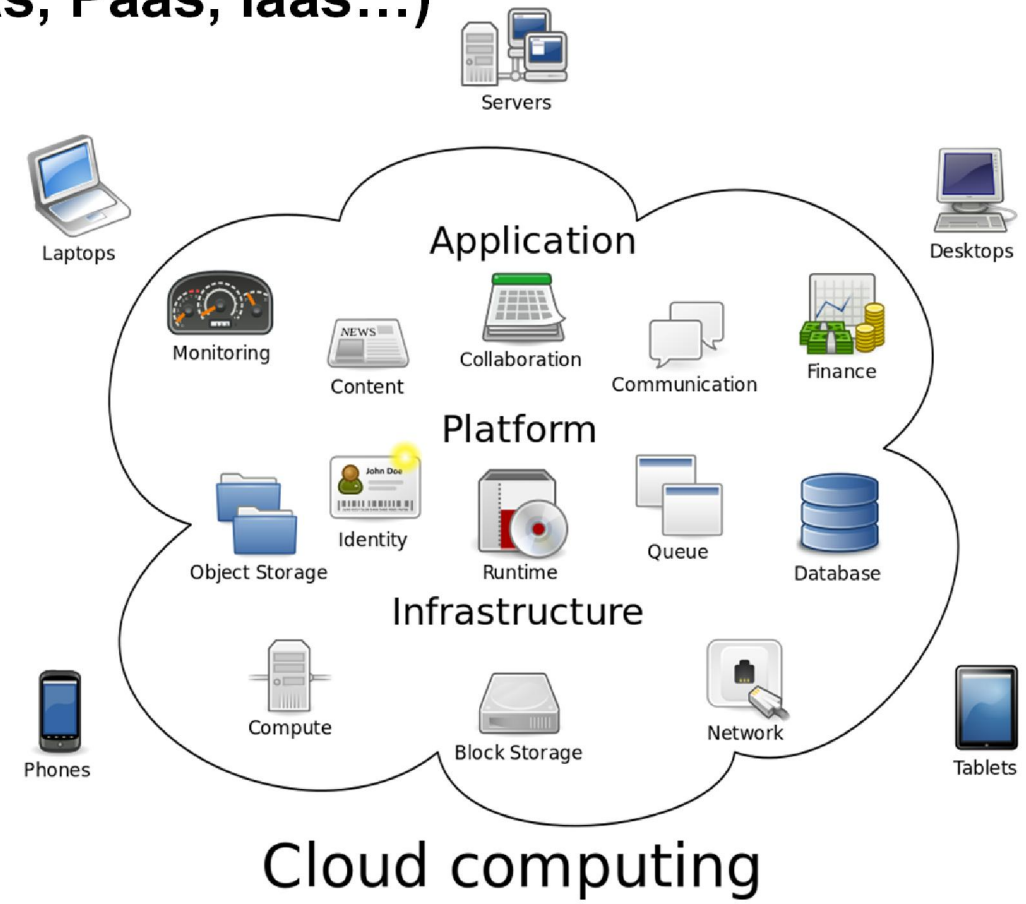
Cloud computing

- **Considered a key technology for future mobile networks**



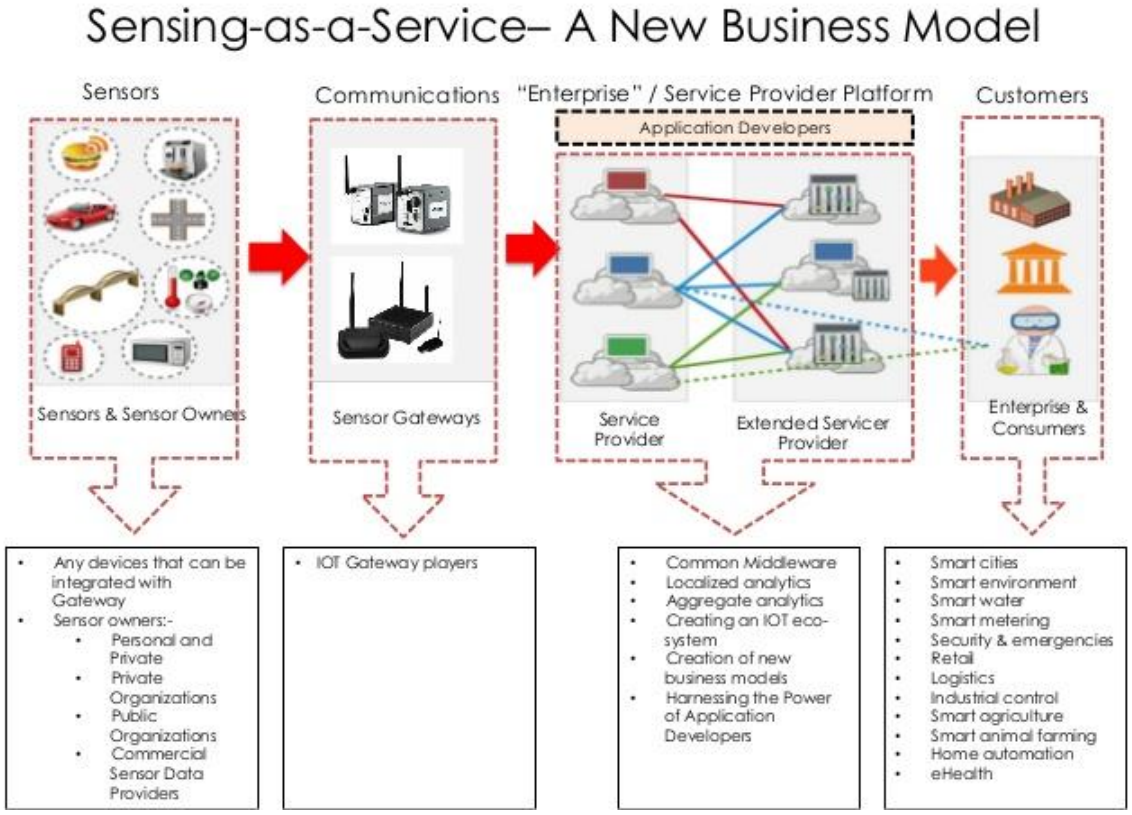
Why Cloud computing?

- **Various services already available and mature (Saas, Paas, laas…)**



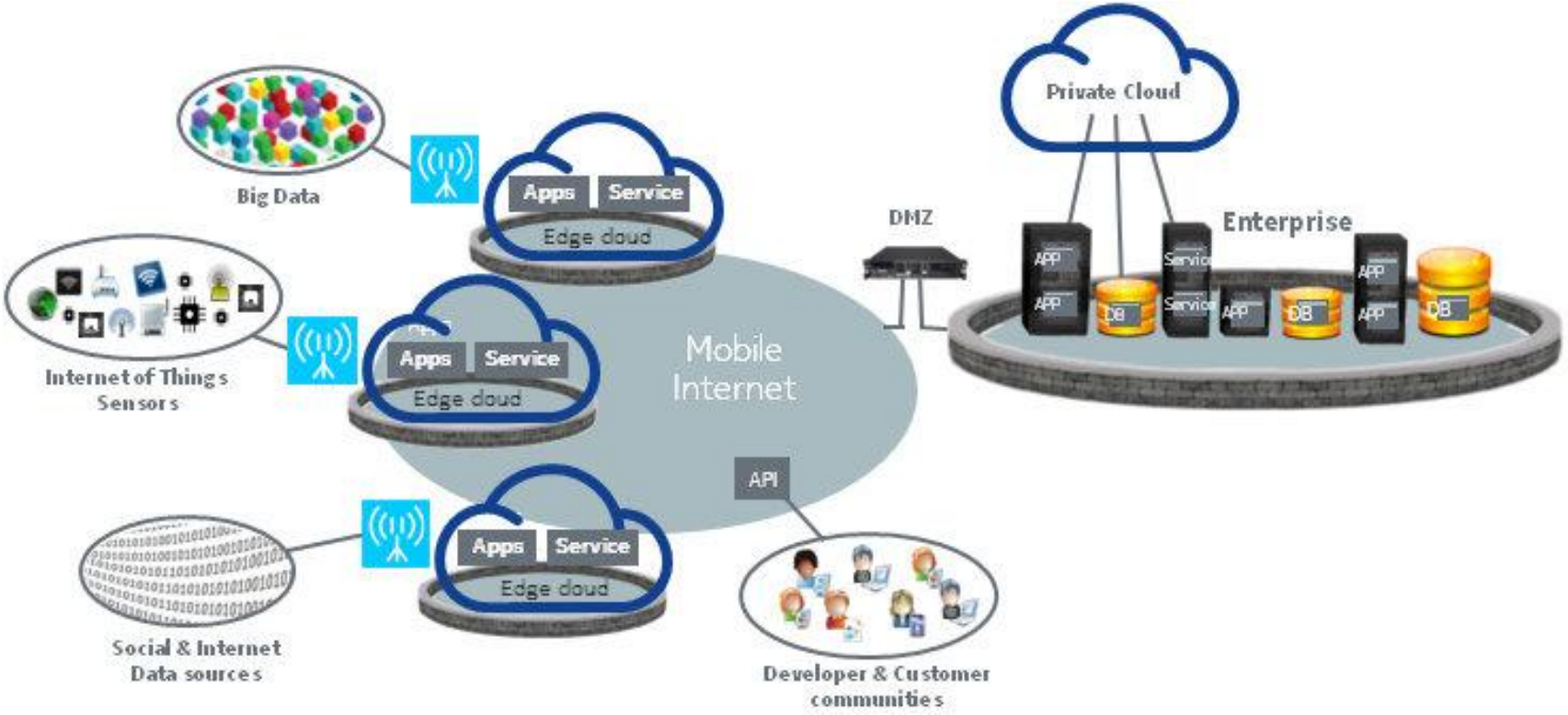
Sensing aaS? Things aaS?

- **IoT suggests new cloud computing models as a future service model**



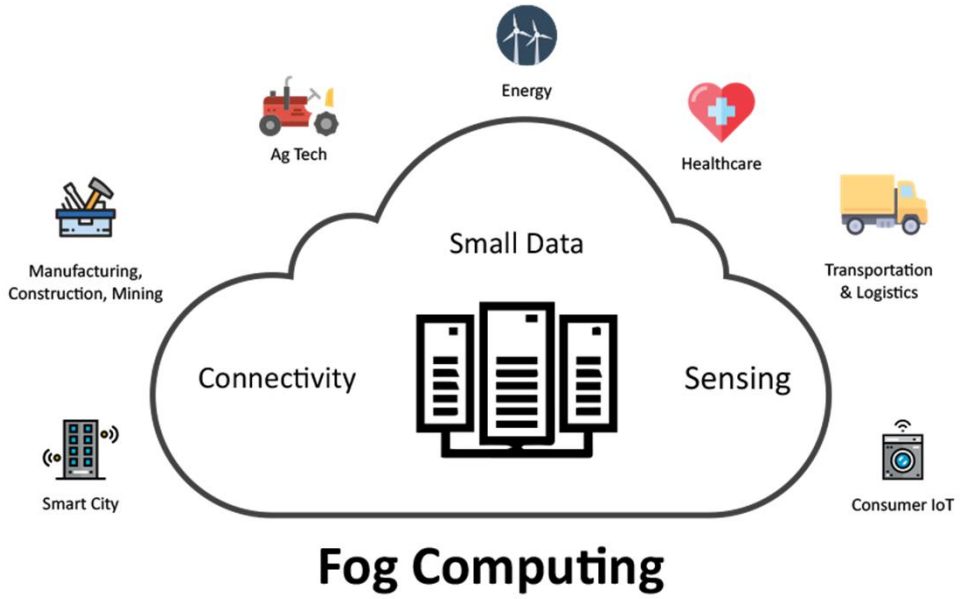
Mobile edge computing

- An example of utilizing clouds – edge clouds



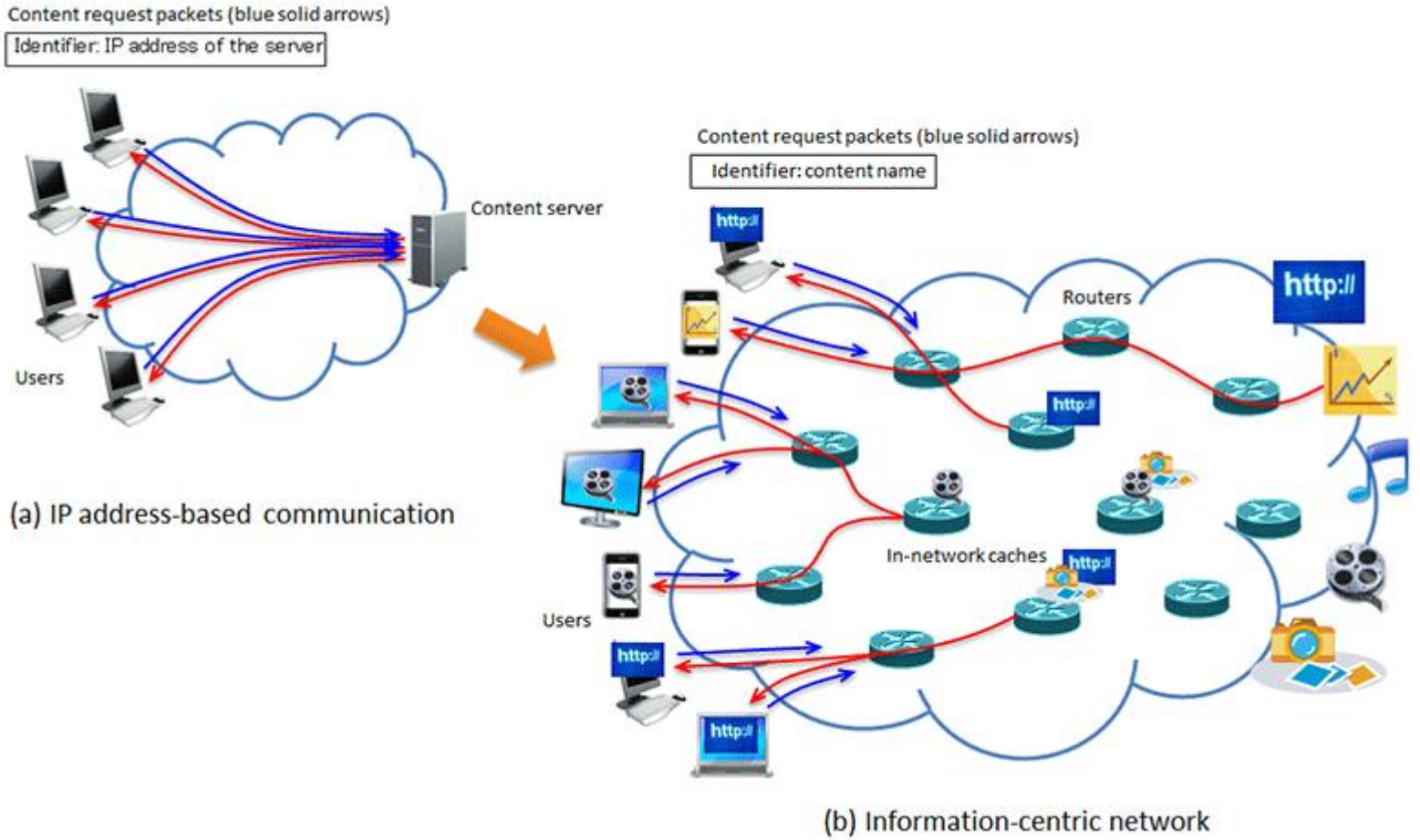
Fog computing

- Term created by Cisco
  - Extending cloud computing to the edge of an enterprise's network
  - Can be considered an definition of edge computing



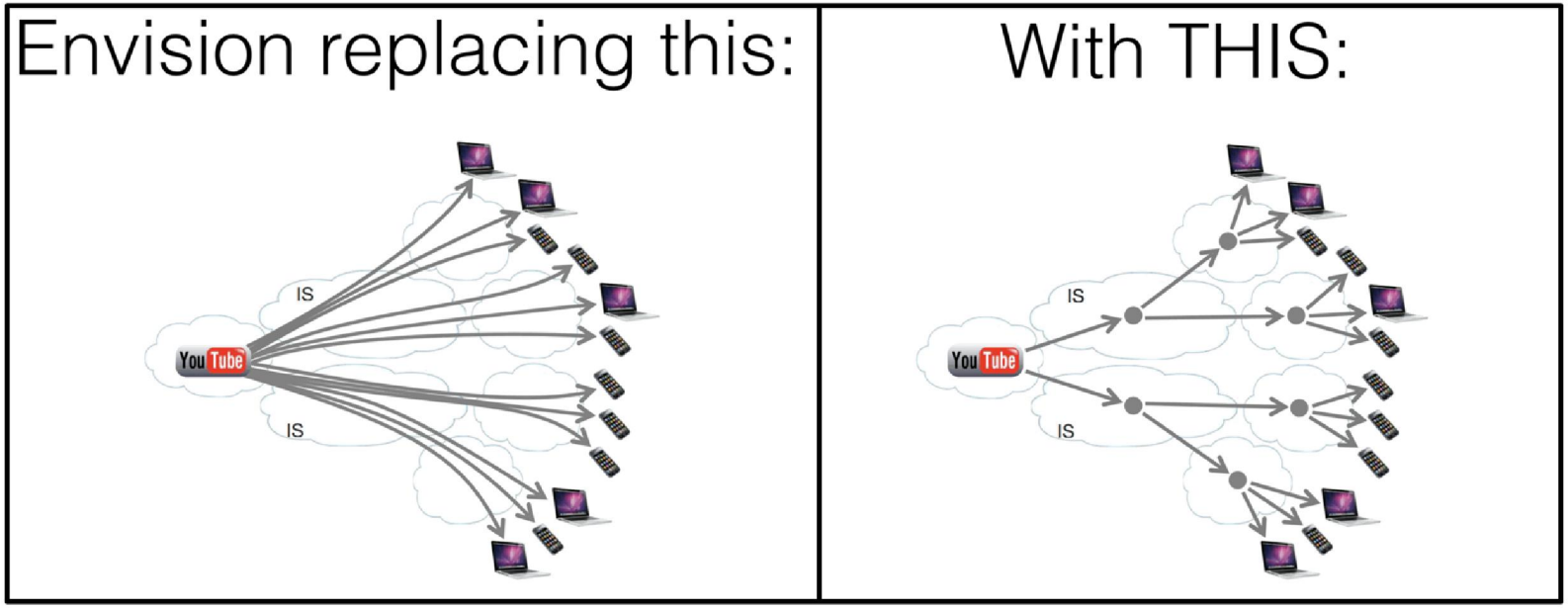
Information centric-networking

- From IP addresses to contents!



Caching technology

- **One major aspect of information centric networking**
  - Use of caches to reduce traffic



The future of 5G?

- **Not yet finished**
- **But when it is, it should be enough for quite a while**
  - Good speed
  - Good coverage
  - Good for the current mobile services

Mobile data analytics

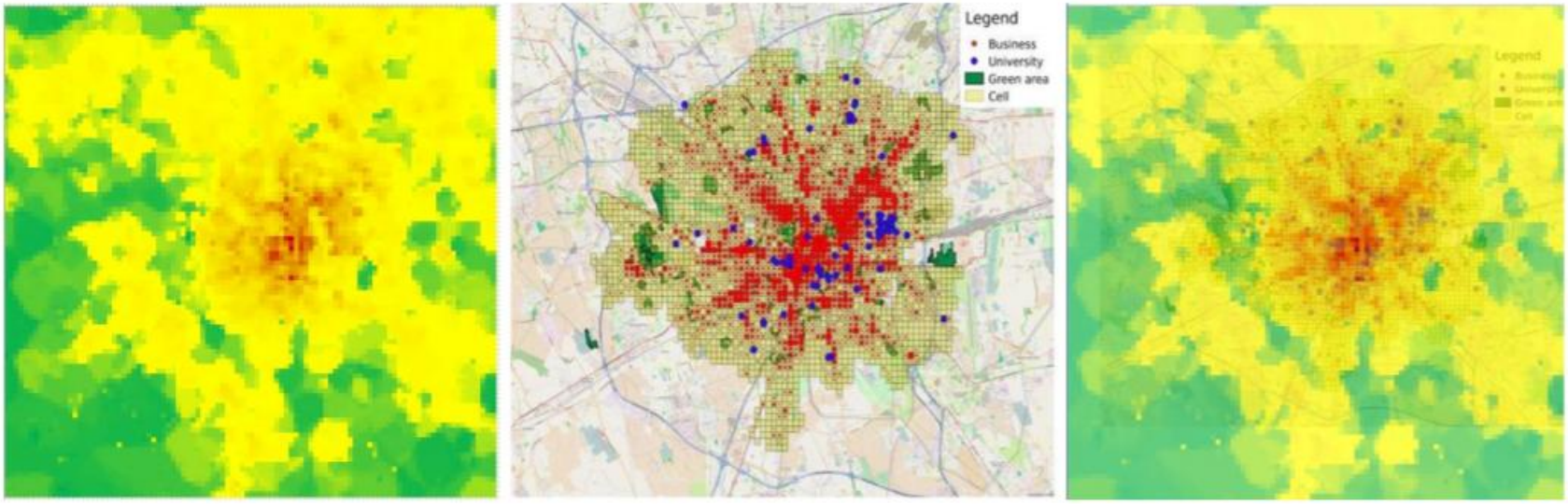
Why is mobile data analysis important?

- **Information of human behavior from mobile data usage logs is:**
  - Not just random, it hides valuable information regarding our behavior
  - These information can greatly influence our lives in the future
- **Abundant already in 4G/LTE providers**
  - Bound to increase with IoT, 5G

An example of mobile data analytics

- **A brilliant work done by my previous student**
  - A dataset of Milano, Italy

- **Challenge question**
  - What can you derive from this? (Many, many things!)



Logistics & urban planning

- **Movement of individuals, planning transportation & utilities**

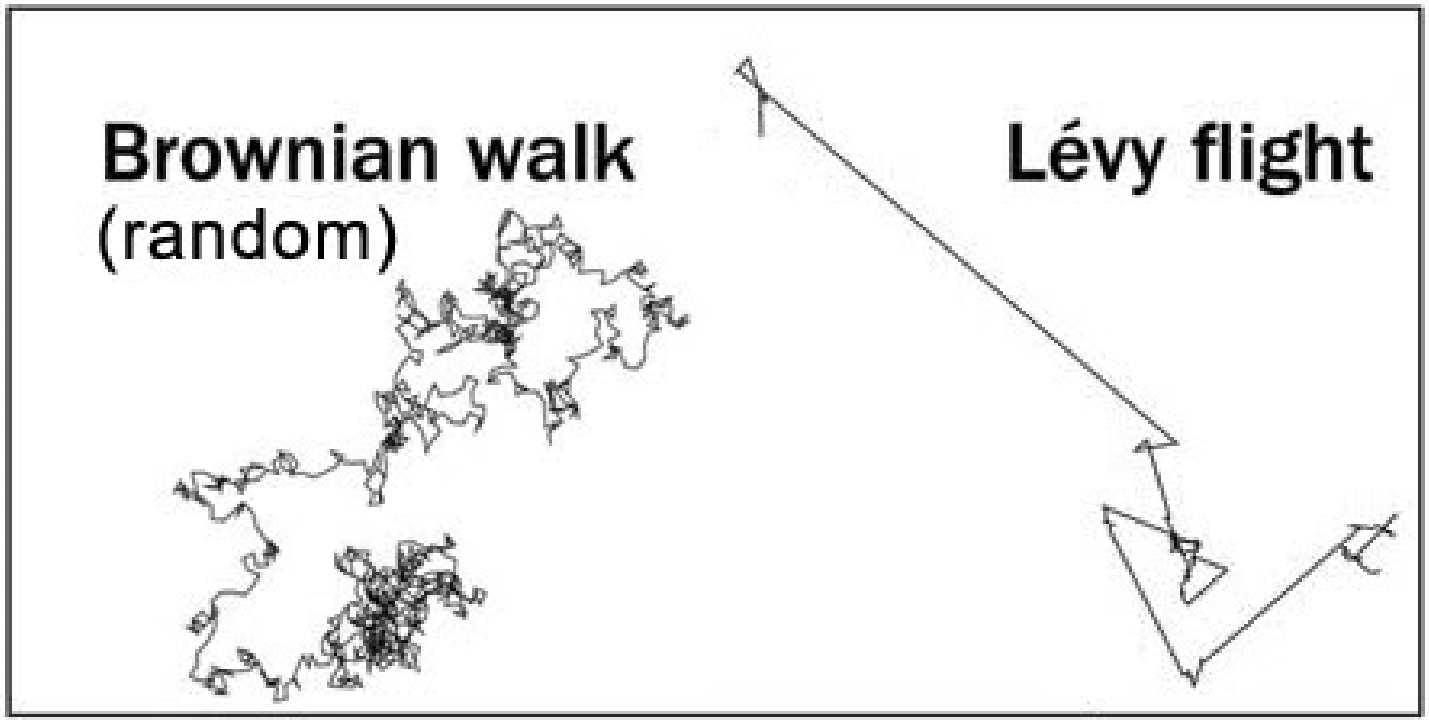
- **Human Mobility**
  - Fundamental mobility laws of human
  - High-level regularity in human movement [1]
- **Transportation**
  - Analysis of transportation methods and traffic congestion [2]

Logistics and urban planning

[1] "Understanding individual human mobility patterns," Natur
[2] J. Schlaich, et al., "Generating trajectories from mobile phone data," TRB Meeting

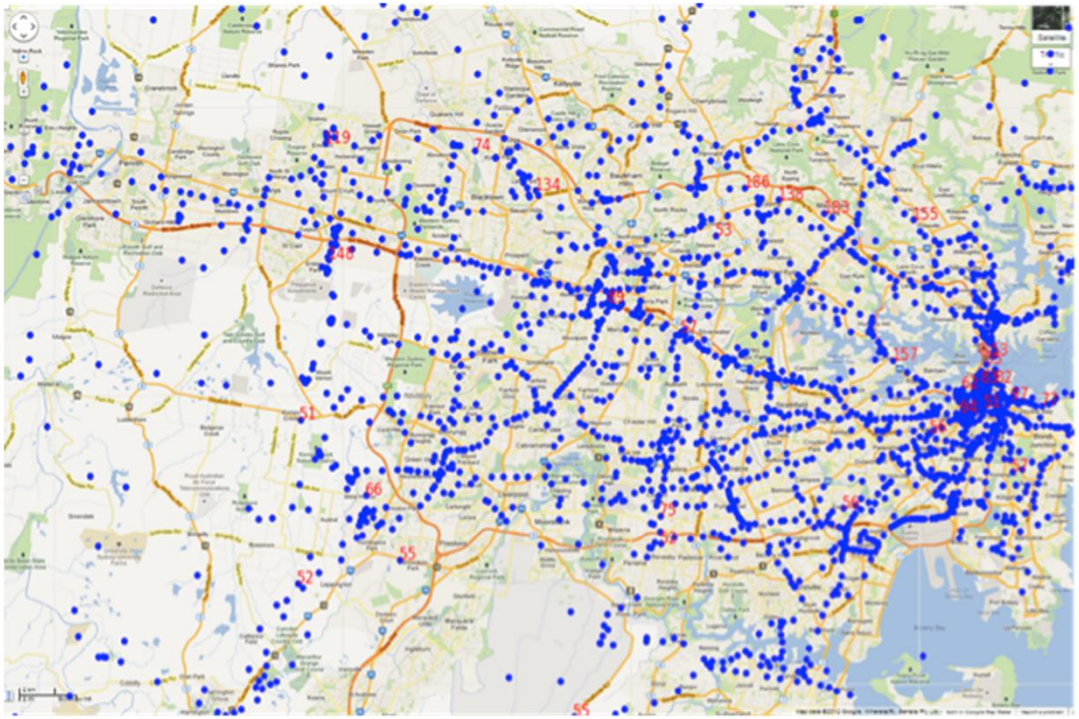
About human mobility?

- **Predicting people's movement by tracking their phone usage**



About transportation?

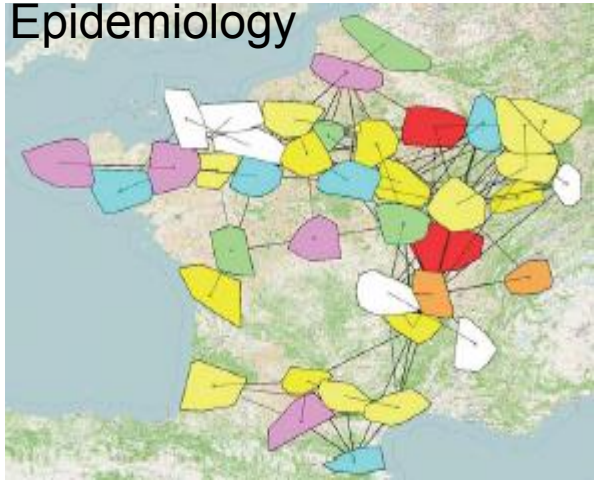
- **People don’t just move anywhere they want**
  - Follow trajectories



Human behavior

- **Analysis of social behavior derived from demographics study**
- **Interactions between users**
  - Analysis of caller-collee relationship [3]
- **Epidemics**
  - Mobility of masses of individuals
  - Malaria diffusion [4]

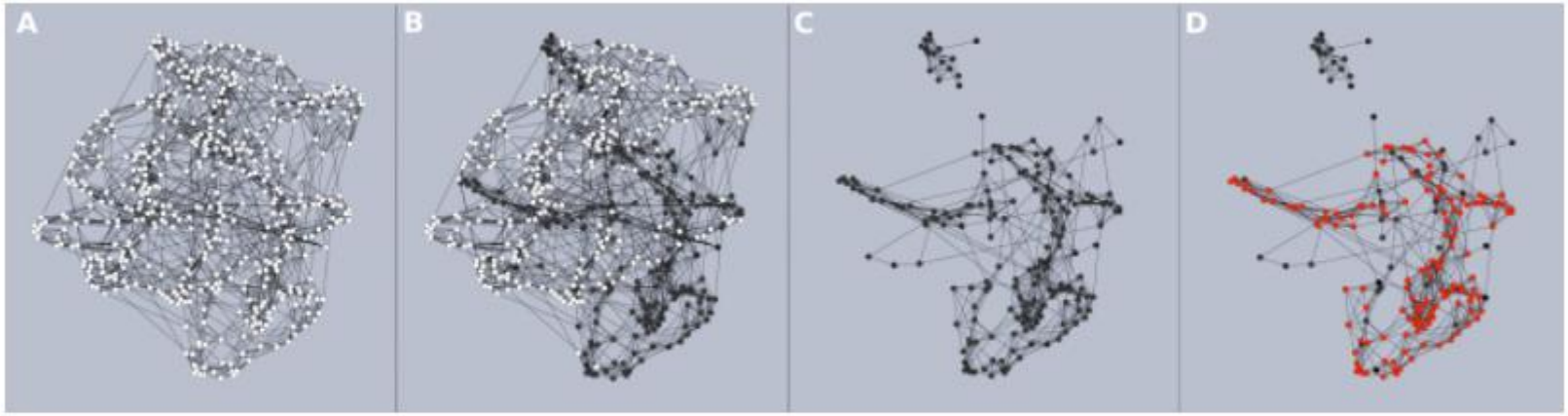
Human Behavior, Epidemiology



[3] A. Nanavati, et al., “On the structural properties of massive telecom call graphs:
s,” ACM CIKM, 2006..
ntifying the impact of human mobility on malaria,” Science,
2012

Epidemiology?

Social Networks & Epidemiology



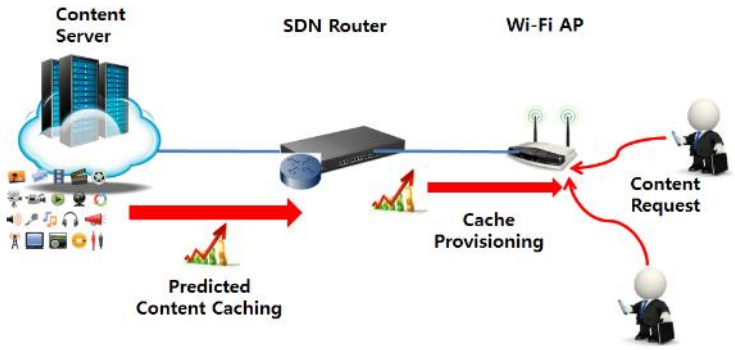
Social networks affect the spread of diseases in two major ways. **First**, social networks are the road systems on which pathogen traffic occurs. Since most diseases are directly transmitted from person to person, the web of such contacts forms the social network that is relevant for the spread of an infectious disease, and it is highly dependent on the specific tranmission route of the disease causing organism. **Second**, social networks are also relevant for the diffusion of health behaviors such as vaccination.

https://salathelab.epfl.ch/page-124950-en.html

Application in networking

- **Improve the performance of the network itself**
- **Analysis of aggregate network usage**
  - Spatial, time diversity in call profile according to eNodeBs [5]
- **Application in networks**
  - Work focused on handoff, resource allocation, energy efficiency, etc.

Application in Networking



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To conclude...

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Just a simple part of technological blocks

- There are many more interesting, important aspects in IoT worth mentioning

Any Questions?