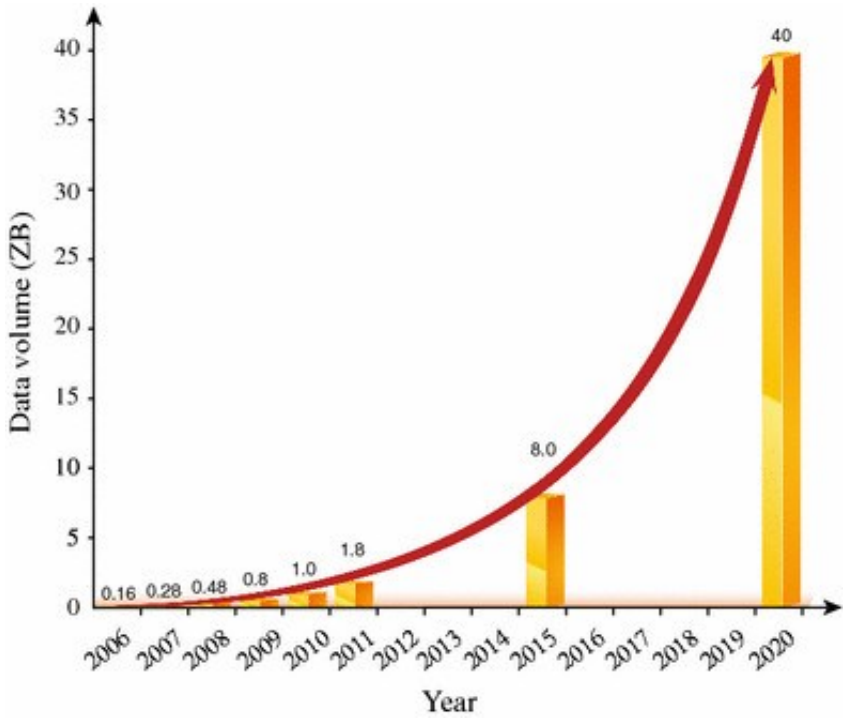
IoT and Big Data

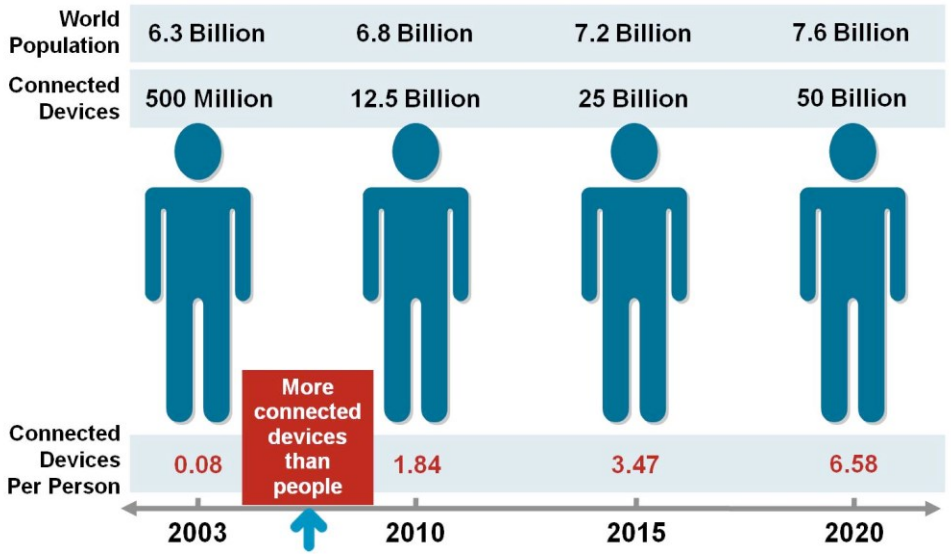
New Challenges and Architectures

Francesco Palmieri

Under the data deluge…

- In 2018 we produced more data than in the previous 5000 years of human history
- Who enabled this phenomenon?



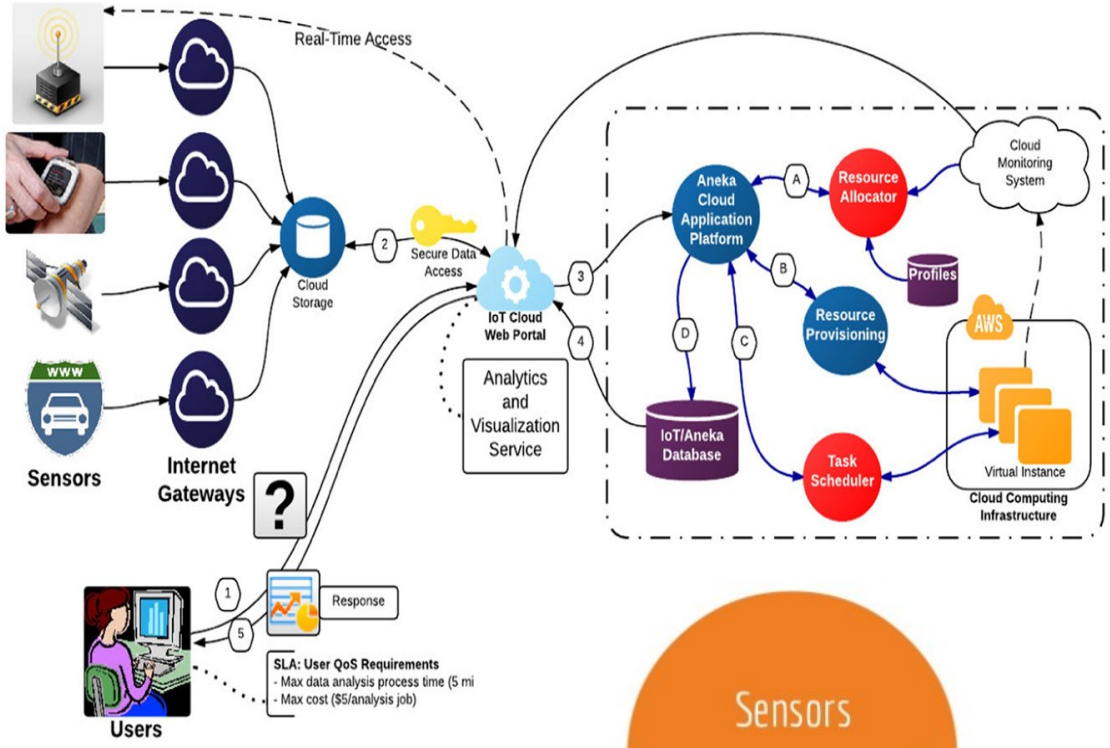


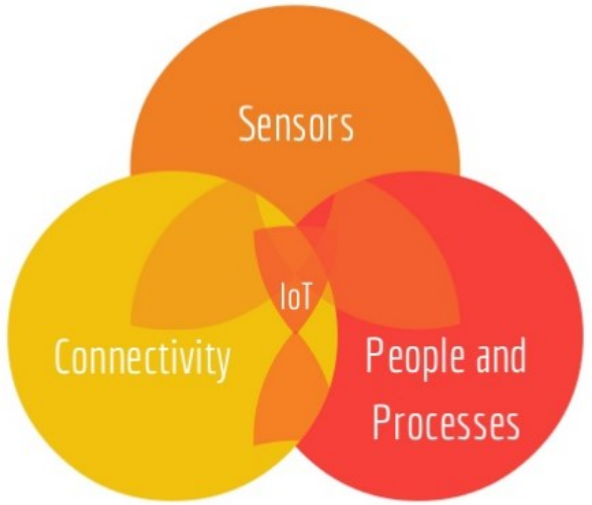
1. Richard Harris, More data will be created in 2017 than the previous 5,000 years of humanity, App Developer Magazine, December 23, 2016

… the 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 (IoT).
- A Thing may be a sensor or actuator. It may be able to execute computations and or communicate over wired or wireless interfaces.
- A Thing may be tagged (passive) or connected.

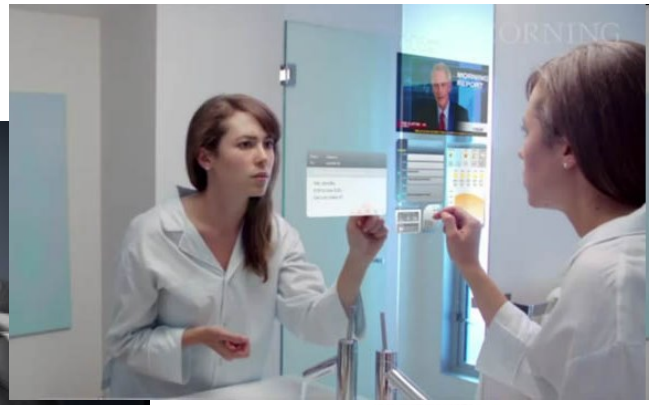
Definitions from “Building the Web of Things” Guinard and Trifa





New active “Things” are being connected

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







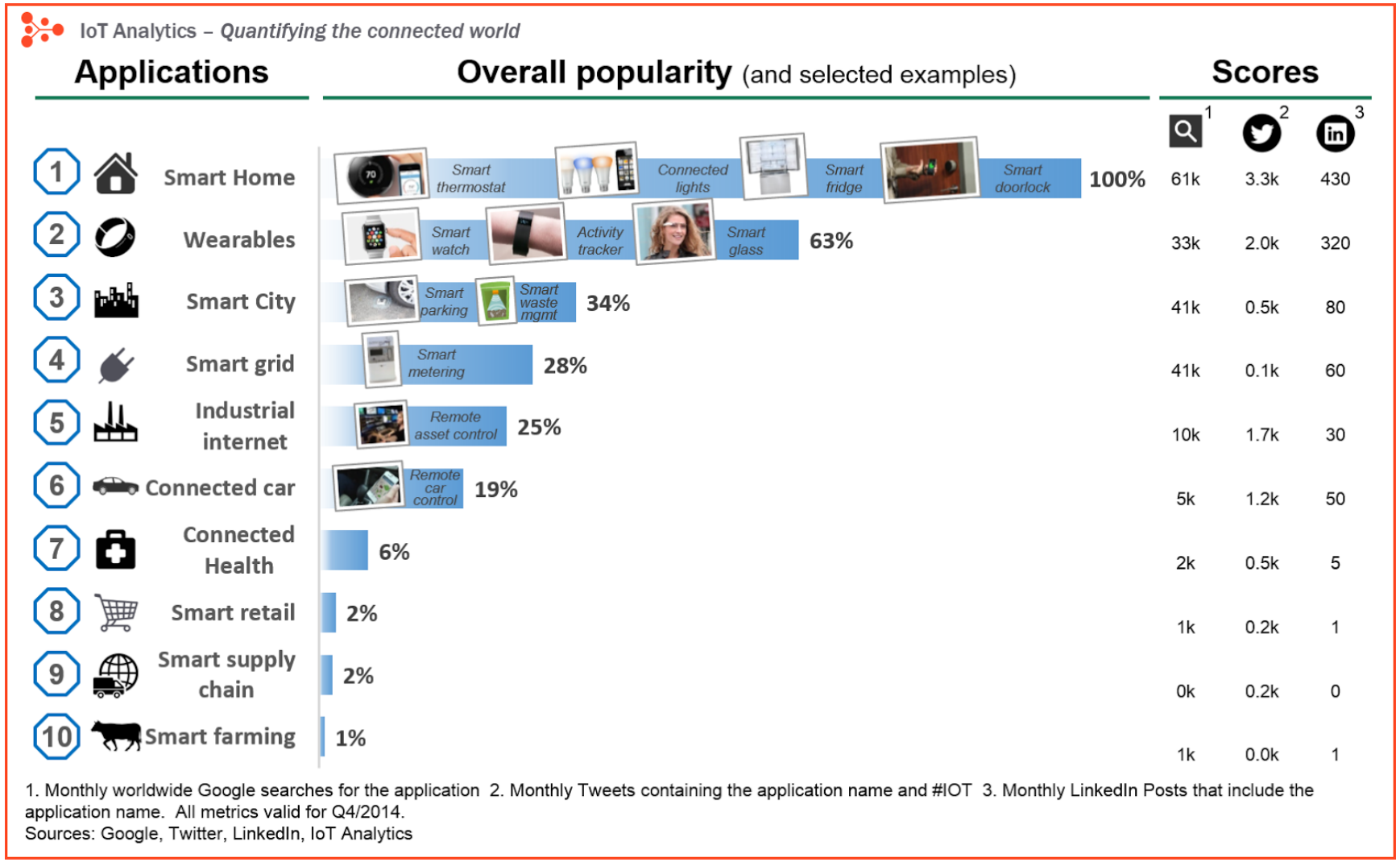


But also «passive» ones…

NFC

Pay

Application environment

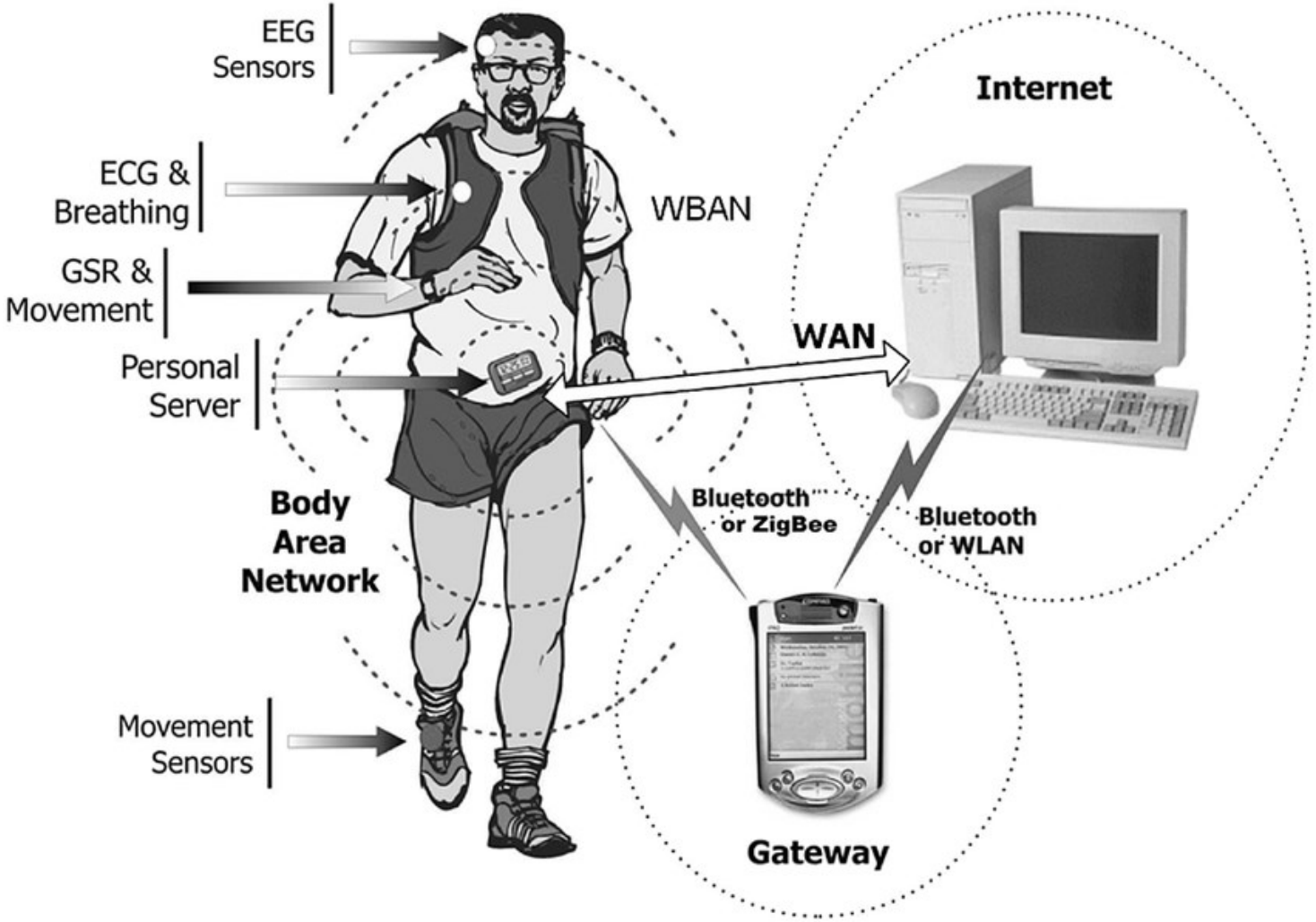


Smart homes and smart cities

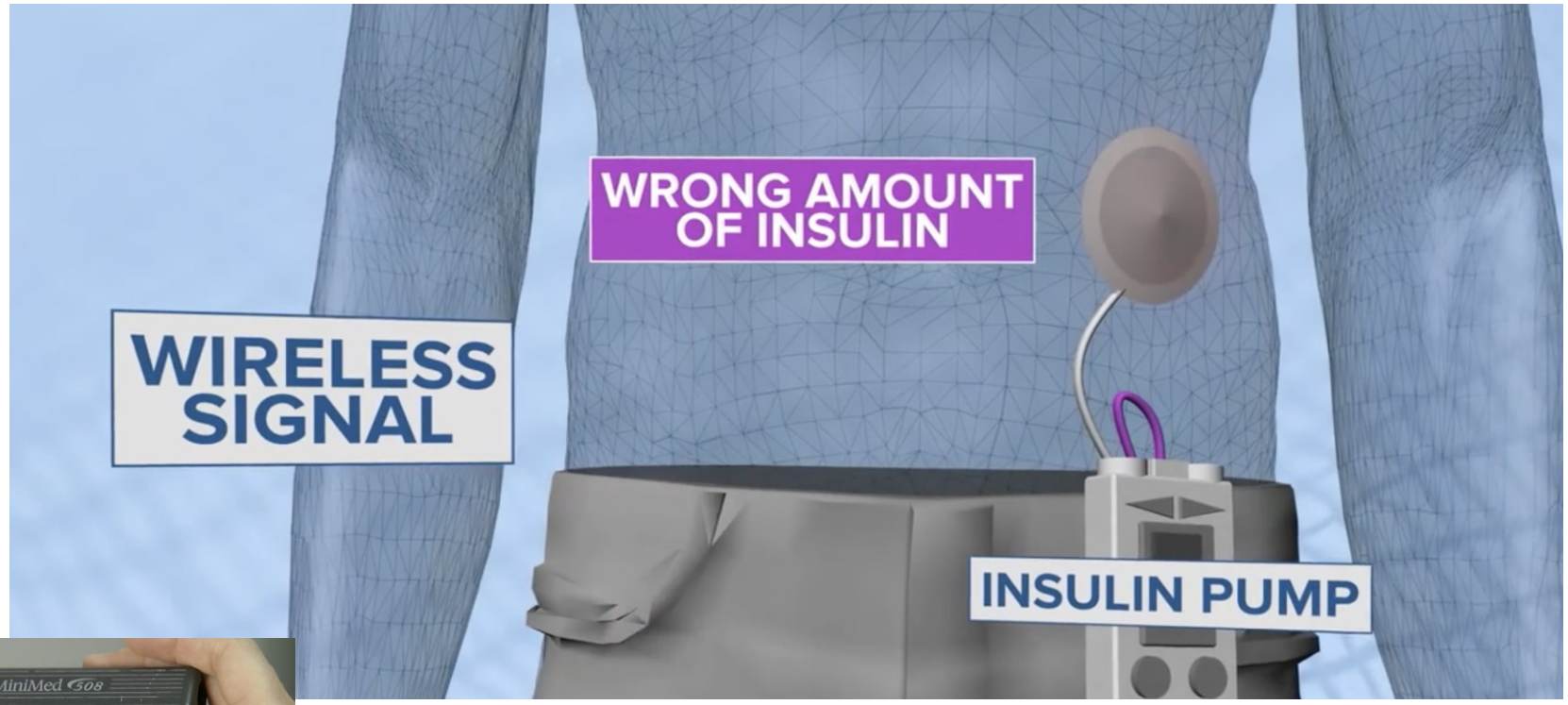
- **Smart Home Applications**
  - Remote Control
  - Monitoring and Sensing
  - Security & Protection

- **Smaty City Applications**
  - VANETs
  - Fleet Management
  - Traffic Optimizartion
  - Emergency Management
  - Surveillance

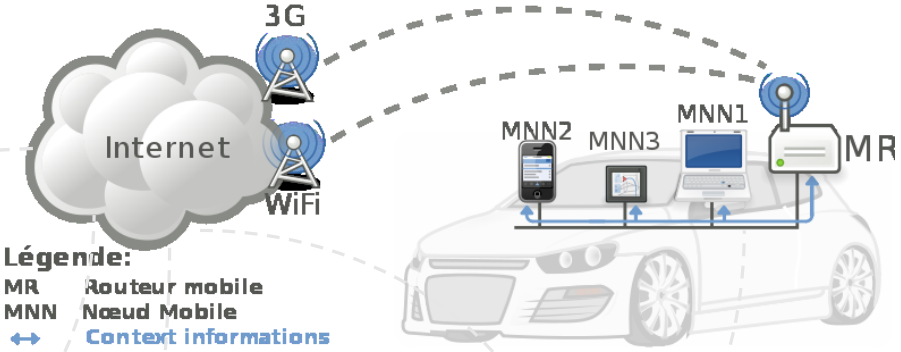
People Connecting to Things



… and Things Connecting to People



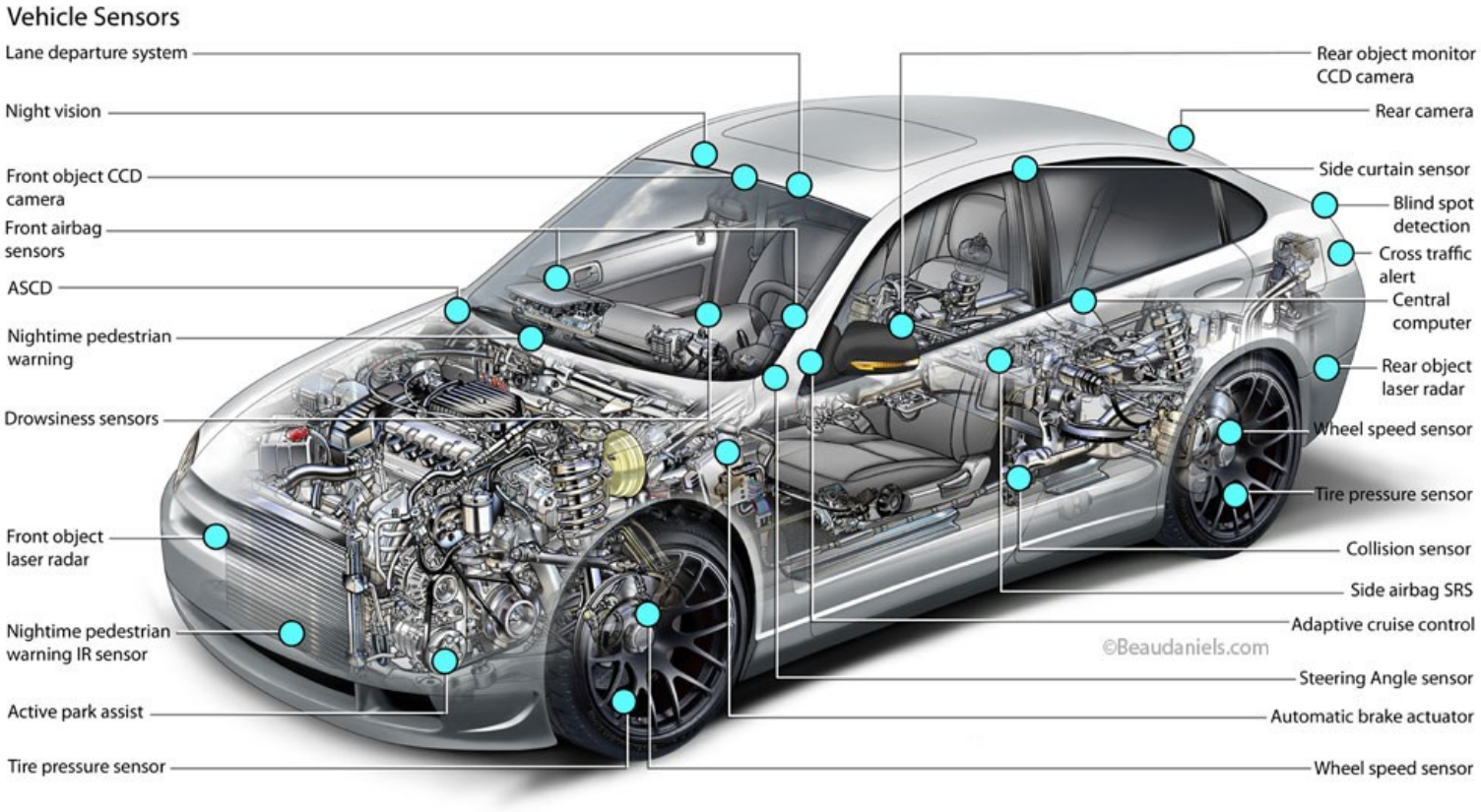
Things Connecting to Things



- Complex and heterogeneous resources
- Connected through wireless/wired networks
- Machine to Machine (m2m) communications

An example: modern cars

- economy car: more than 200 sensors (brakes, belts, air bags, doors, etc.)
- luxury car: more than 600 sensors (A/C, ABS, lights, radar, road conditions)
- Vehicle safety and comfort has improved via sensors and actuators



Another example: Google glasses

- The amazing internet connected glasses that contain a camera, microphone, display and will generally revolutionize the wearable device market

Another example: Luggage tracking

- monitor your luggage on air travel and text you when it arrives at the destination as well as how far it is from the luggage belt.

Another example: WiFi light bulbs

- energy efficient and wifi enabled light bulb that you can control from your smartphone – you can even change colours and mood

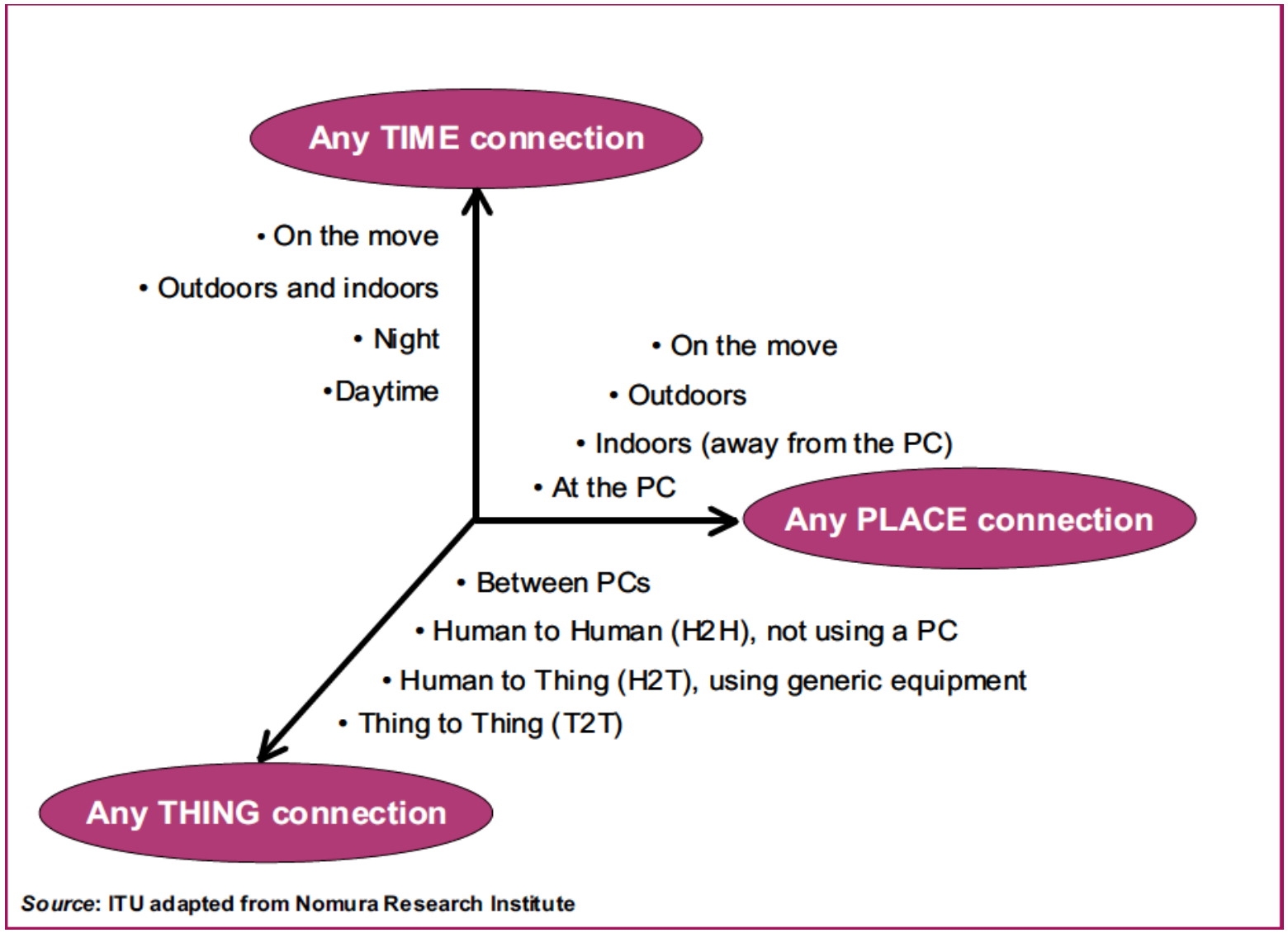
Another example: electronic fork

- Electronic Bluetooth connected fork that helps you monitor and track your eating habits

Another example: electronic thermostat

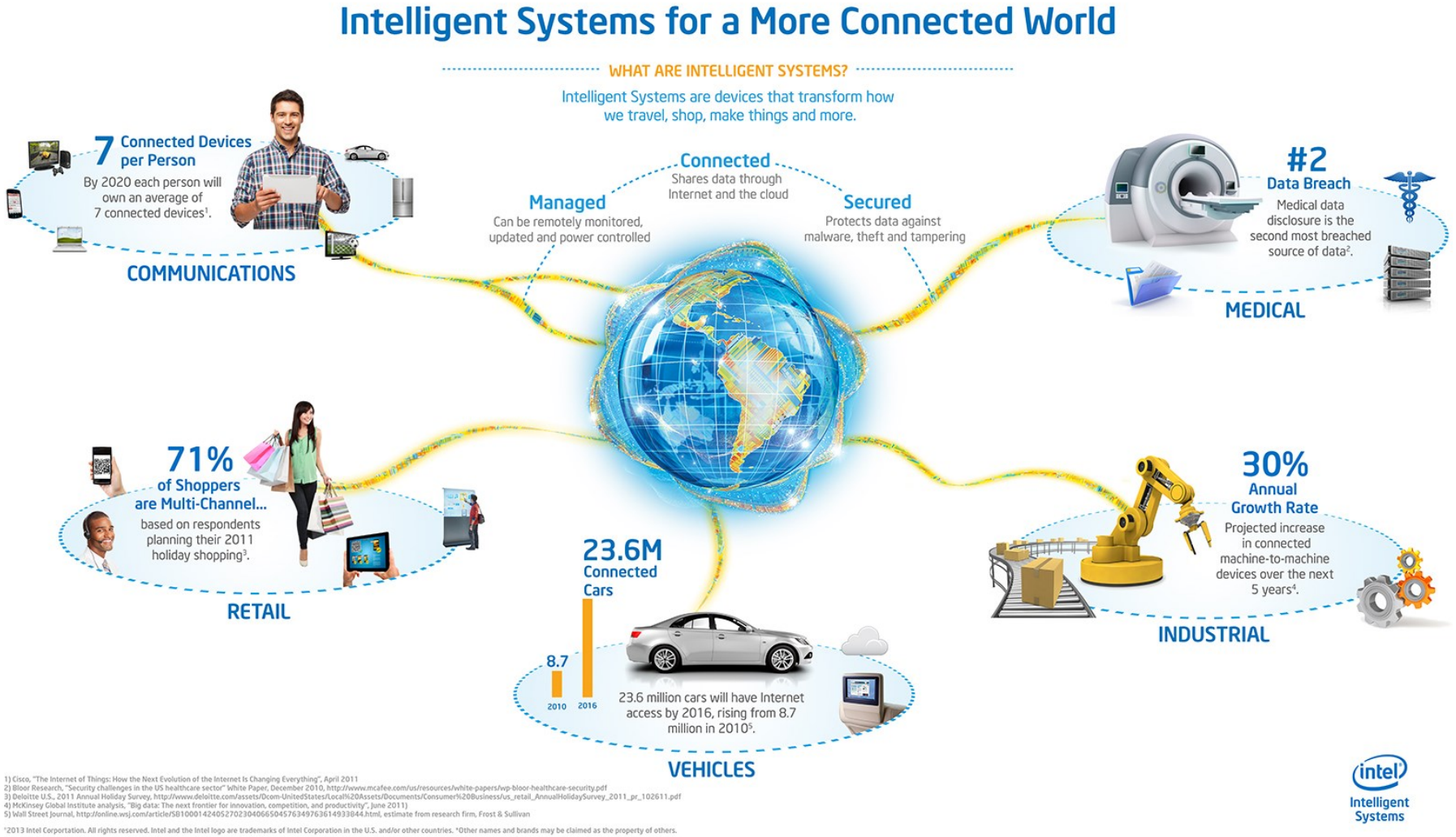
- A thermostat that will get to know you and learn from the way it is used to automatically adjust the temperature in your home

New Dimensions



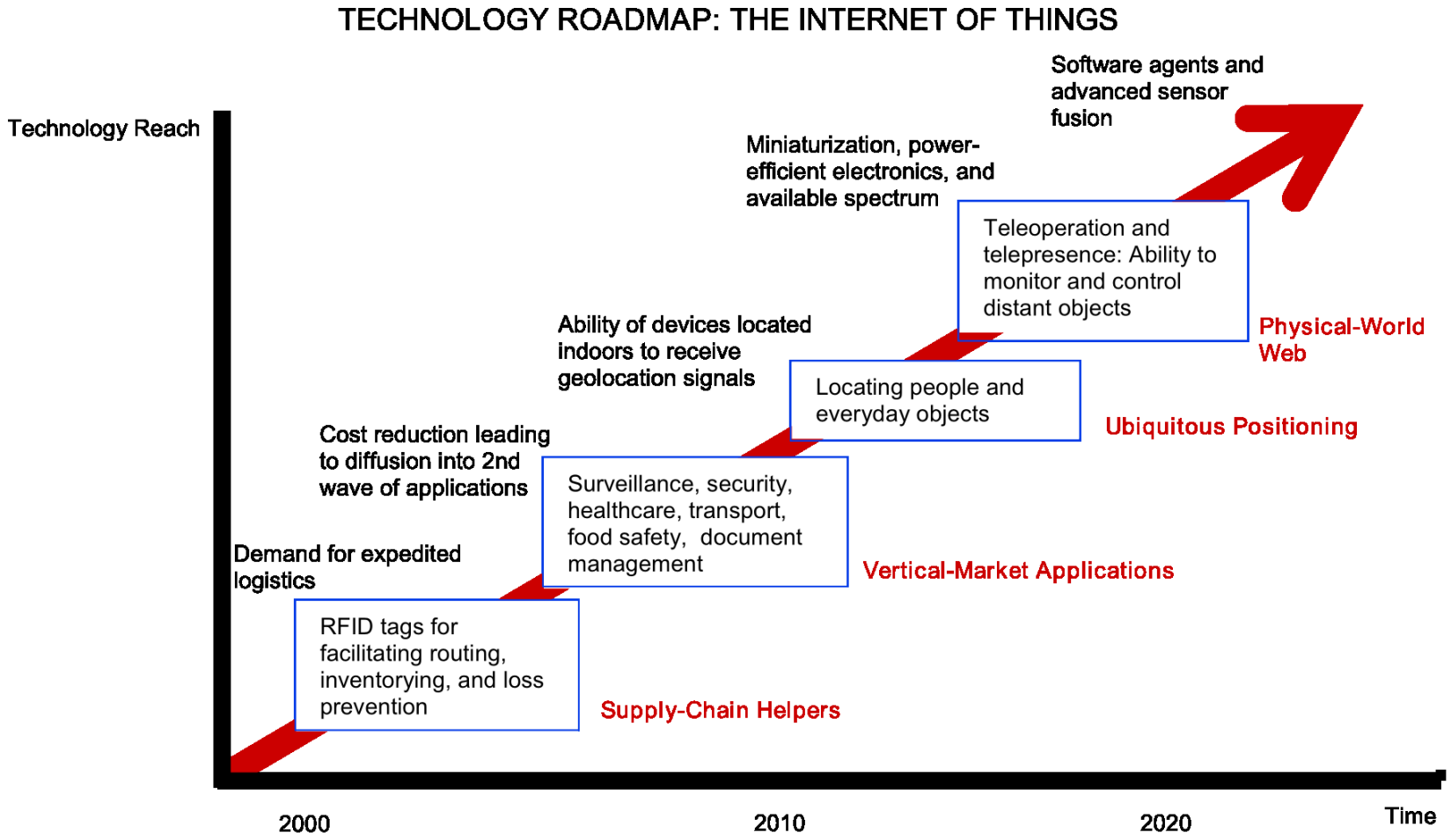
Source: ITU adapted from Nomura Research Institute

New Opportunities



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

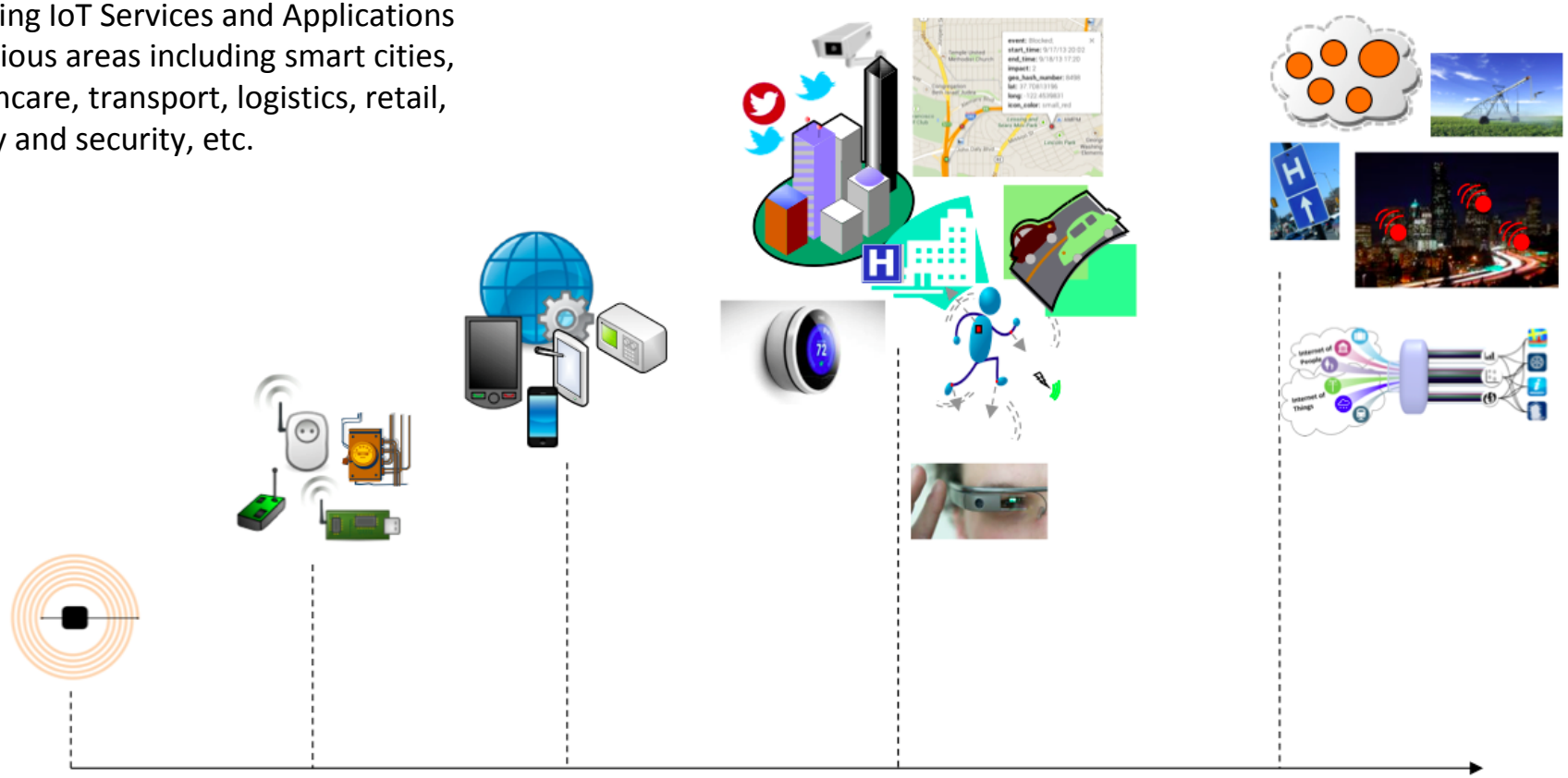
Technology trend



Source: SRI Consulting Business Intelligence

Internet of Things Evolution

Growing IoT Services and Applications in various areas including smart cities, healthcare, transport, logistics, retail, safety and security, etc.



1994~1999

RFID based solutions

early 2000

WSAN oriented, Distributed WSANs, Communication technologies, Smart meter …

mid 2000

Smart Devices/ Web-enabled Apps/Services, initial products, vertical applications, concepts and demos, …

~2010

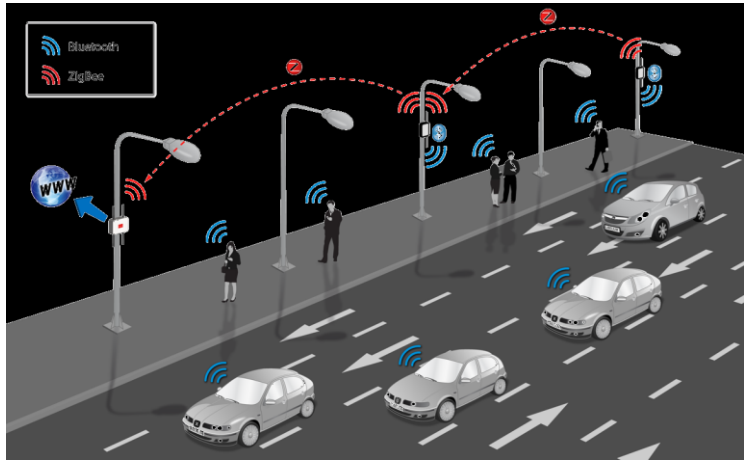
Physical-Cyber-Social Systems, Linked-data, semantics, More products and services (e.g. Smart Buildings), more heterogeneity, control and monitoring applications, …

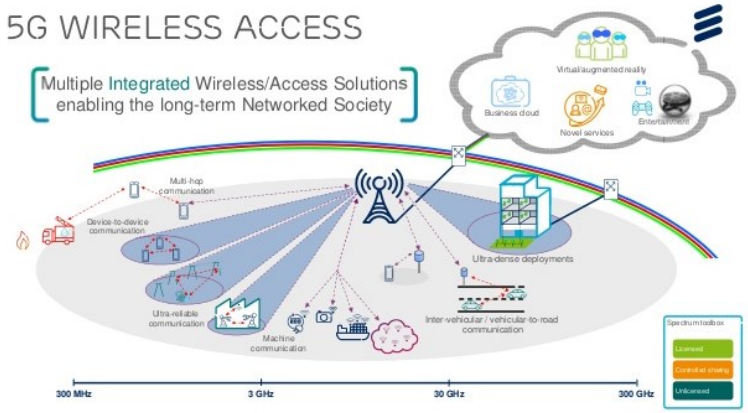
~2020

Cloud platforms, Big (IoT) Data analytics, Mature IoT applications with actionable information, Multimodal fusion and intelligent data processing, Enhanced cellular/ wireless com. for IoT, Operational use-cases and commercial services/ applications, more Standards…

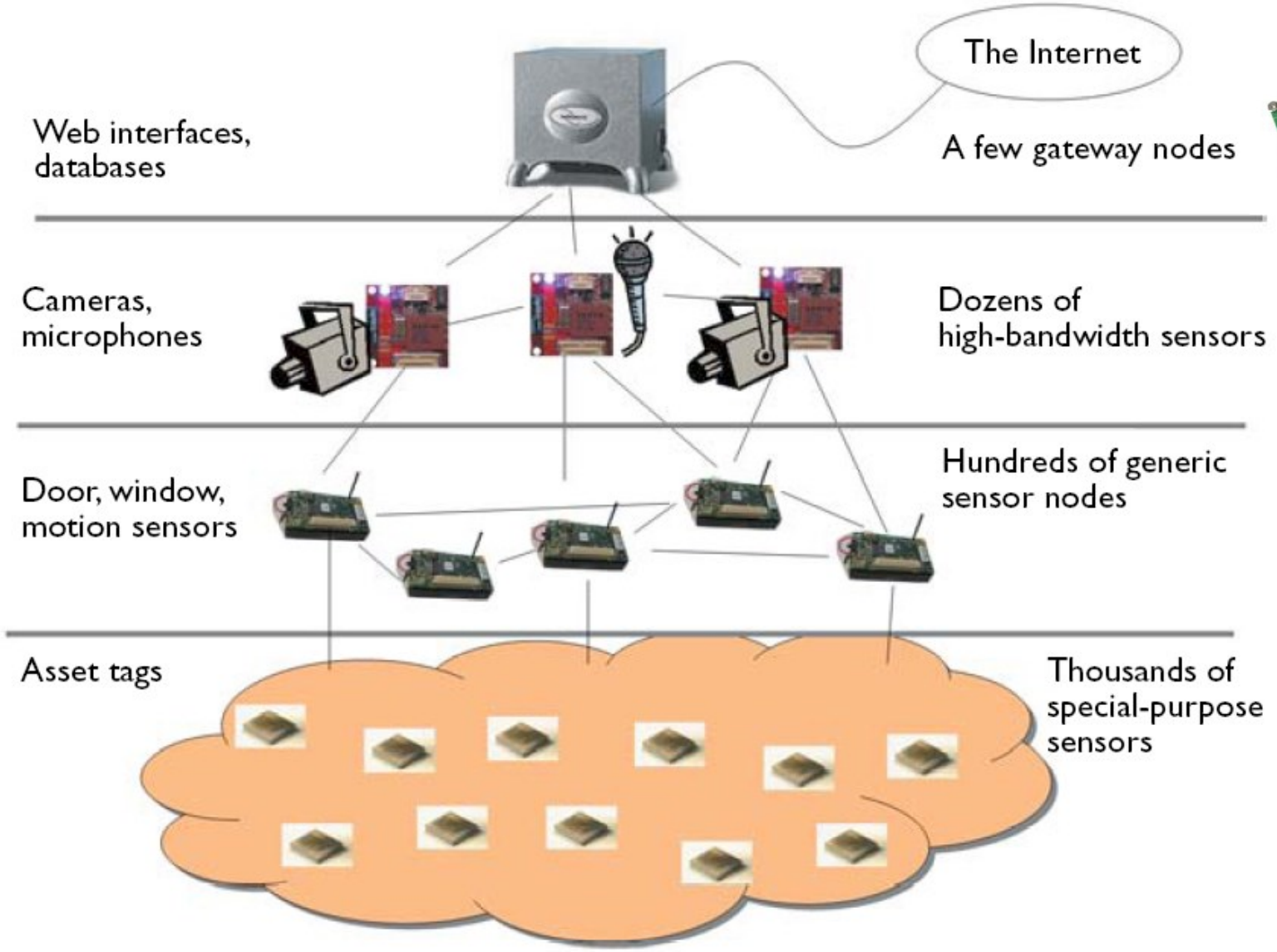
Networks Assume Paramount Importance

- The Roles of Networks
  - Managing nodes (discovery, join, leave, etc).
  - Relaying data packets from the source to the destination node
- RF-based Network in IoT is usually Wireless Multi-hop:
  - Wireless Sensor Networks (WSNs)
  - Mobile Wireless Ad hoc Networks (MANETs)
  - Wireless Mesh Networks (WMNs)
  - Vehicular Ad Hoc Networks (VANETs)
- Main concern: Reliability & Performance





The IoT ecosystem

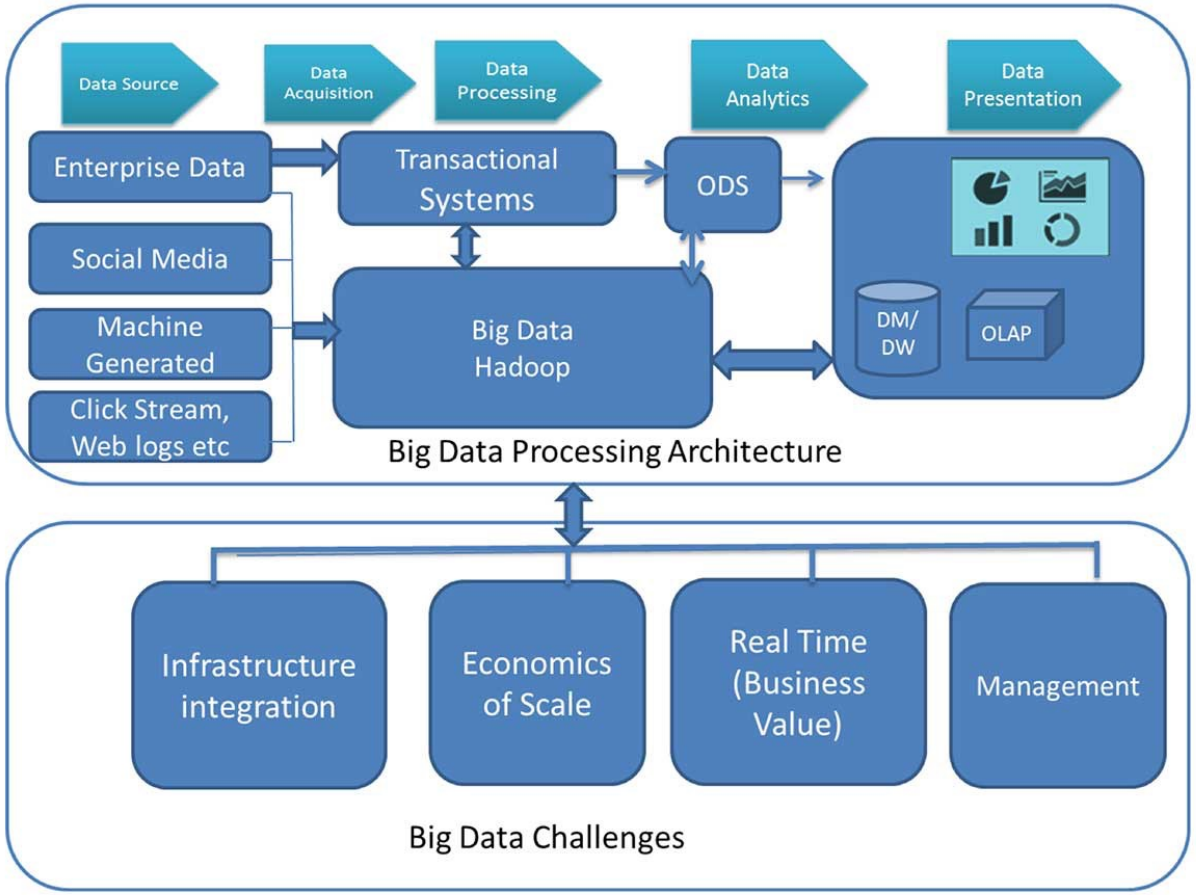


Stargate

- 802.11a/b
- Ethernet
- Mica2
- PCMCIA
- Compact-flash
- USB
- JTAG
- RS232

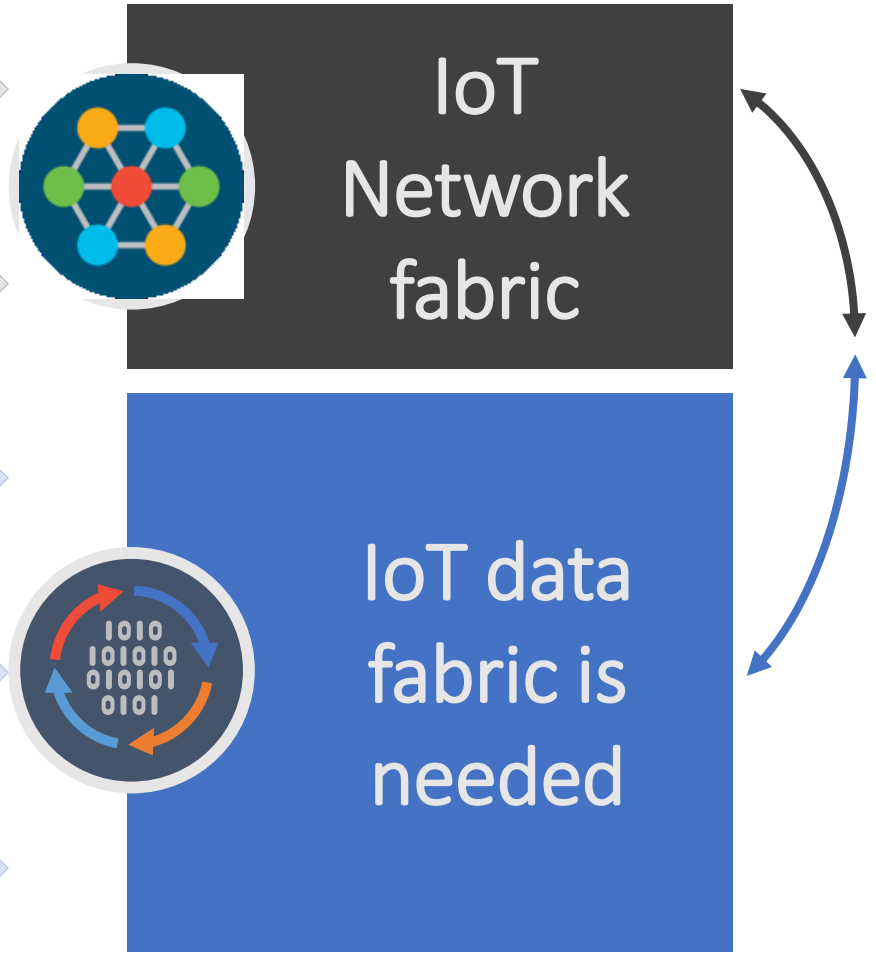
IoT Data Challenges

- Multi-modal and heterogeneous
- Noisy and incomplete
- Time and location dependent
- Dynamic and varies in quality
- Crowed sourced data can be unreliable
- Requires (near-) real-time analysis
- Privacy and security are important issues
- Data can be biased- we need to know our data!



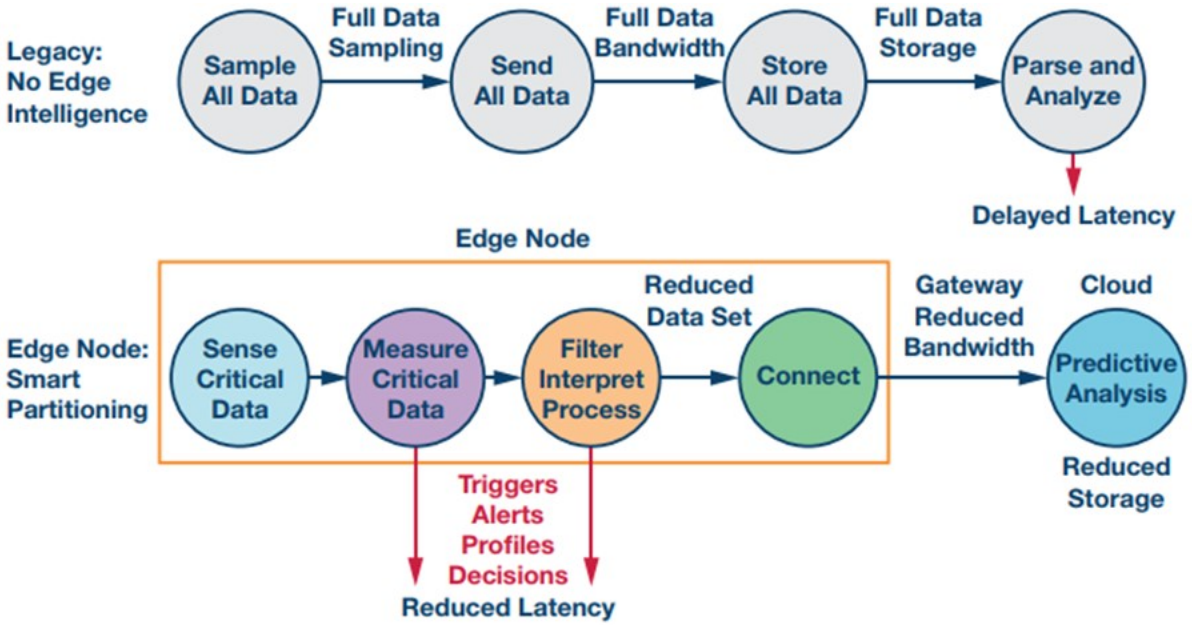
IoT data Challenges

- Interoperability: various data in different formats, from different sources (and different qualities)
- Discovery: finding appropriate device and data sources
- Access: Availability and (open) access to resources and data
- Integration: dealing with heterogeneous device, networks and data
- Scalability: dealing with myriad of data and computational complexity of interpreting the data.



Data processing in IoT

- Turn terabytes of data created each day into analytics related to different events/occurrences or relate them to products and services.
- Convert (billions of) smart meter readings to better predict and balance power consumption.
- Analyze thousands of traffic, pollution, weather, congestion, public transport and event sensory data to provide better traffic and smart city management.
- Monitor patients, elderly care and much more…
- Requires: real-time, reliable, efficient (for low power and resource limited nodes), and scalable solutions.



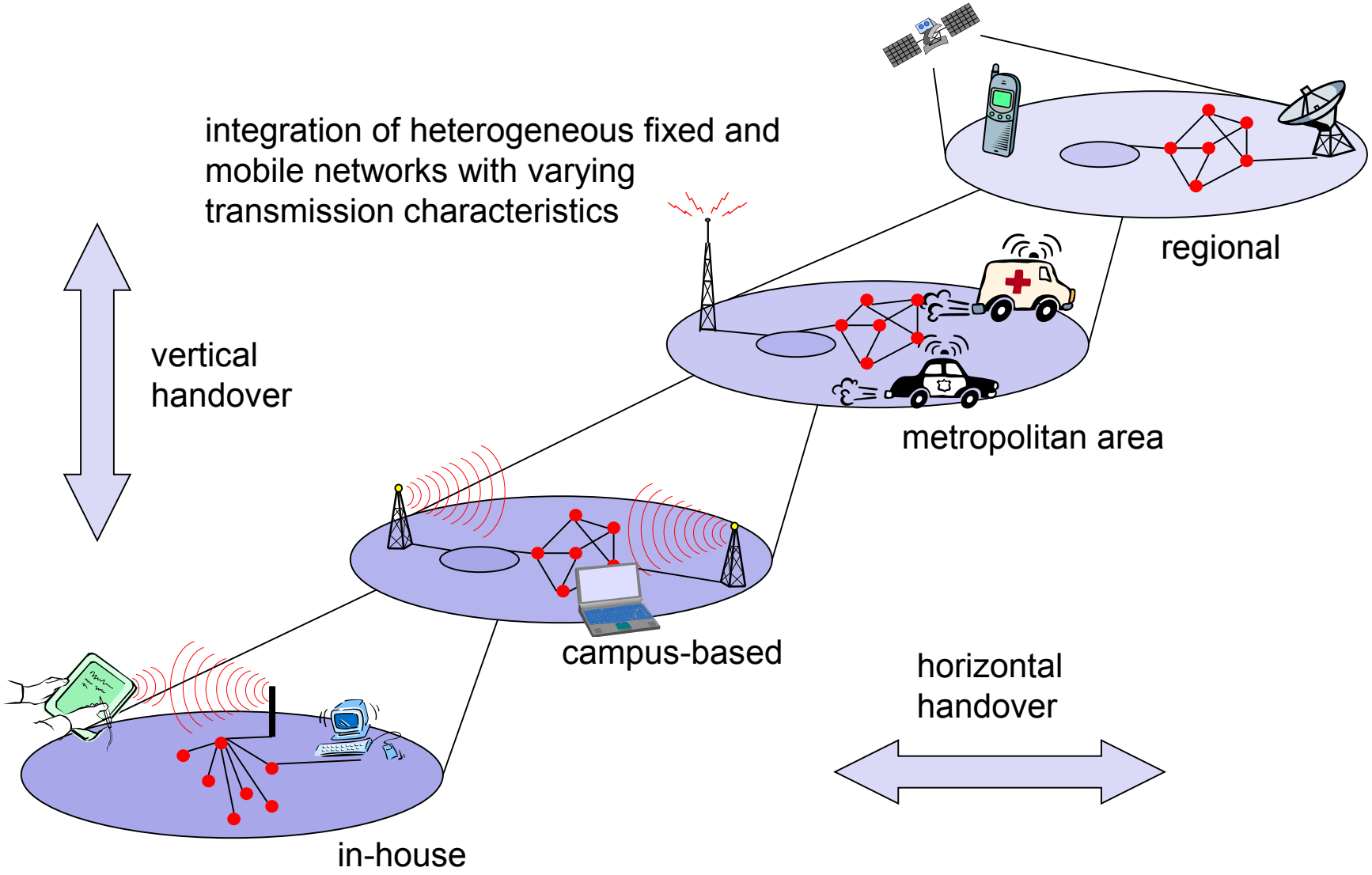
The Need for Integration: Computation

- Things have limited computational and energy resources
  - on-site processing not feasible on site
  - *aggregation nodes* are needed
- Cloud enables
  - task offloading and energy saving
  - scalable, real-time, sensor-centric applications
  - data-driven decisions
  - AI, ML, prediction algorithms

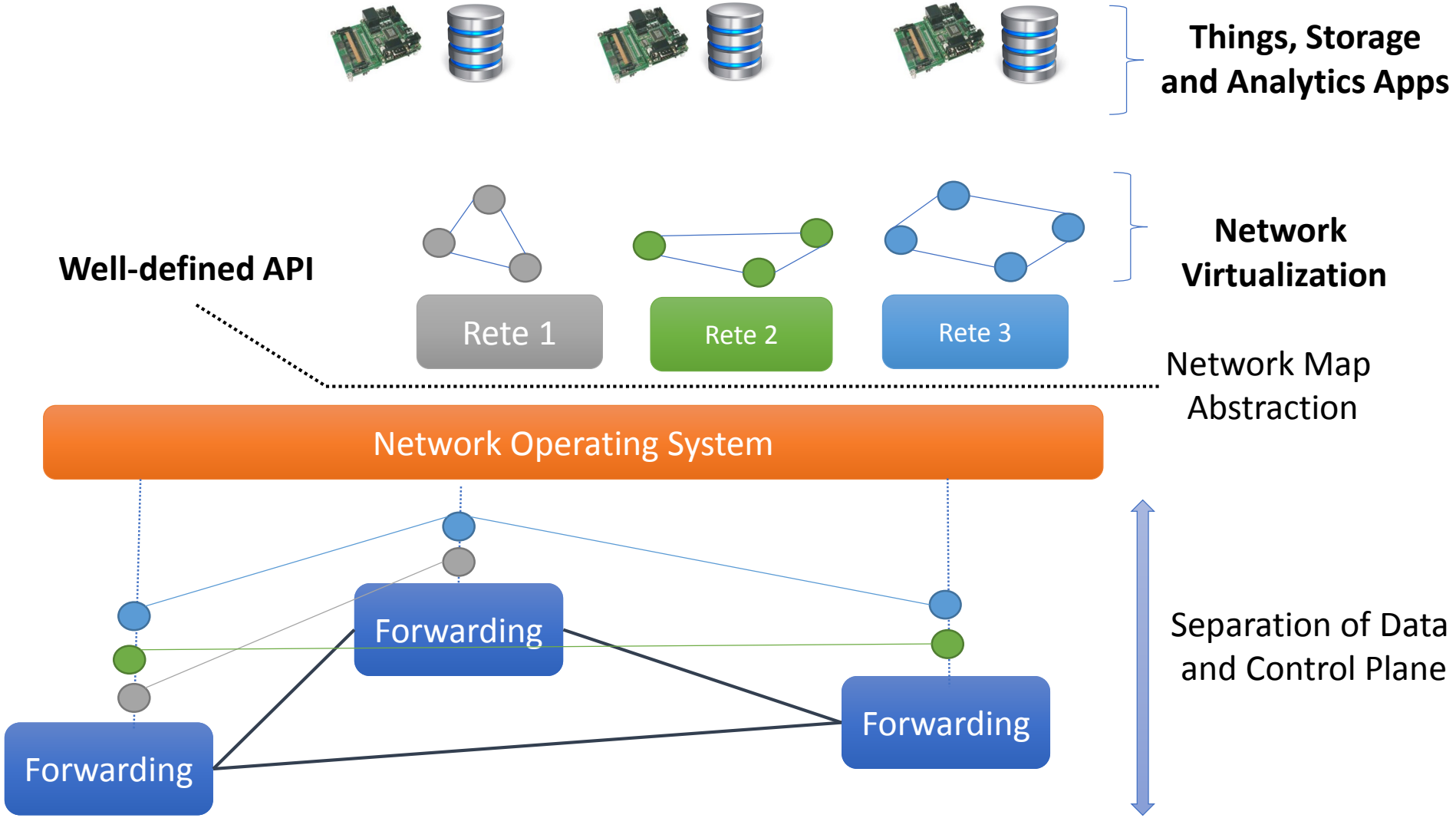
The Need for Integration: Storage

- IoT involves
  - a large set of information sources
  - a huge amount of non-structured/semi-structured (BIG) data
  - the need for *collecting*, *searching*, *accessing*, *sharing*, *visualizing* this data
- Cloud is the most convenient and effective solution to accomplish these tasks

The Need for Integration: Overlay Networks

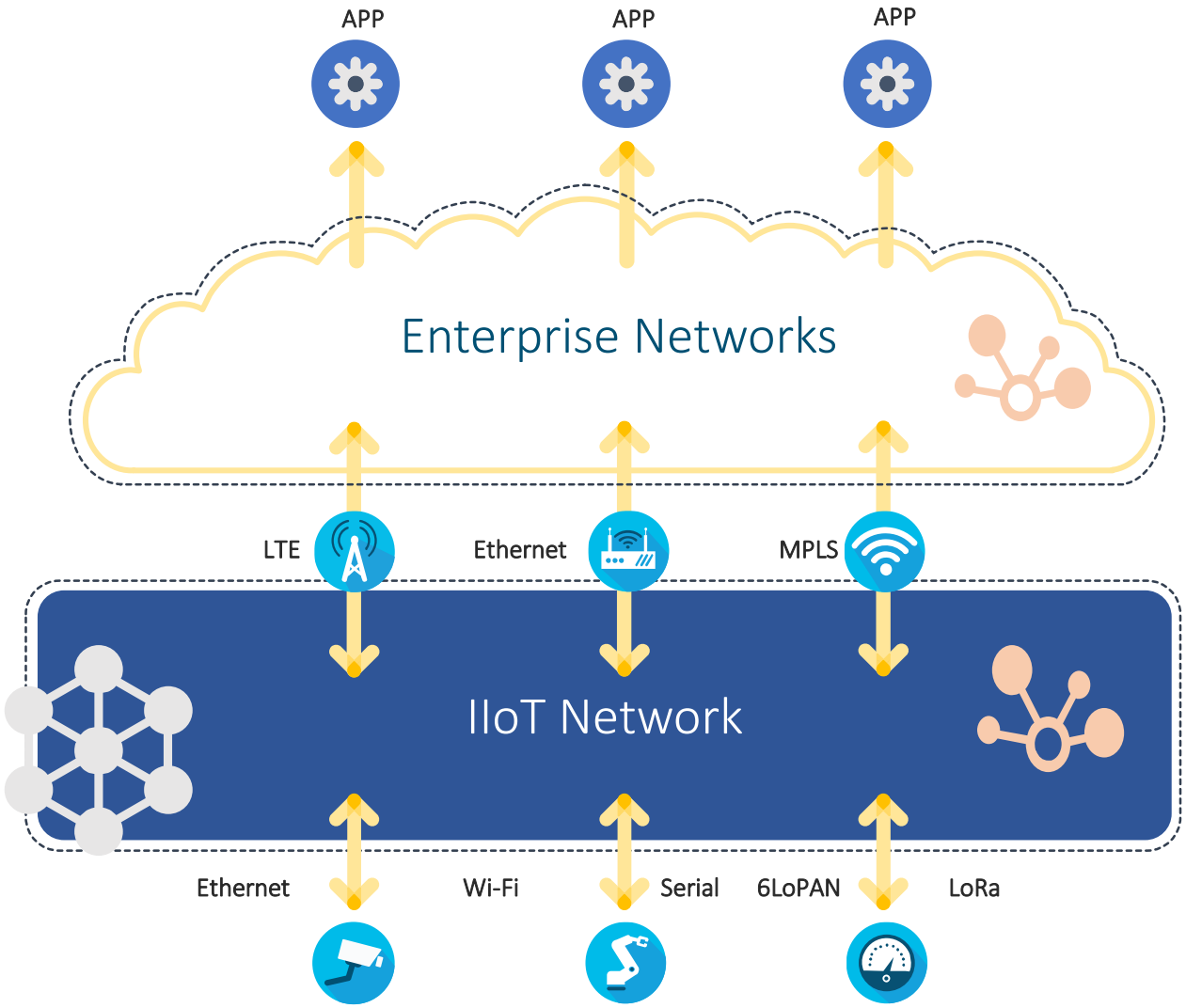


Overlay through SDN and slicing



Data-centric networking

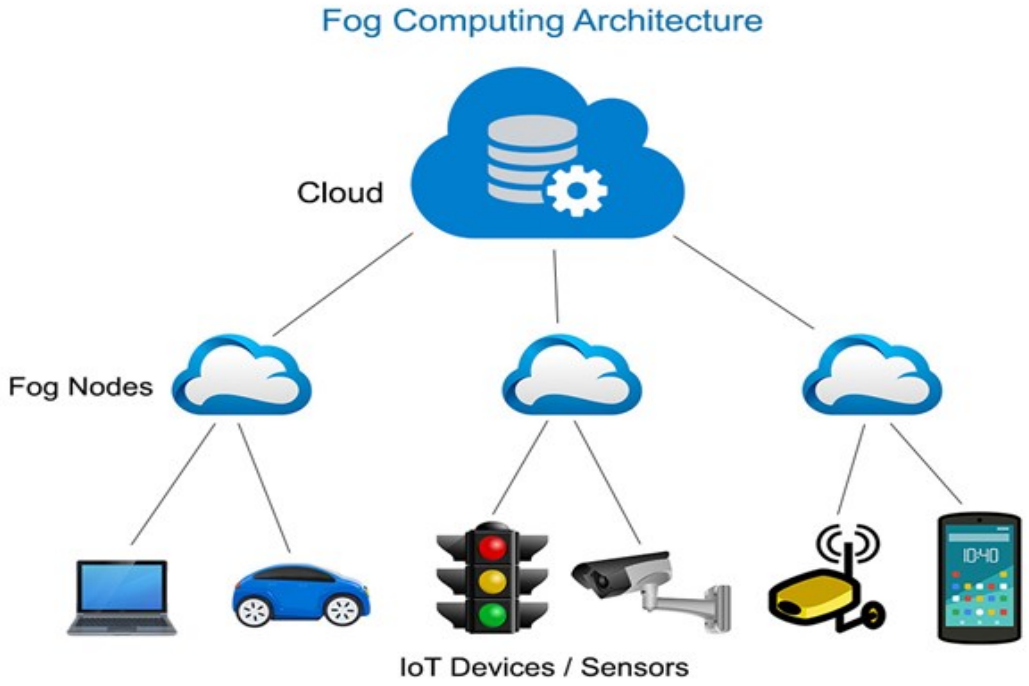
- In typical networks (including ad-hoc networks), network transactions are addressed to the identities of specific nodes
  - A “node-centric” or “address-centric” networking paradigm
- In a redundantly deployed sensor networks, specific source of an event, alarm, etc. might not be important
  - Redundancy: e.g., several nodes can observe the same area
- Thus: focus networking transactions on the data directly instead of their senders and transmitters; data-centric networking
  - Specially this idea is reinforced by the fact that we might have multiple sources to provide information and observations form the same or similar areas.
  - Principal design change



Source: Protocols and Architectures for Wireless Sensor Networks, Protocols and Architectures for Wireless Sensor Networks Holger Karl, Andreas Willig, chapter 3, Wiley, 2005 .

In-network processing

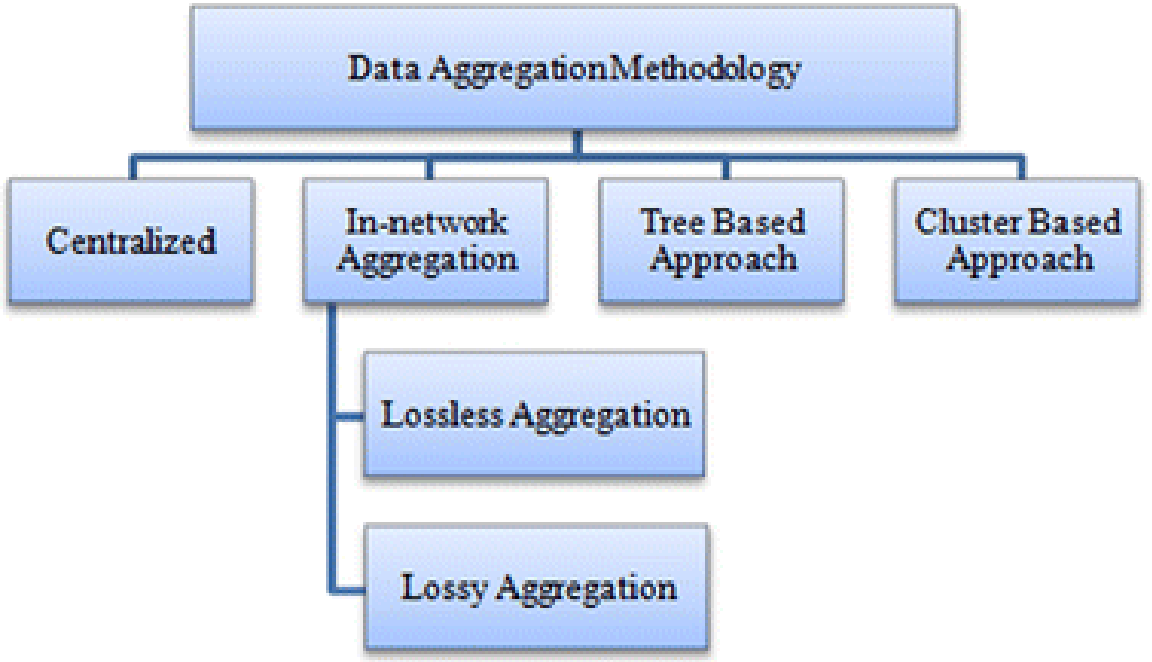
- Mobile Ad-hoc Networks can be seen as a set of nodes that deliver bits from one end to the other;
- IoT infrastructures on the other end, are expected to provide additional services within the network
  - Gives additional options
  - e.g., manipulate or process the data in the network
- Main example: fog-based aggregation
  - Applying aggregation functions on measurement data to:
  - Reduce number of transmitted bits/packets by applying an aggregation function in the network
  - Reduce the size of the data representation
  - Reduce Latency: delay time to compute and report the aggregated data



Source: Protocols and Architectures for Wireless Sensor Networks, Protocols and Architectures for Wireless Sensor Networks Holger Karl, Andreas Willig, chapter 3, Wiley, 2005 .

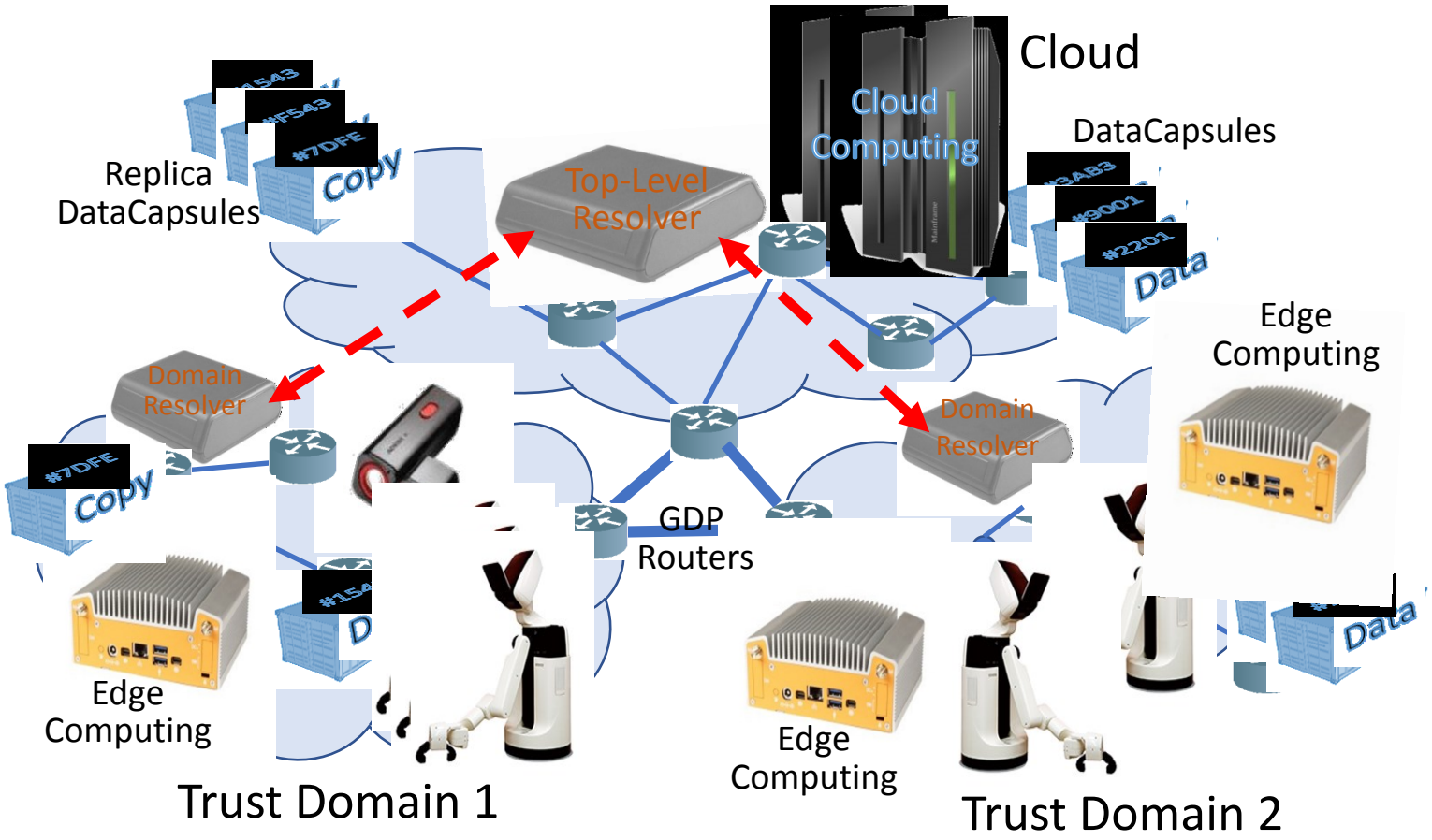
Data Aggregation

- Computing a smaller representation of a number of data items (or messages) that is extracted from all the individual data items.
- For example computing min/max or mean of sensor data.
- More advance aggregation solutions could use approximation techniques to transform high-dimensionality data to lower-dimensionality abstractions/representations.
- The aggregated data can be smaller in size, represent patterns/abstractions; so in multi-hop networks, nodes can receive data form other node and aggregate them before forwarding them to a sink or gateway.
- Or the aggregation can happen on a sink/gateway node.



Edge/Fog Optimization in the IoT Network

- Depending on application, more sophisticated processing of data can take place within the network
- Exploit temporal and spatial correlation
- Move intelligence towards data through edge computing
- Perform traffic engineering within the transport network to optimize data movements



Q & A?

Thanks for attention…