Universita Degli Studi di Padova

department of mathematics

Mobile Crowdsensing and Computing

A.Y. 2017/2018
Brain Mind and Computer Science

UniPadova MobileLab Research Group

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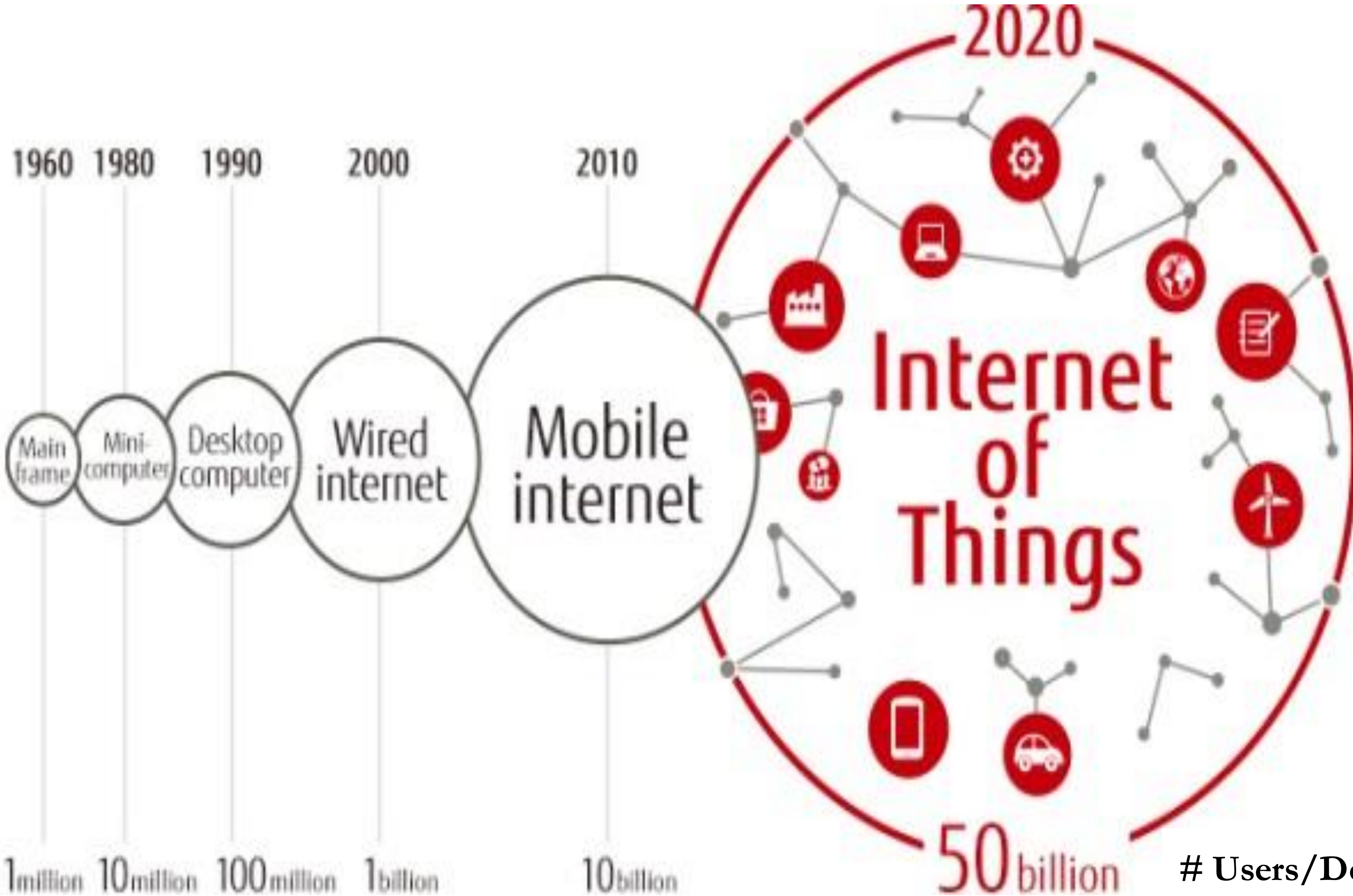
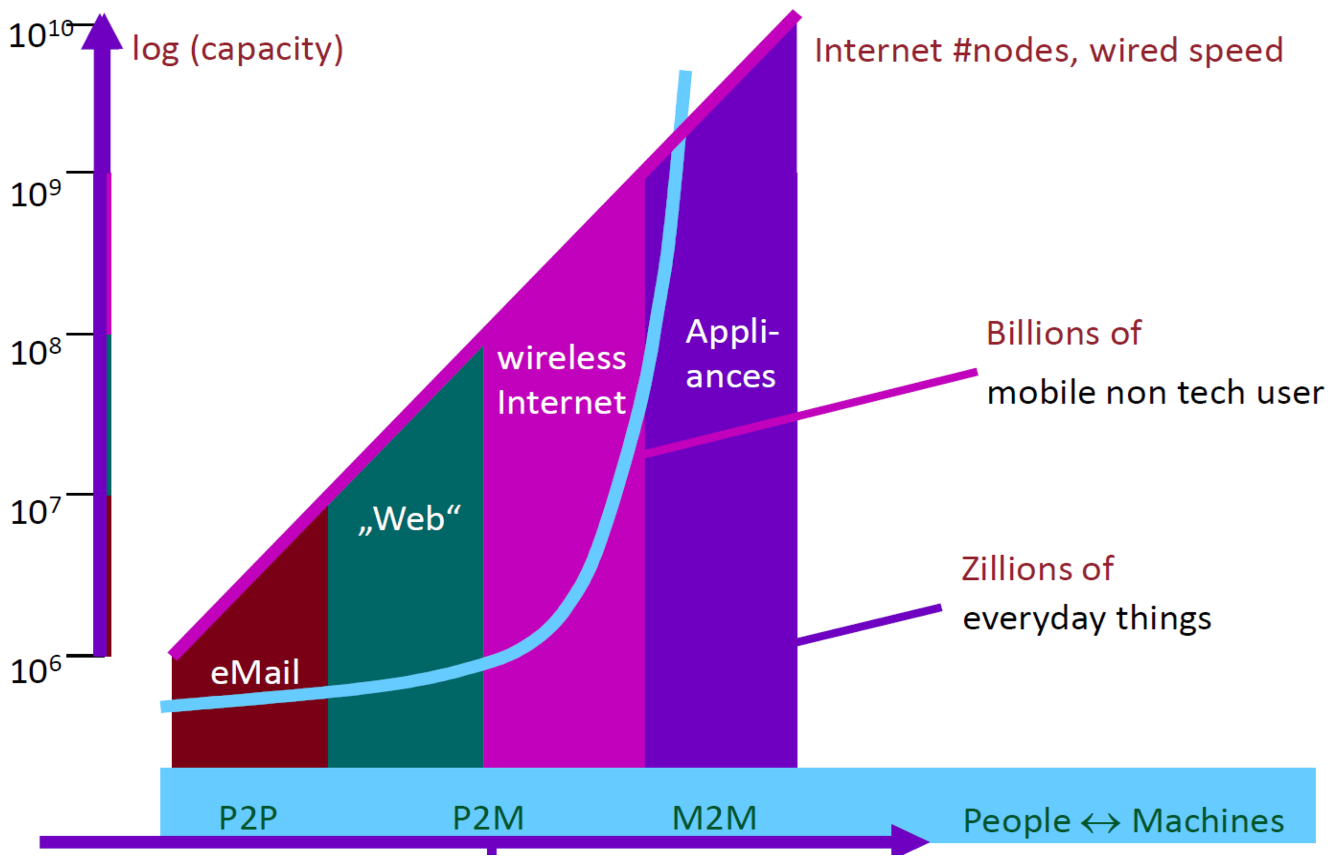
A brief history of computing



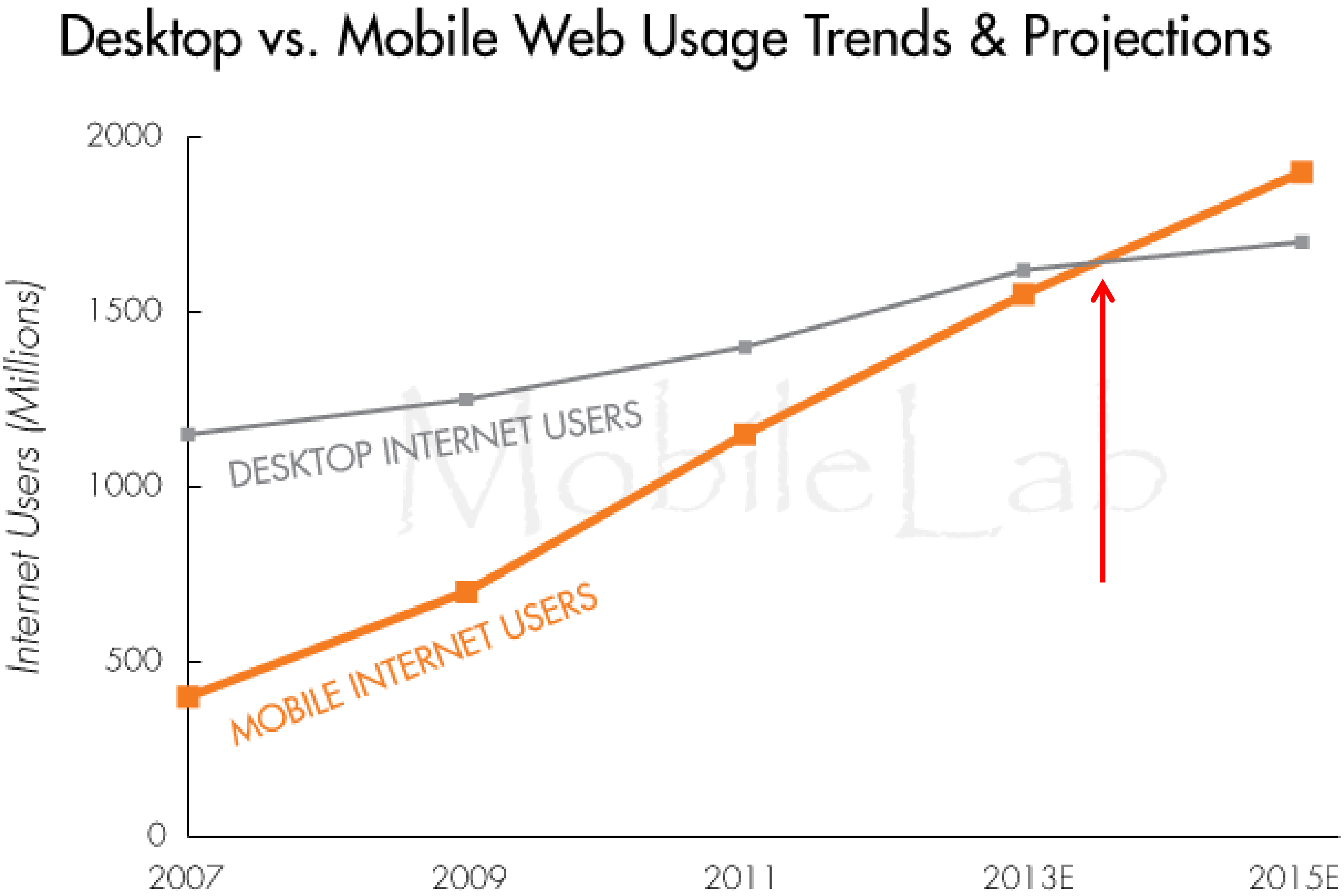
Users/Devices

Explosion of nodes

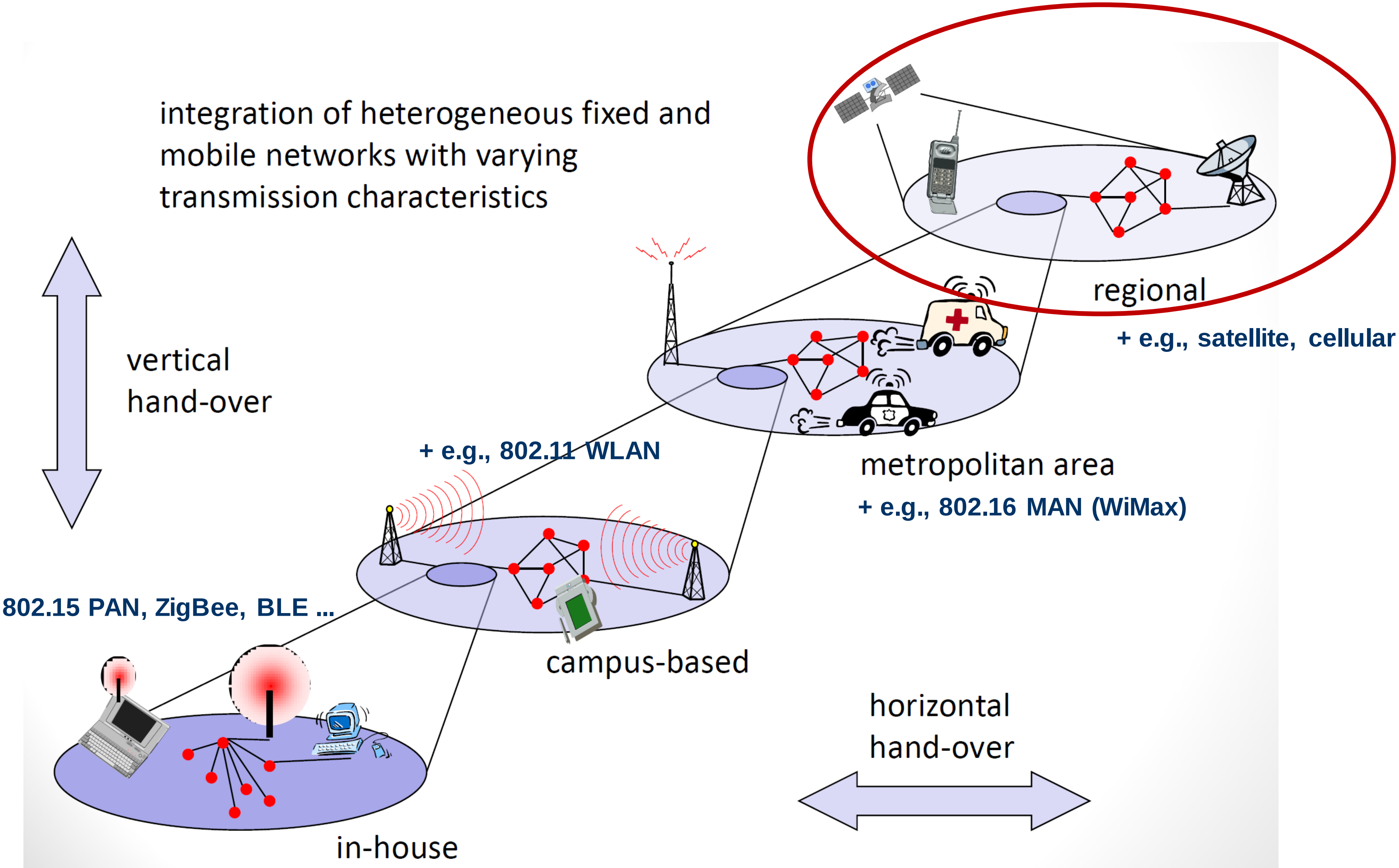
issue: on the networking side, the exponential growth (# of nodes connected in the Internet) continues way beyond the world's population consequence: scalability becomes even more crucial



Mobile surpassing desktop users



An Overlay of Networks



On-going research: Nano-Satellites

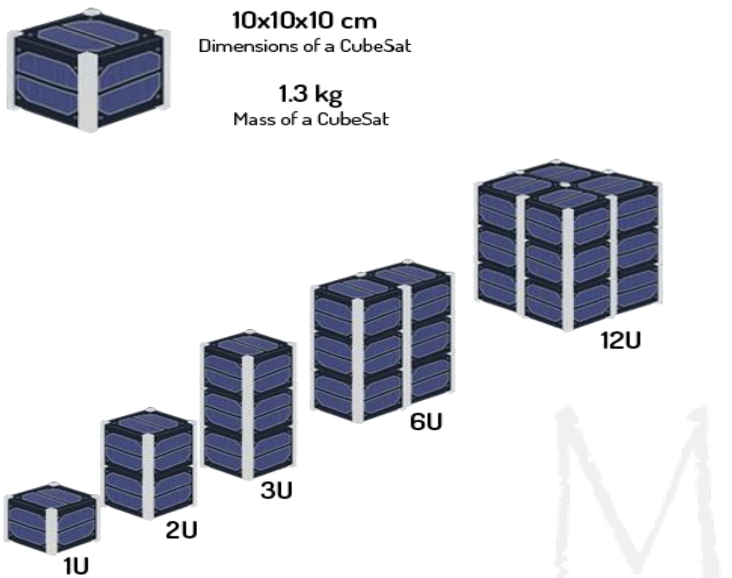


Figure: CubeSat taxonomy

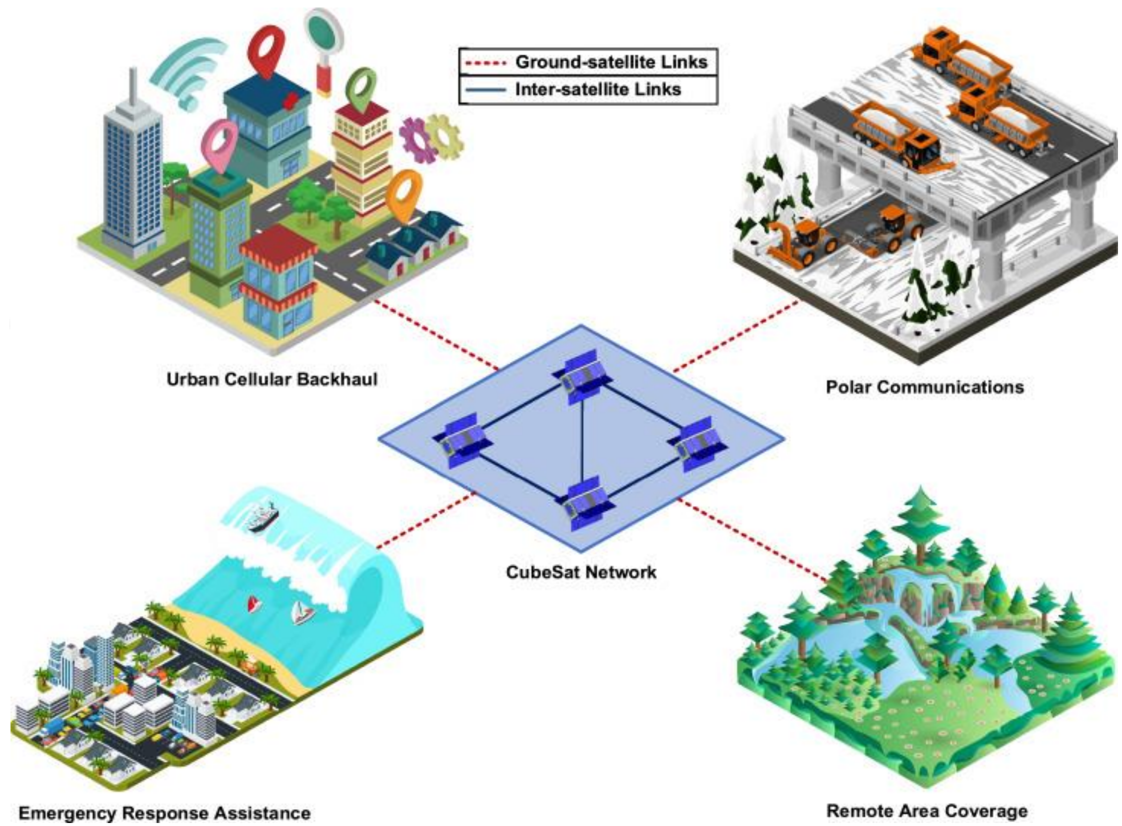


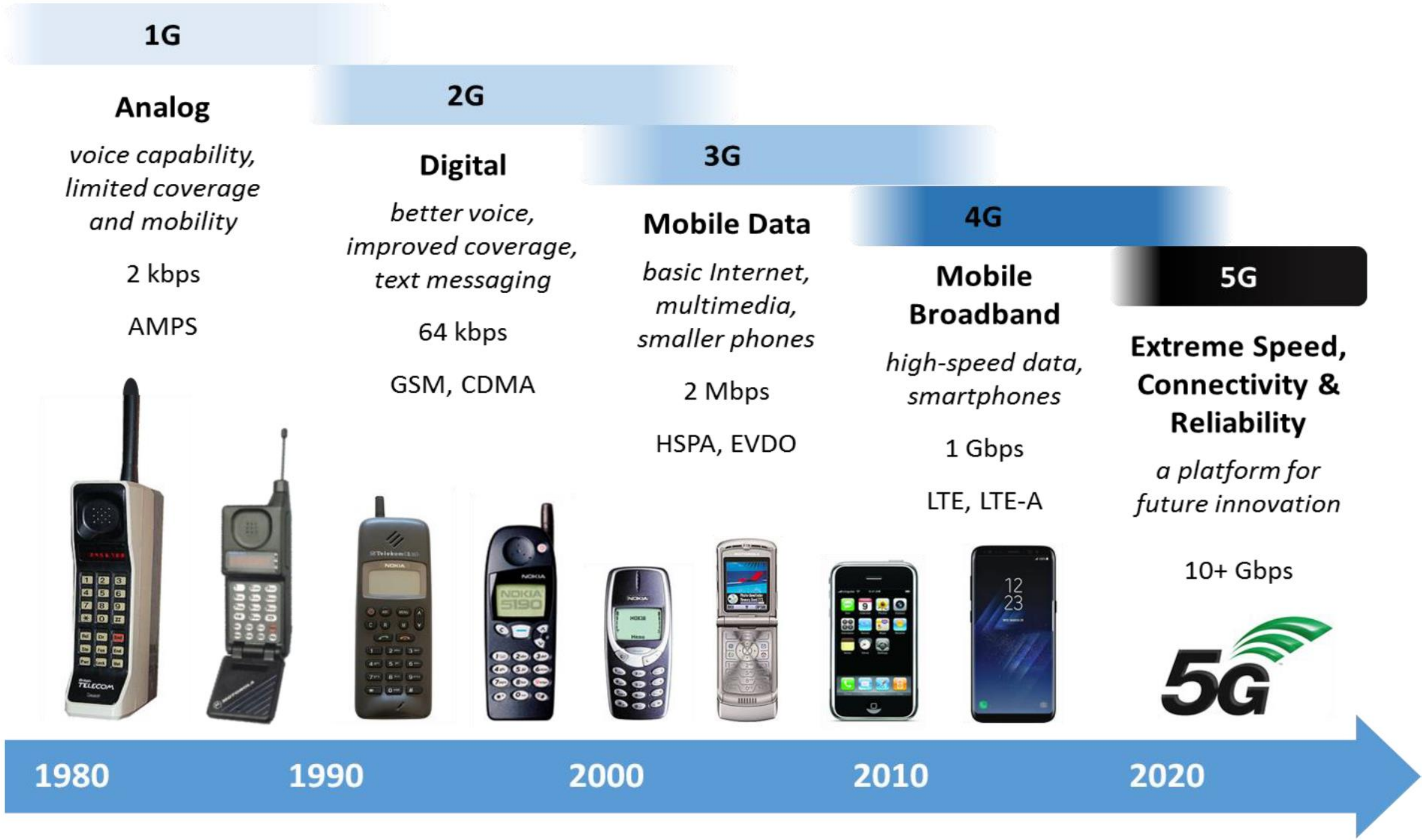
Figure: CubeSat launch from ISS in 2012, over 1000 launched till 2019.

Figure: In-space backhaul scenarios.

Internet of Space Things (IoST)

Internet of Space Things (IoST)

Evolution from 1G to 5G



5G service & use cases – Nov 2017 – 5G America White Paper

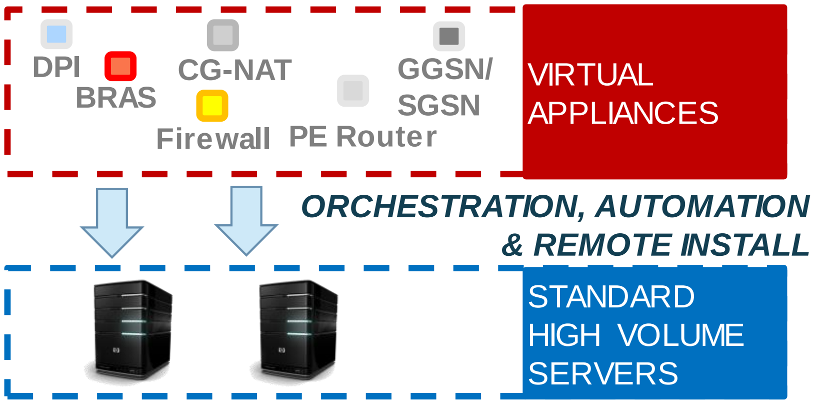
The NFV Concept

A means to make the network more flexible and simple by minimising dependence on HW constraints

Traditional Network Model: APPLIANCE APPROACH

- Network Functions are **based on specific HW&SW**
- **One physical node per role**

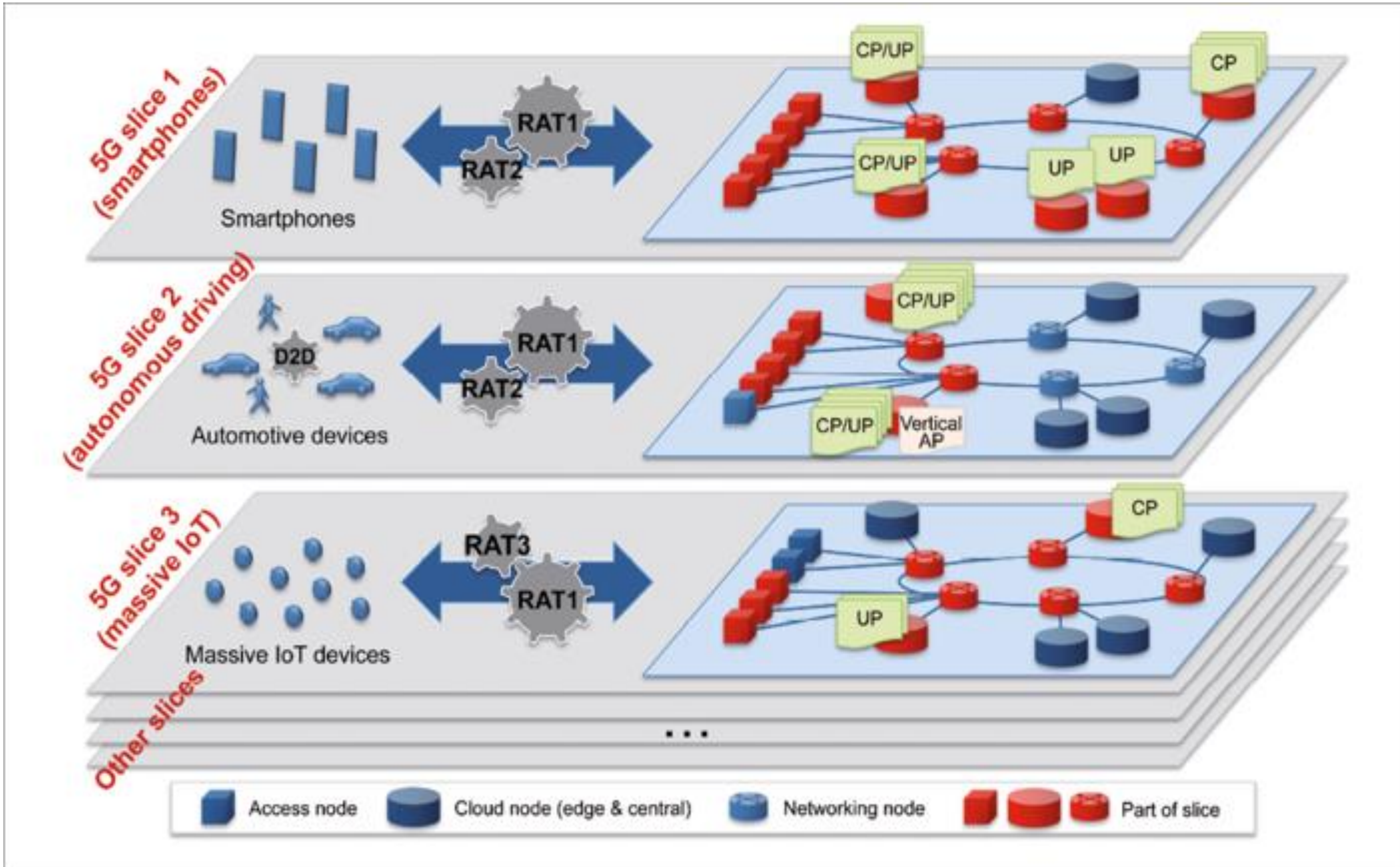
Virtualised Network Model: VIRTUAL APPLIANCE APPROACH



- Network Functions are **SW-based over well-known HW**
- **Multiple roles** over **same HW**

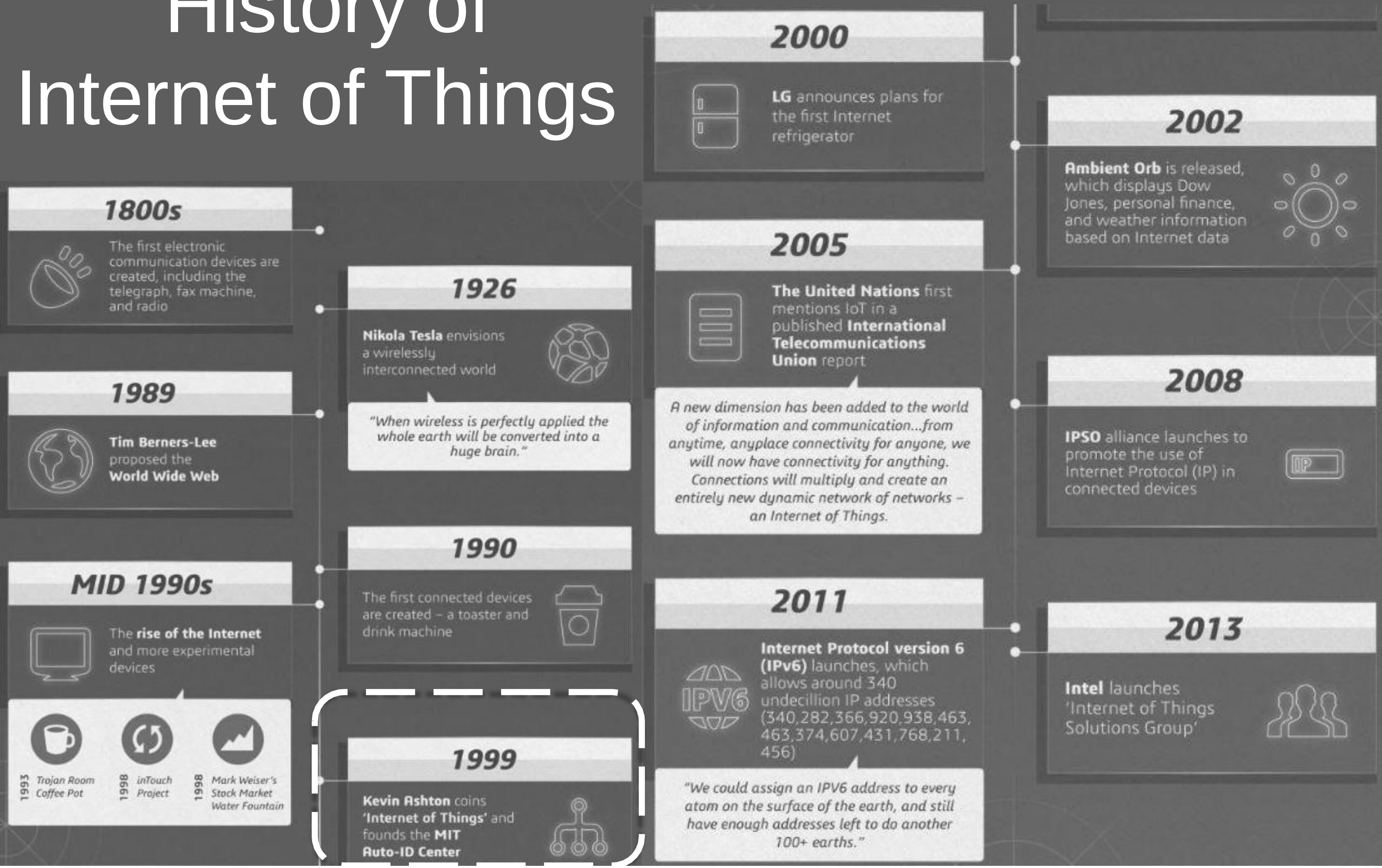
Source: Adapted from D. Lopez Telefonica I+D, NFV

5G – Network Slicing Concept

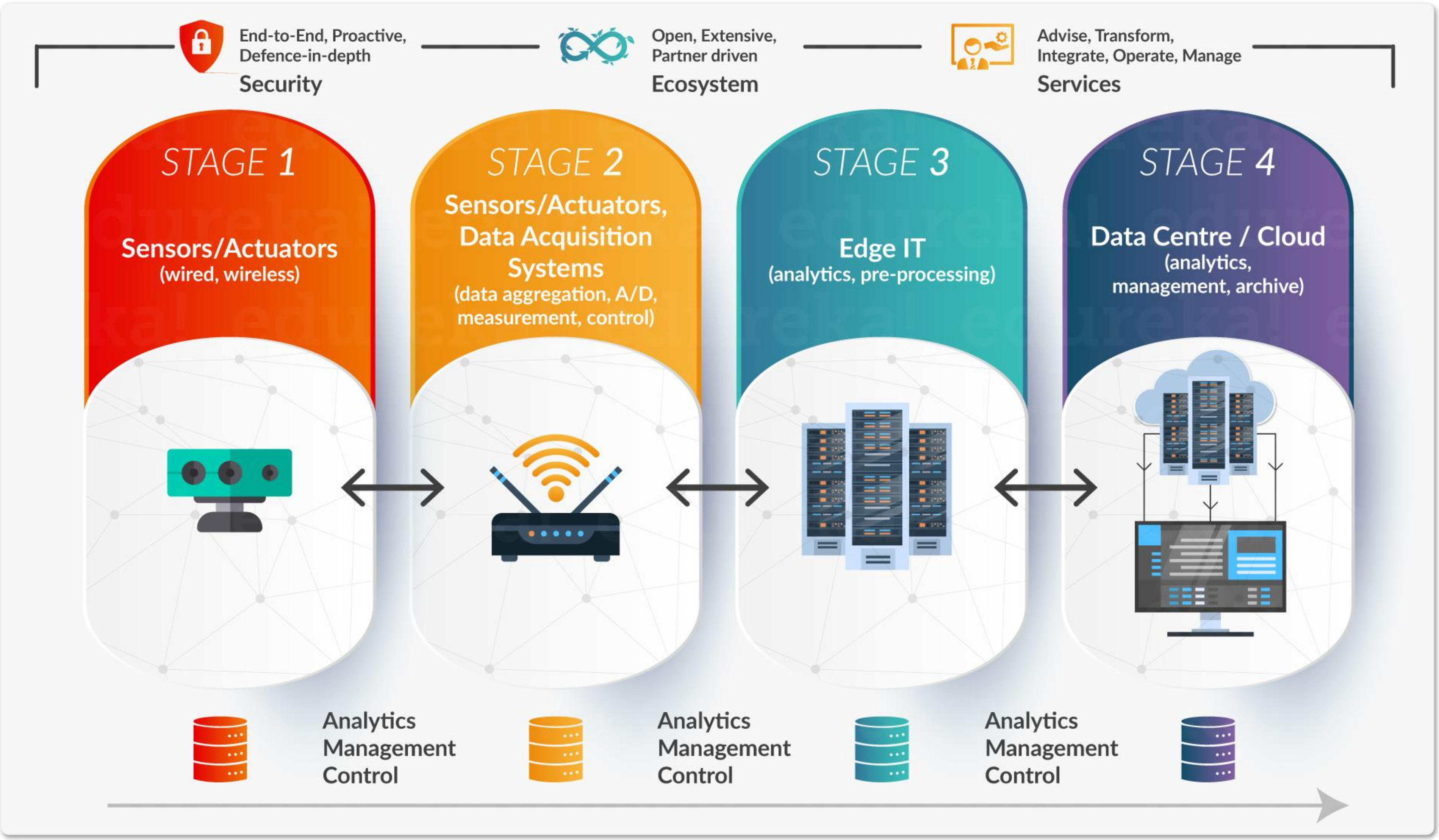



The Internet
of Things?

History of Internet of Things



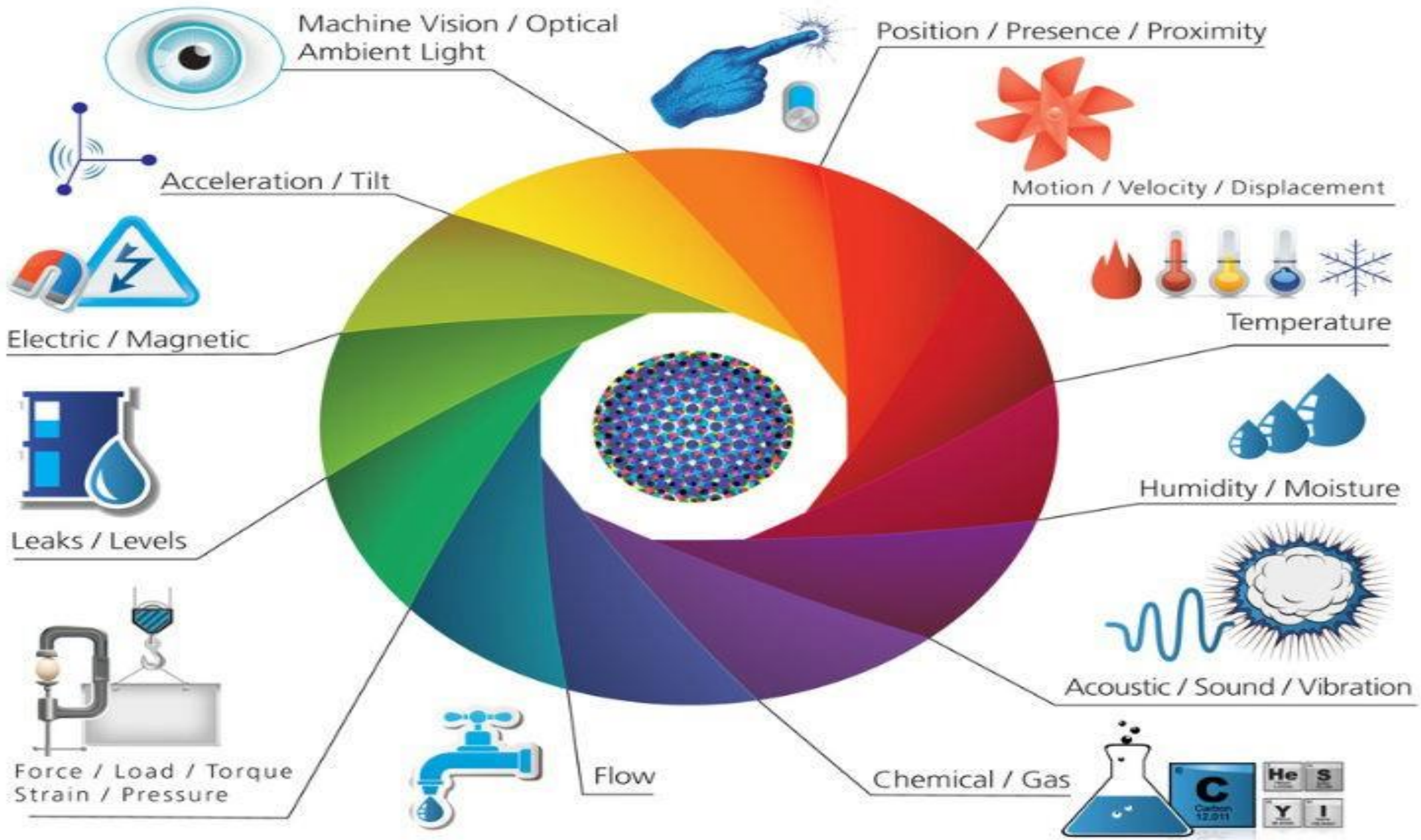
Core stages of an IoT architecture



[Source: Postscape - http://postscapes.com/what-exactly-is-the-internet-of-things-infographic]

1 SENSORS & ACTUATORS

We are giving our world a digital nervous system. Location data using GPS sensors. Eyes and ears using cameras and microphones, along with sensory organs that can measure everything from temperature to pressure changes.



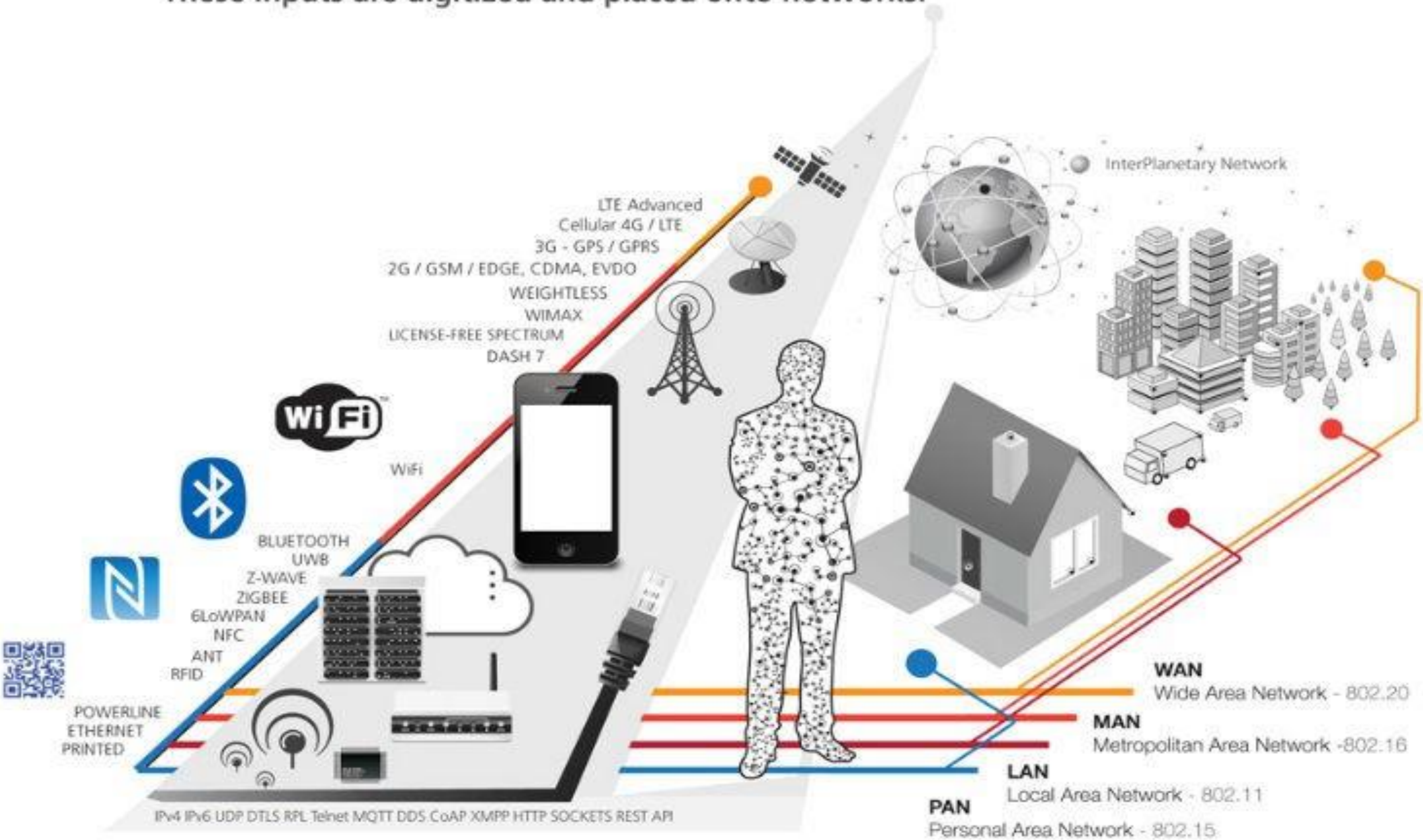
[Source: Postscape - http://postscapes.com/what-exactly-is-the-internet-of-things-infographic]

What a driverless car sees

[Google's driverless car program]()

2 CONNECTIVITY

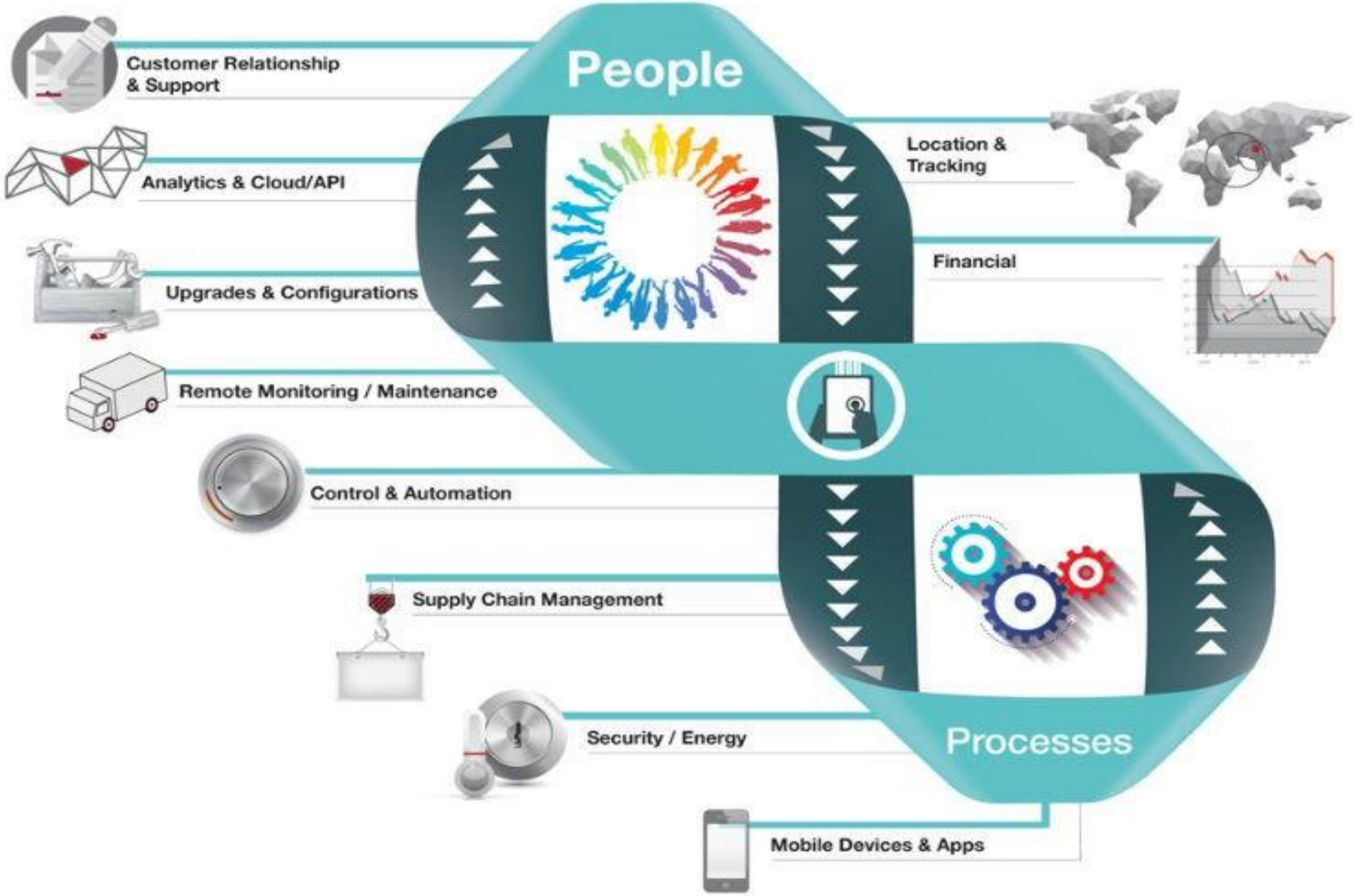
These inputs are digitized and placed onto networks.



[Source: Postscape - http://postscapes.com/what-exactly-is-the-internet-of-things-infographic]

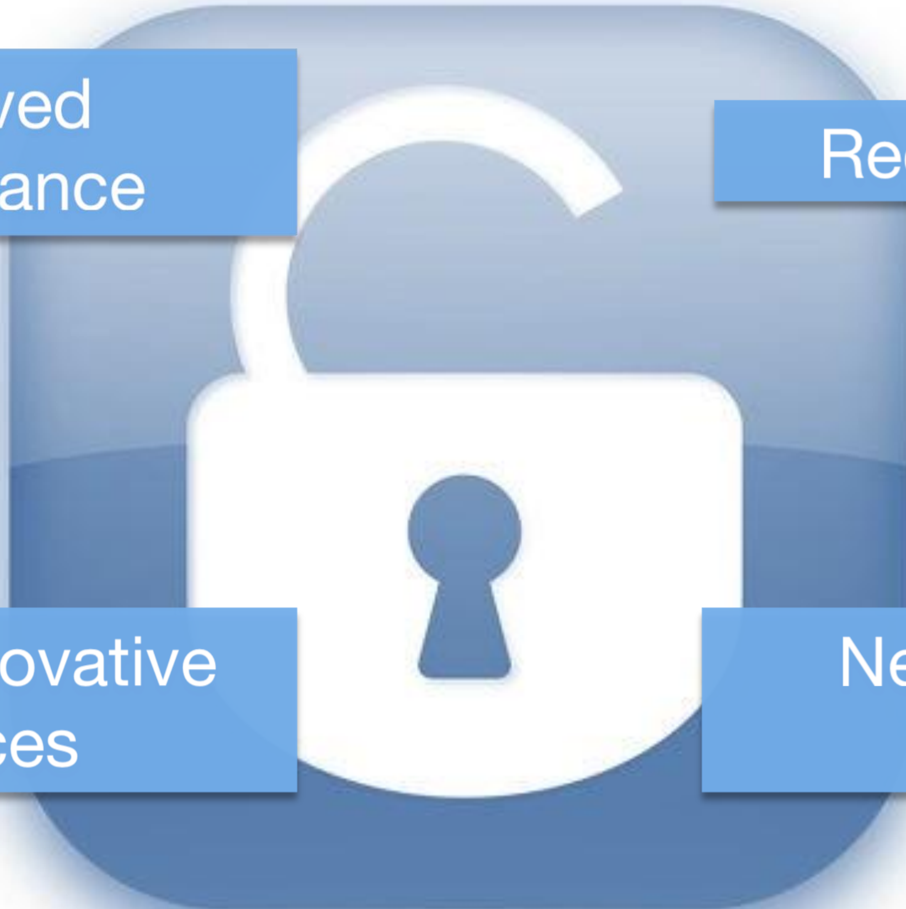
3 PEOPLE & *PROCESSES*

These networked inputs can then be combined into bi-directional systems that integrate data, people, processes and systems for better decision making.



[Source: Postscape - http://postscapes.com/what-exactly-is-the-internet-of-things-infographic]

Unlocking the Massive Potential of IoT



Improved Performance

Reduced Costs

Create Innovative Services

New Revenue Stream

The interactions between these entities are creating new types of smart applications and services.

SENSORS + CONNECTIVITY + PEOPLE + PROCESSES

Starting with popular connected devices already on the market

SMART THERMOSTATS

nest

Save resources and money on your heating bills by adapting to your usage patterns and turning the temperature down when you're away from home.

CONNECTED CARS

CAR 2GO

Tracked and rented using a smartphone. Car2Go also handles billing, parking and insurance automatically.

ACTIVITY TRACKERS

BASIS

Continuously capture heart rate patterns, activity levels, calorie expenditure and skin temperature on your wrist 24/7.

SMART OUTLETS

belkin

Remotely turn any device or appliance on or off. Track a device's energy usage and receive personalized notifications from your smartphone.

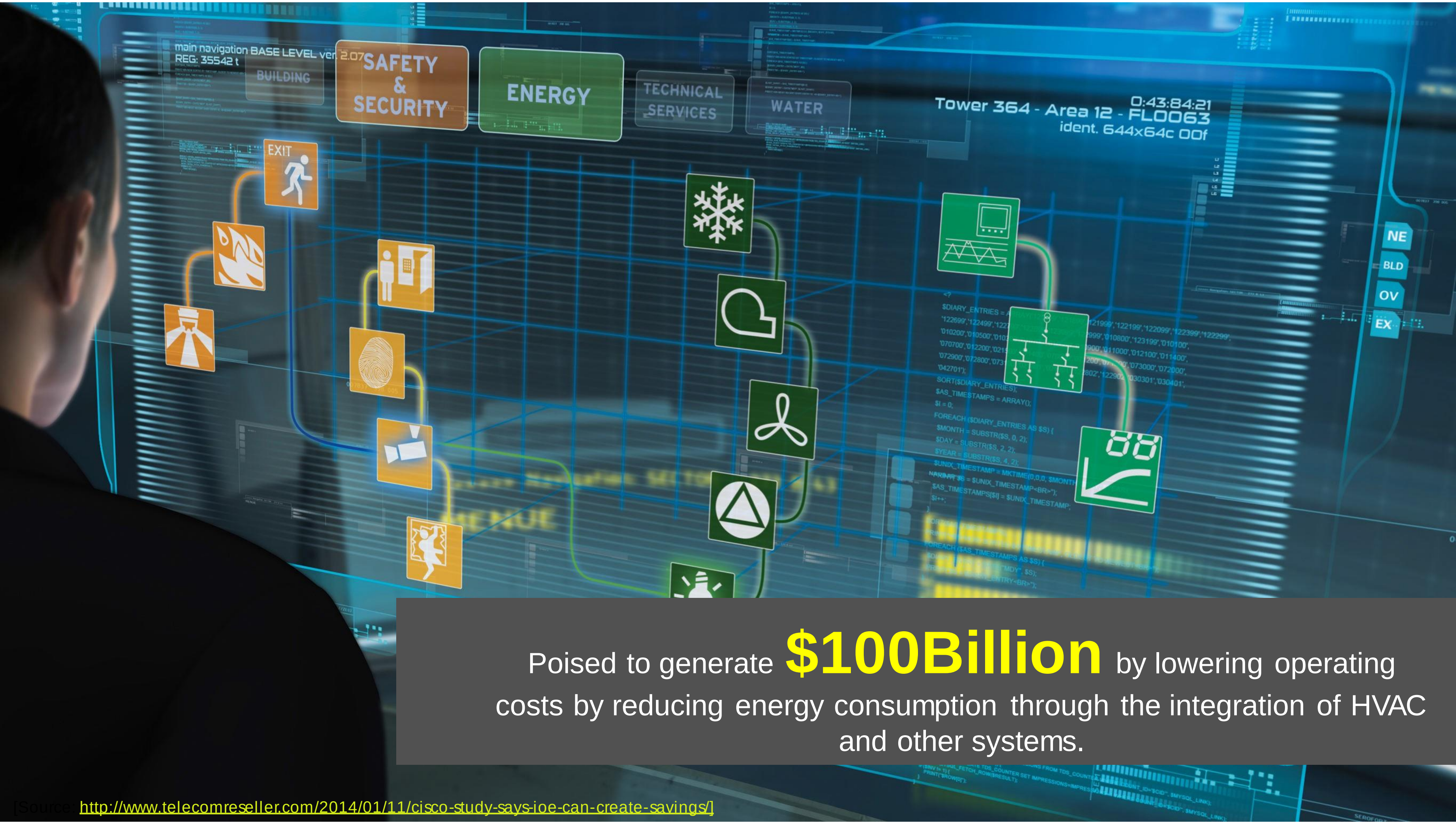
PARKING SENSORS

STREETLINE
CONNECTING THE REAL WORLD

Using embedded street sensors, users can identify real-time availability of parking spaces on their phone. City officials can manage and price their resources based on actual use.

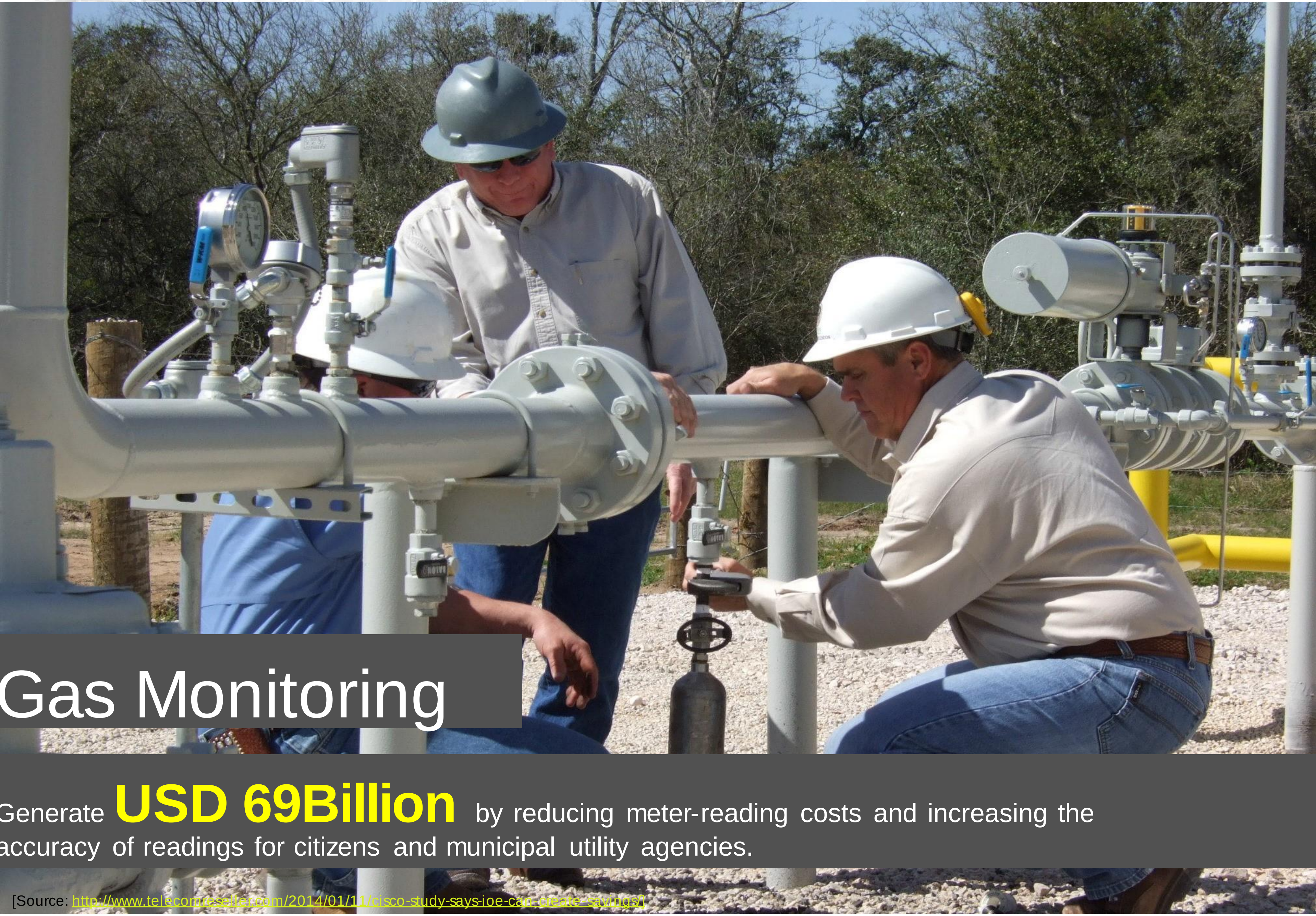
[Source: Postscape - http://postscapes.com/what-exactly-is-the-internet-of-things-infographic]

Smart Building



Poised to generate **$100Billion** by lowering operating costs by reducing energy consumption through the integration of HVAC and other systems.

[Source: http://www.telecomreseller.com/2014/01/11/cisco-study-says-ioe-can-create-savings/]



Gas Monitoring

Generate **USD 69Billion** by reducing meter-reading costs and increasing the accuracy of readings for citizens and municipal utility agencies.

[Source: http://www.telecomreseller.com/2014/01/11/cisco-study-says-ioe-can-create-savings/]

Smart Parking

Create **USD 41Billion** by providing visibility into the availability of parking spaces across the city.

Residents can identify and reserve the closest available space, traffic wardens can identify non-compliant usage, and municipalities can introduce demand- based pricing.

[Source: http://www.telecomreseller.com/2014/01/11/cisco-study-says-ioe-can-create-savings/]

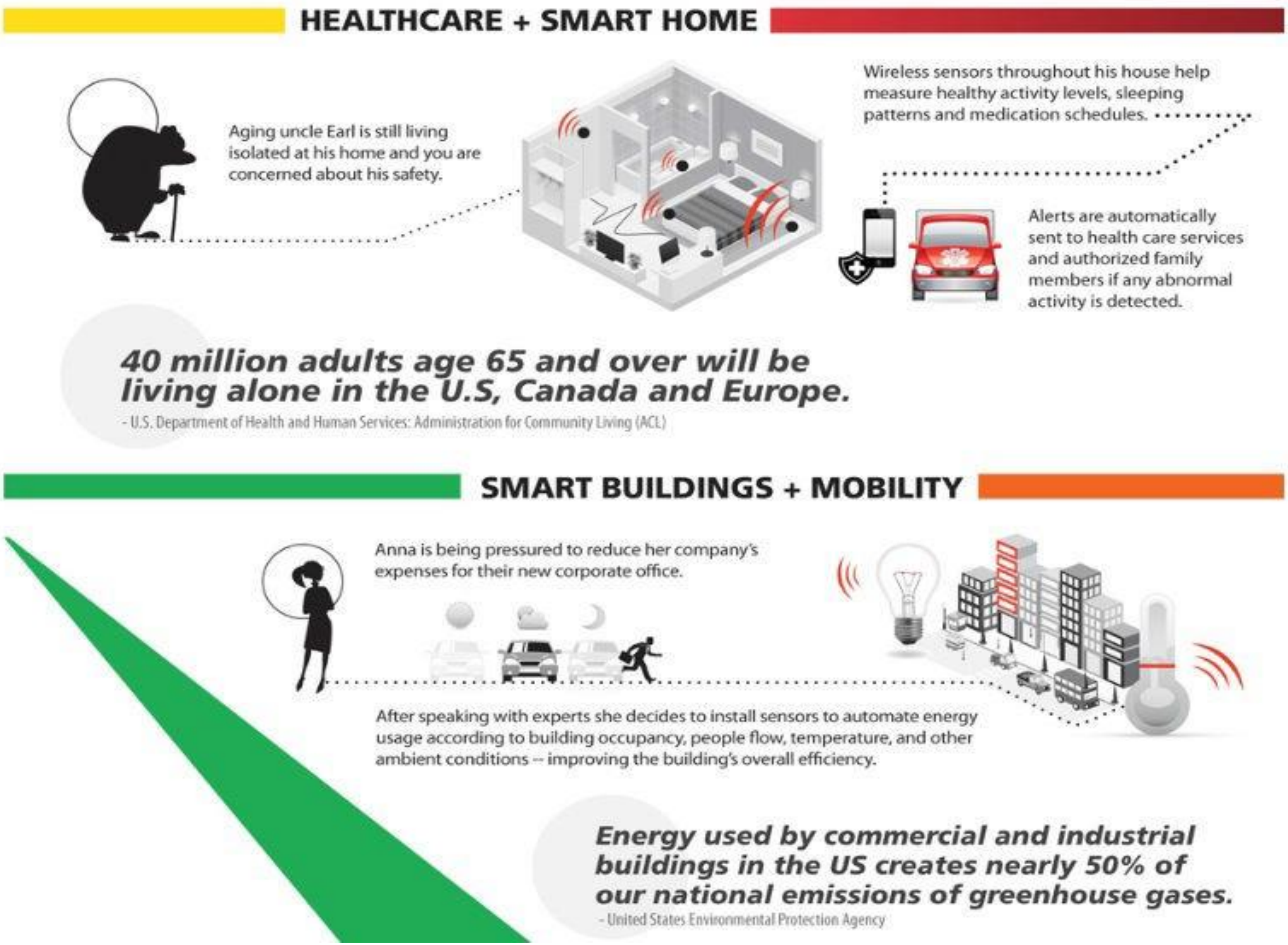
Water Management

Could generate **USD 39Billion** by connecting the household water meter over an IP network to provide remote information on use and status

[Source: http://www.telecomreseller.com/2014/01/11/cisco-study-says-ioe-can-create-savings/]

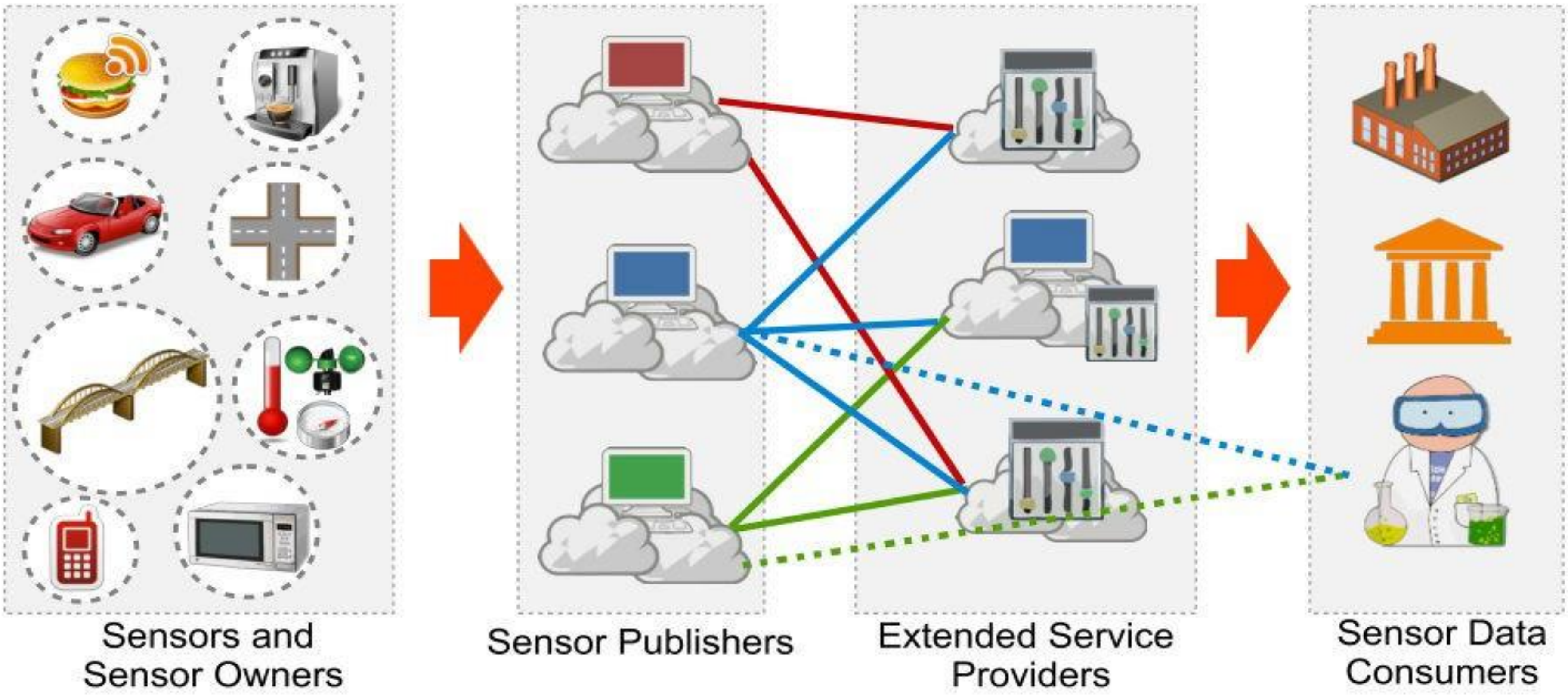
FOR EXAMPLE

http://postscapes.com/what-exactly-is-the-internet-of-things-infographic

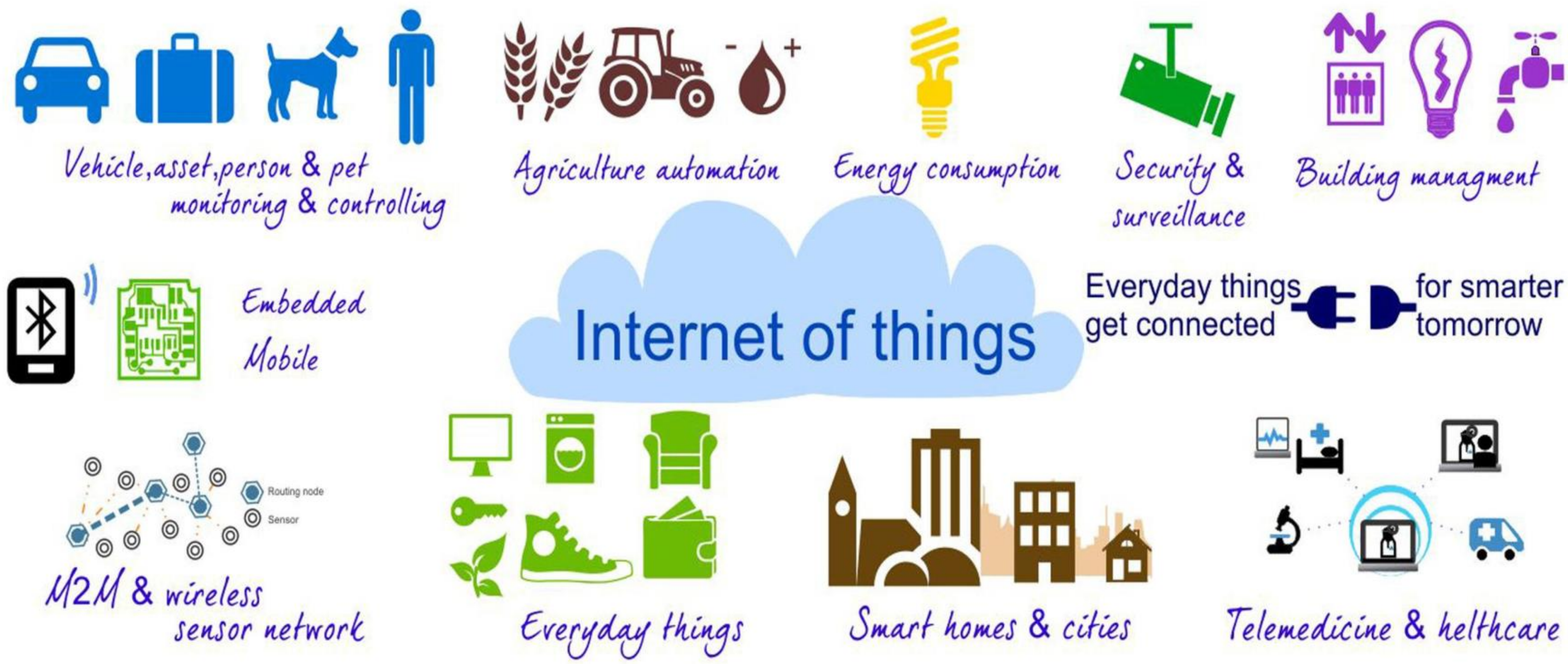


http://postscapes.com/what-exactly-is-the-internet-of-things-infographic

The Sensing-as-a-Service Model



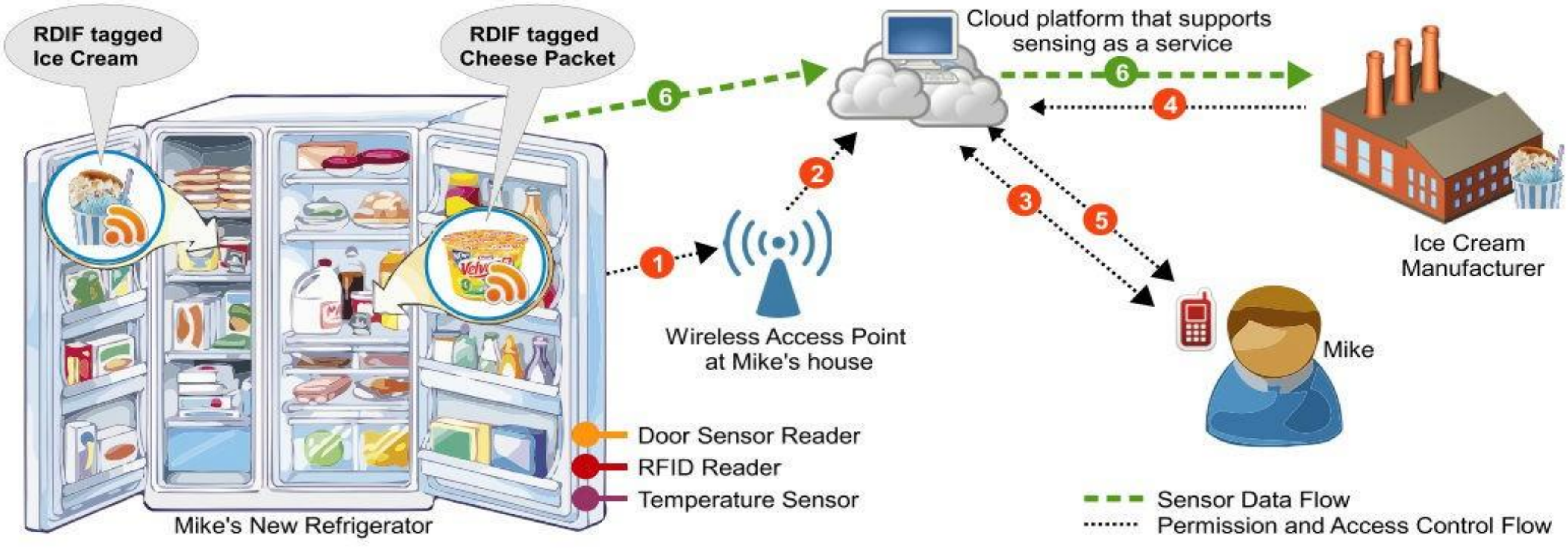
[Source: "Sensing as a Service Model for Smart Cities Supported by Internet of Things", Charith Perera et. al., Transactions on Emerging Telecommunications Technology, 2014]



Sensing-As-A-Service

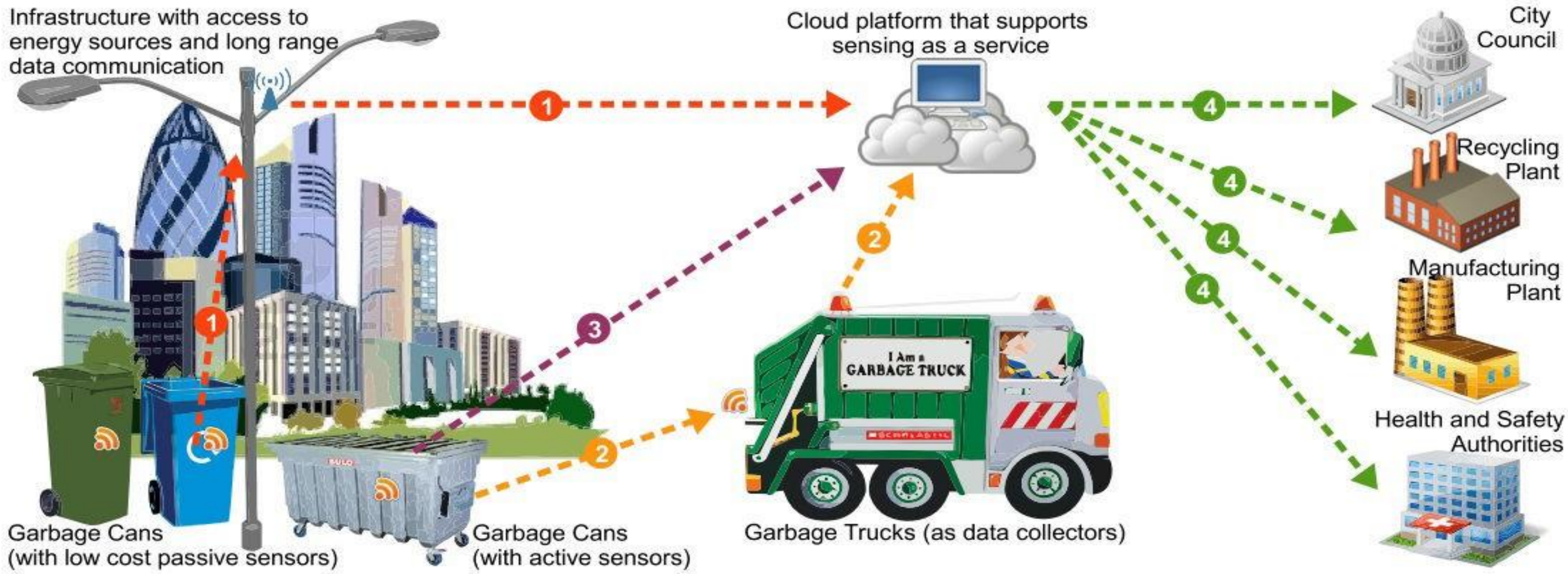
BENEFITS

Smart Home Scenario – Interactions in Sensing-as-a- Service Model



[Source: "Sensing as a Service Model for Smart Cities Supported by Internet of Things", Charith Perera et. al., Transactions on Emerging Telecommunications Technology, 2014]

Efficient Waste Management in Smart Cities Supported by the Sensing-as-a-Service



[Source: “Sensing as a Service Model for Smart Cities Supported by Internet of Things”, Charith Perera et. al., Transactions on Emerging Telecommunications Technology, 2014]

IOT Application Scenario - Shopping

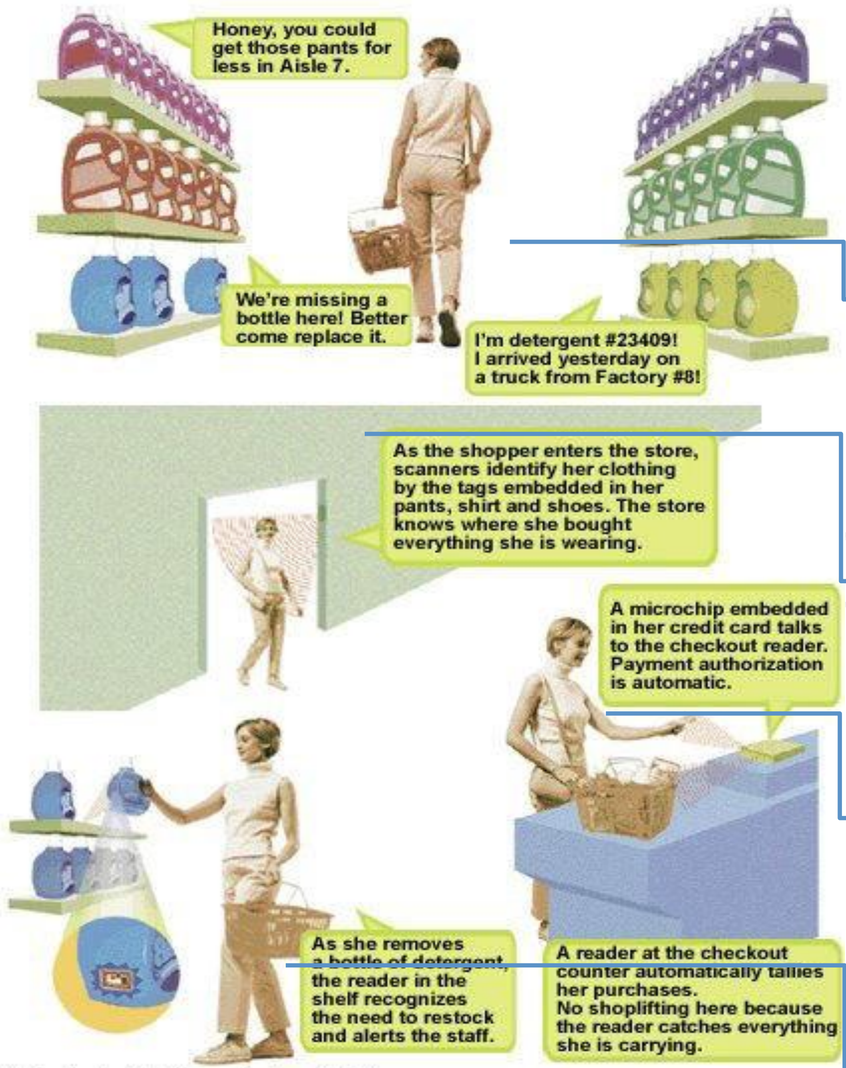


Illustration by Lisa Knouse Braiman for Forbes

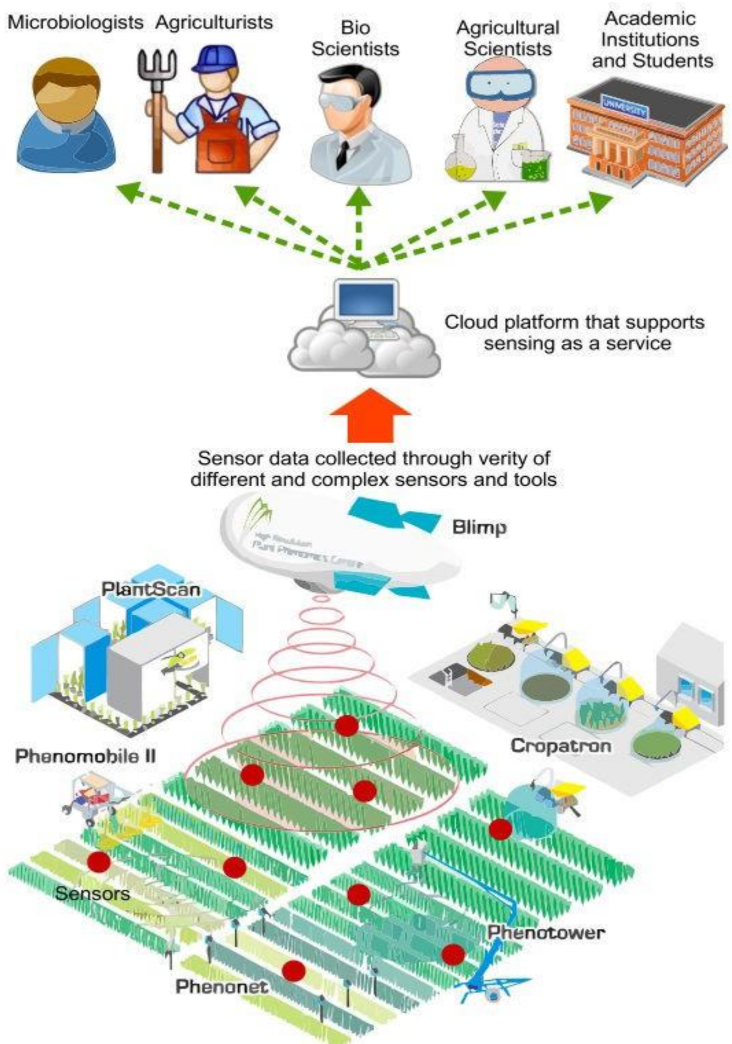
(2) When shopping in the market, the goods will introduce themselves.

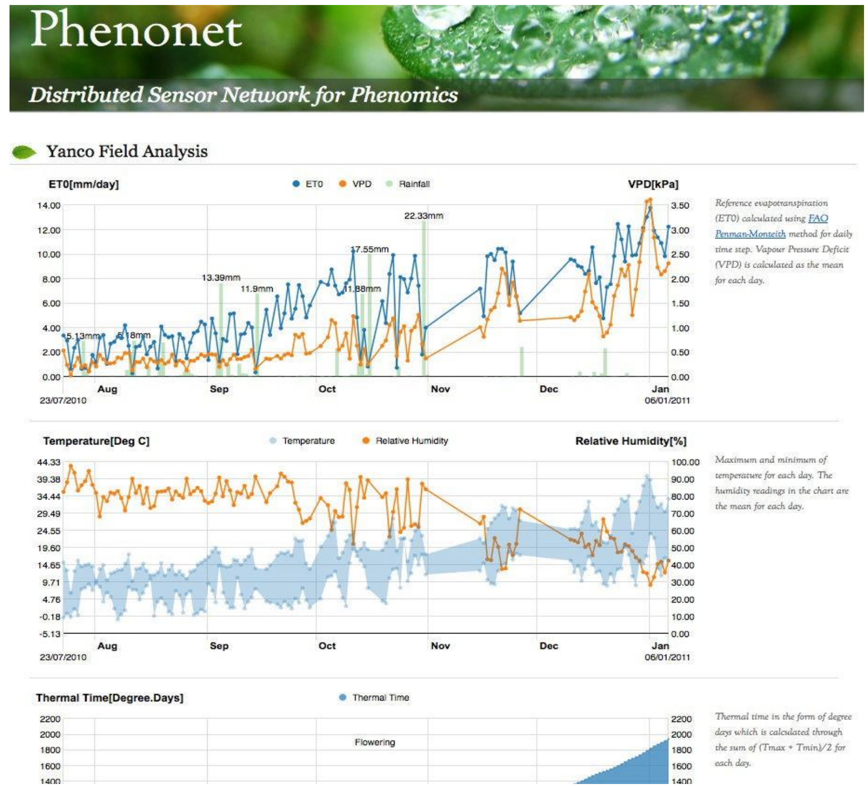
(1) When entering the doors, scanners will identify the tags on her clothing.

(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

(3) When moving the goods, the reader will tell the staff to put a new one.

Efficient and Effective Collaborative Research Supported by Sensing-as-a-Service Model

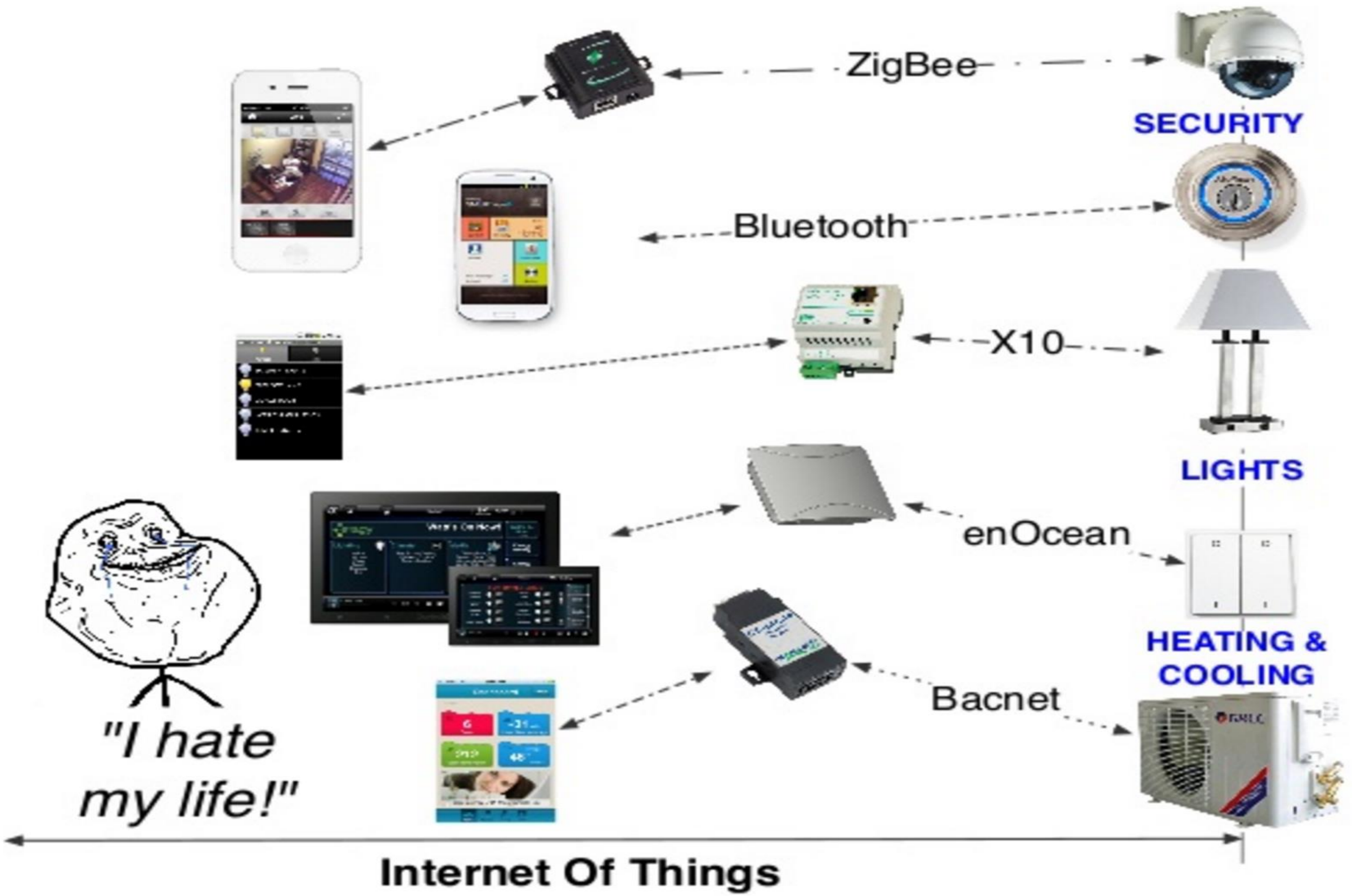




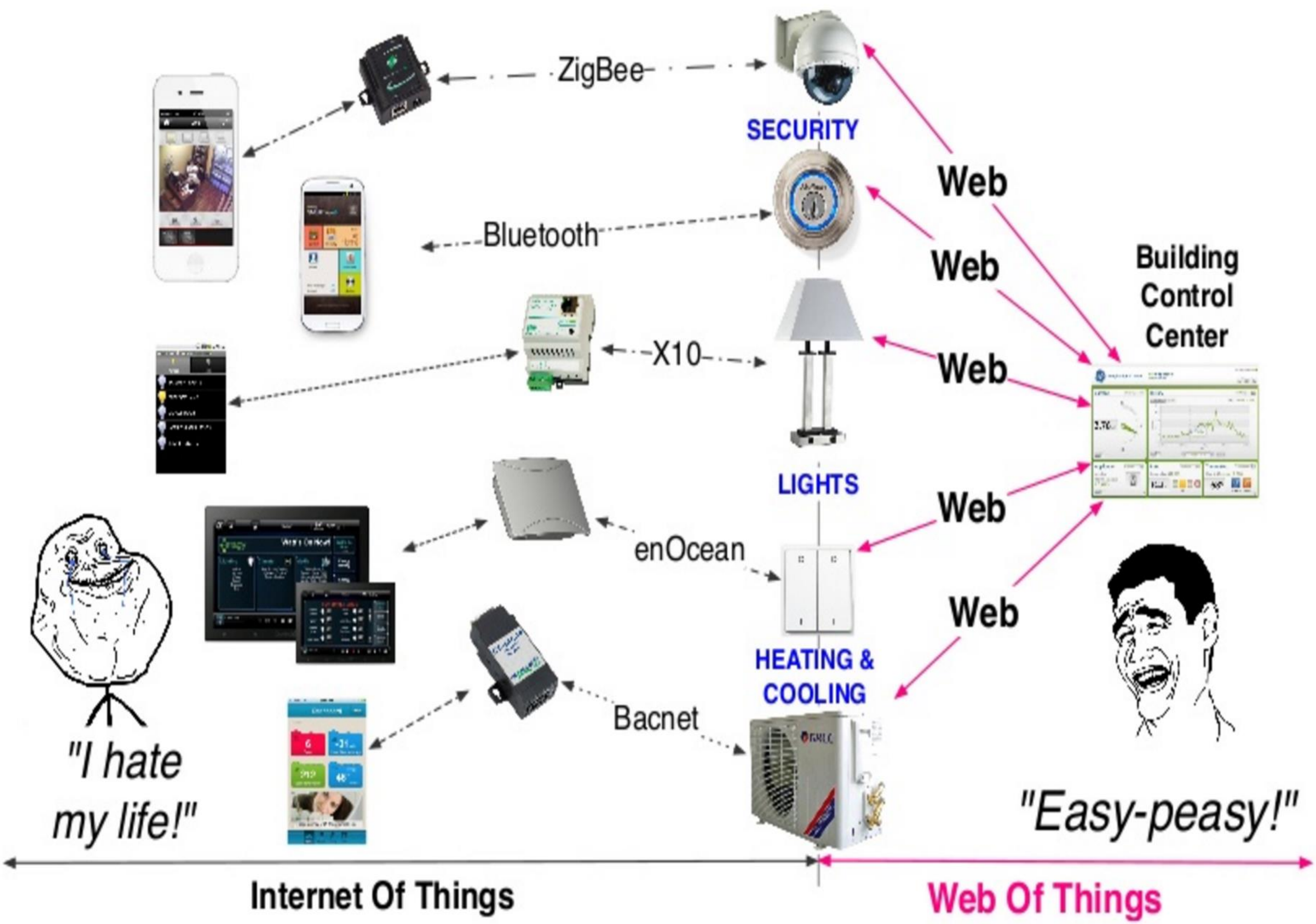
The sensing-as-a-service model allows researchers to share resources across borders and understand phenomenon which are not available in their own countries.

The Web Of Things

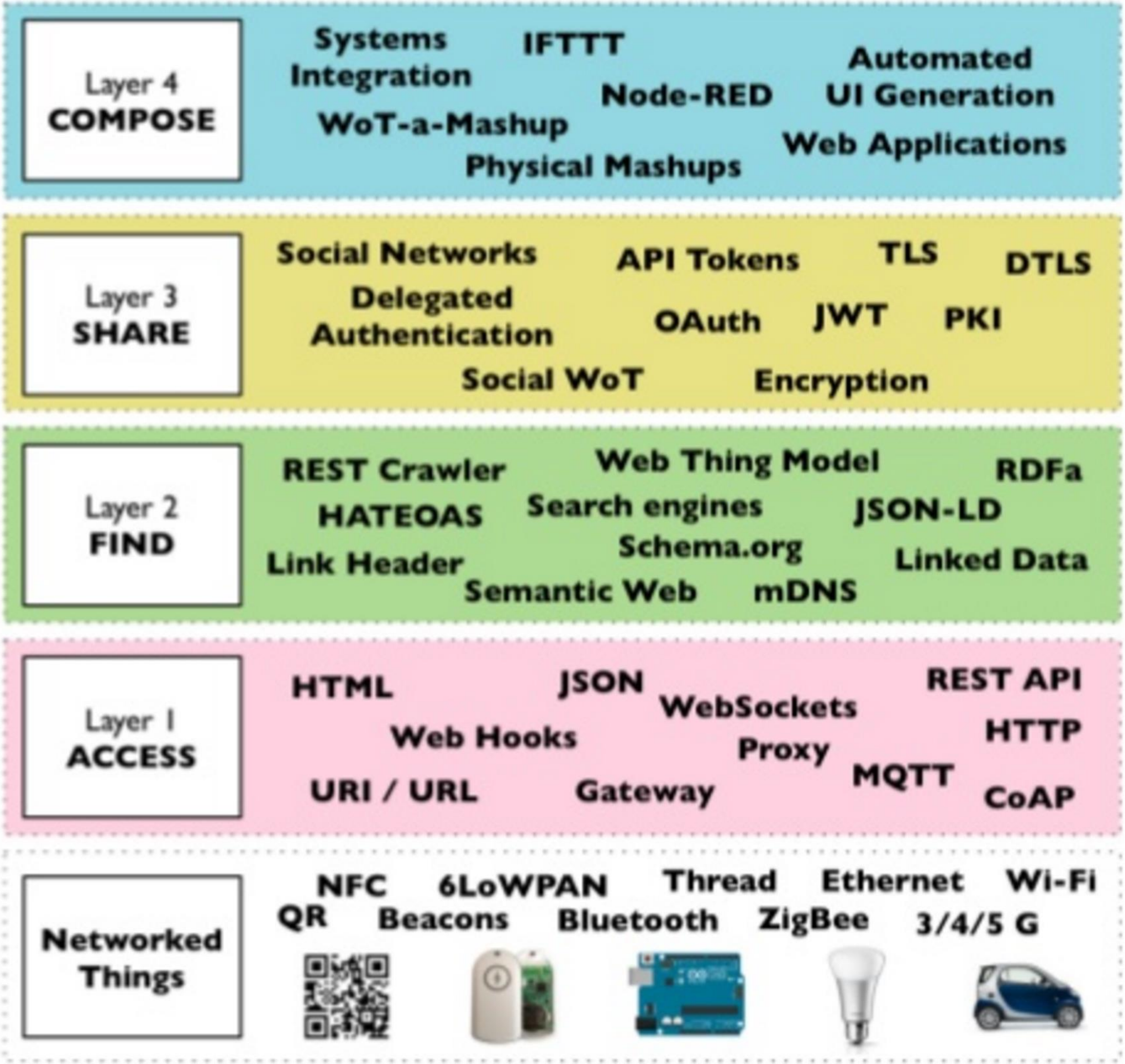
IoT Problem


ZigBee
SECURITY
Bluetooth
X10
LIGHTS
enOcean
HEATING &
COOLING
Bacnet
"I hate
my life!"
Internet Of Things

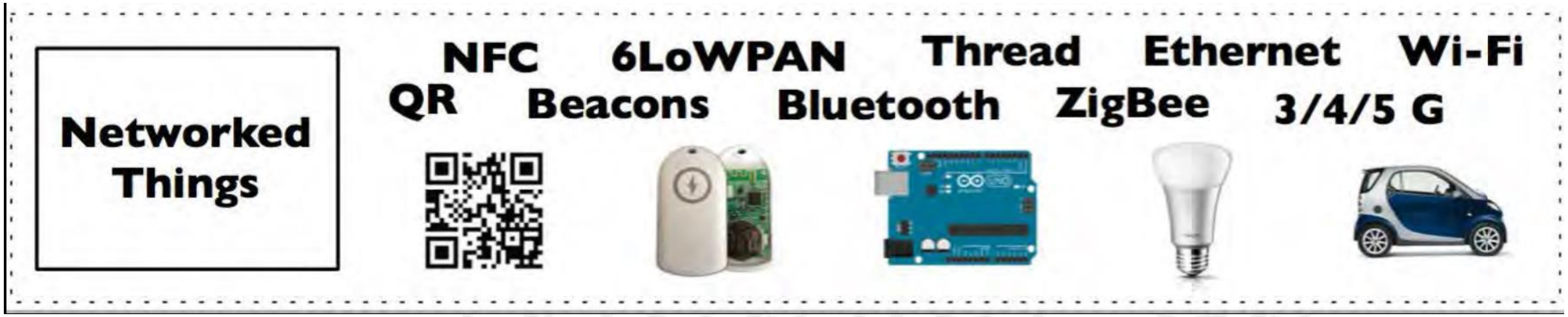
Solution is the Web of Things (WoT)



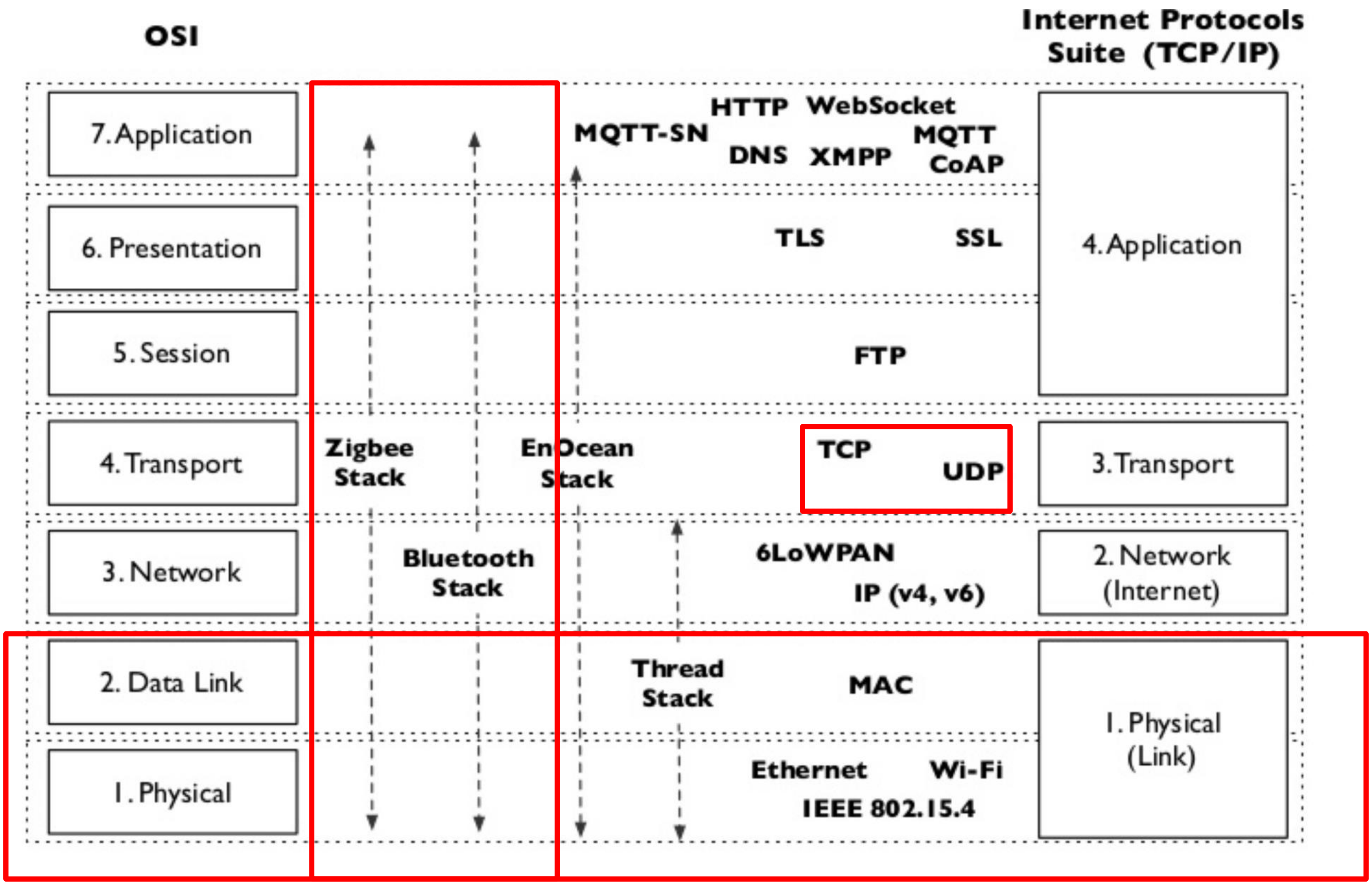
IoT: Web of Things



IoT – Network Layer

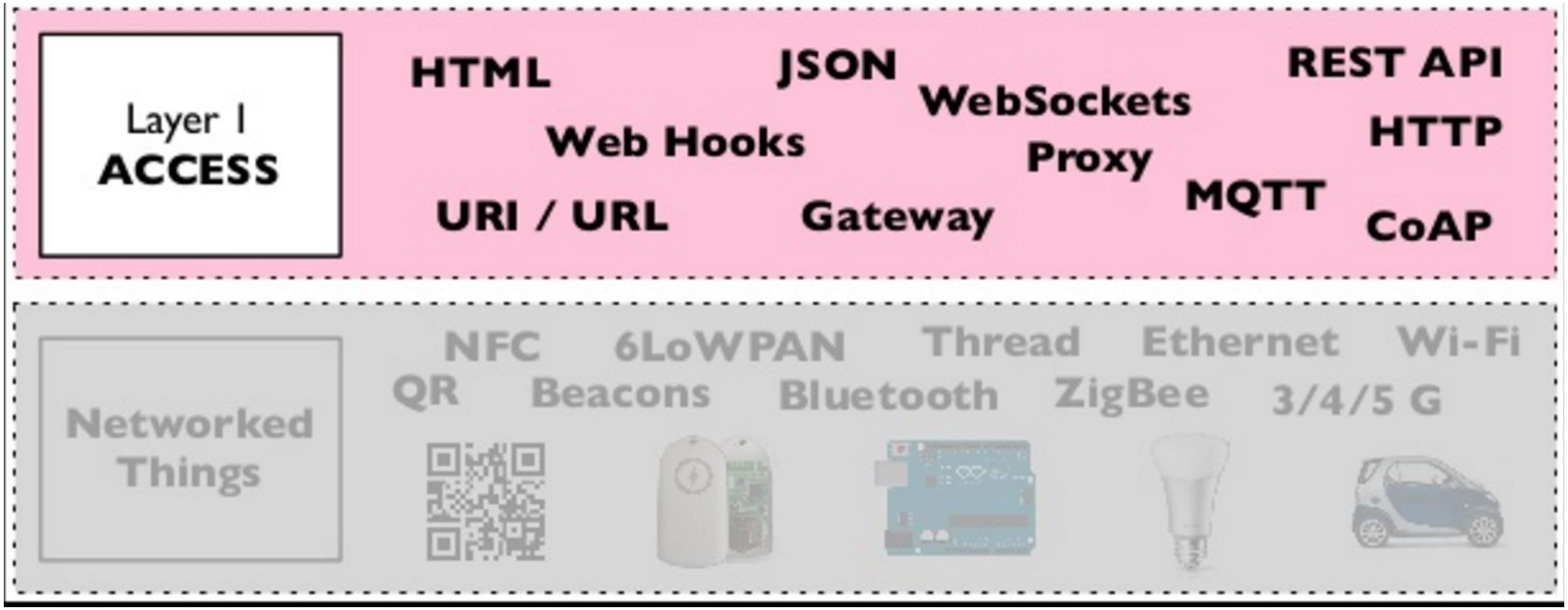


Network Layer – Choose a Physical Protocol



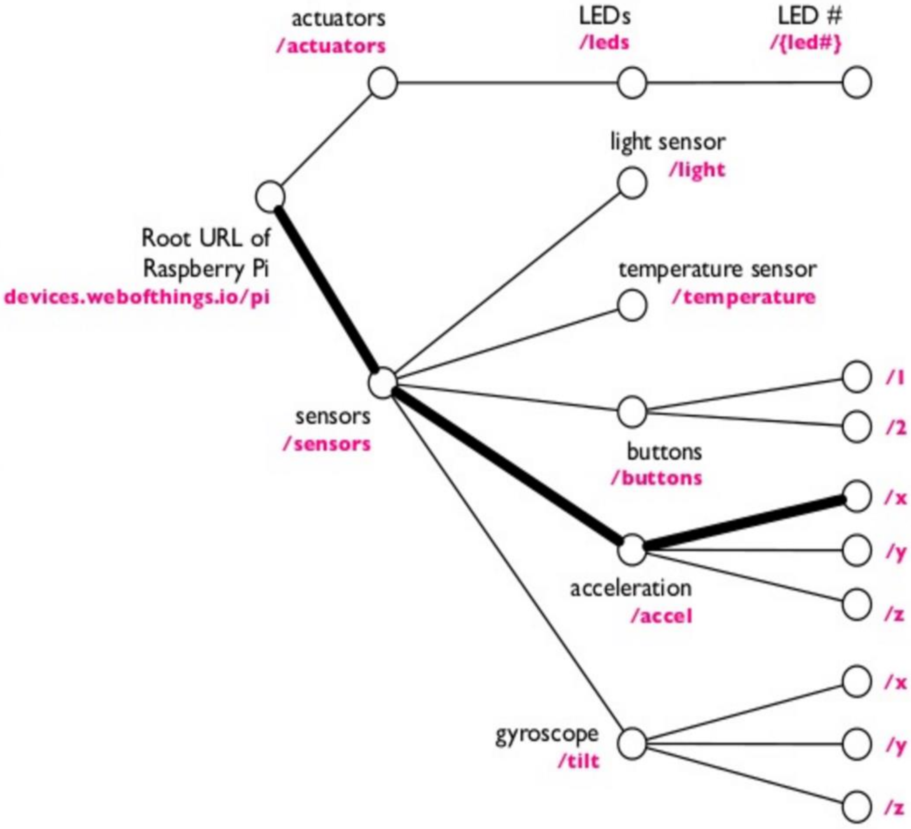
We previously discussed some pieces fitting here !

IoT – N. Layer



Accessing the Things in a standard and transparent way

IoT – N.L: Basic Access Scheme



A URL for each Thing

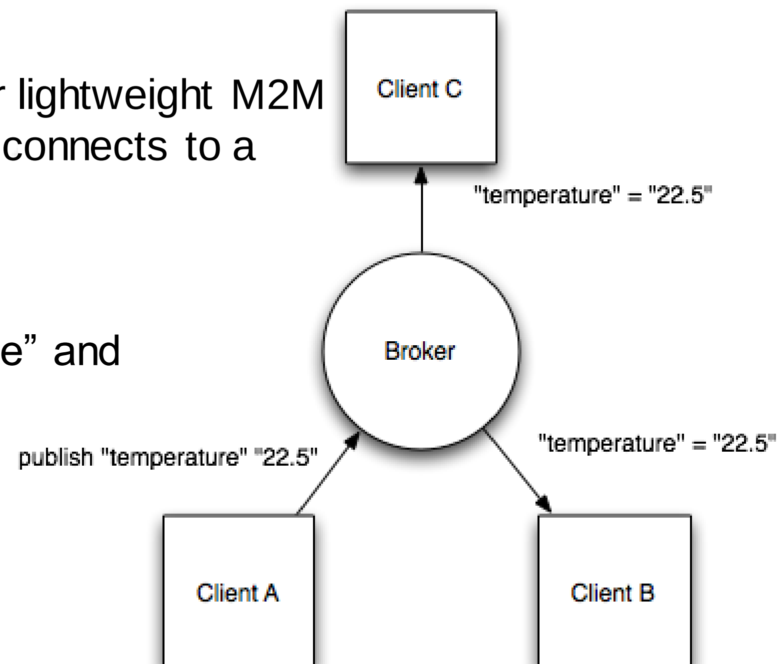
And a RESTful API

IoT – N.L: Not all speak HTTP

	Typical MQTT Protocol Stack	Typical MQTT-SN Protocol Stack	Typical CoAP Protocol Stack	
4. Application	MQTT	MQTT-SN	CoAP CoRE	Required
3. Transport	TCP	UDP	UDP	
2. Network (Internet)	IP	Not specified	6LoWPAN	Recommended
1. Physical (Link)	Not specified	Not specified	IEEE 802.15.4	

MQTT: publish/subscribe messaging protocol designed for lightweight M2M

- client/server model, where every sensor is a client and connects to a server (a.k.a. broker)
- clients subscribe to topic channels of interest
- topic channels are hierarchical (e.g., room2BC/heating)
- 3 QoS Levels: “Fire and forget”, “delivered at least once” and “delivered exactly once”.
- username/password authentication.
  TCP over SSL/TLS



IoT – N.L: Not all speak HTTP

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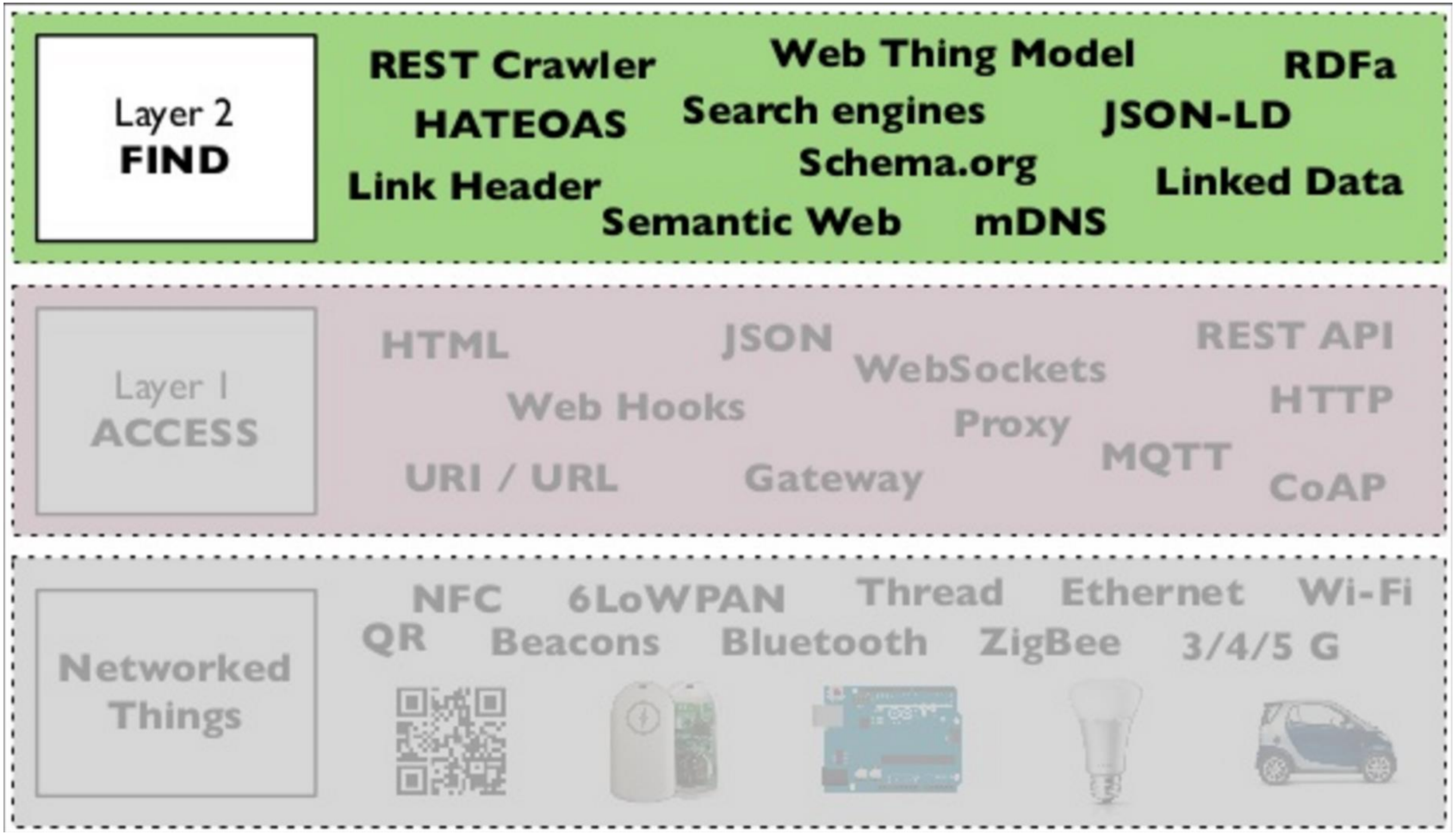
CoAP: Constrained Application Protocol from the CoRE (Constrained Resource Environments) **RFC 7252**

- document transfer protocol designed for the needs of constrained devices;
- packets are much smaller than HTTP TCP flows;
- simpler and faster to parse with small memory footprint;
- over UDP, interoperates with HTTP and the RESTful web through simple proxies;
- client/server model where clients may GET, PUT, POST and DELETE resources
- DTLS capable CoAP devices support RSA and AES or ECC and AES.

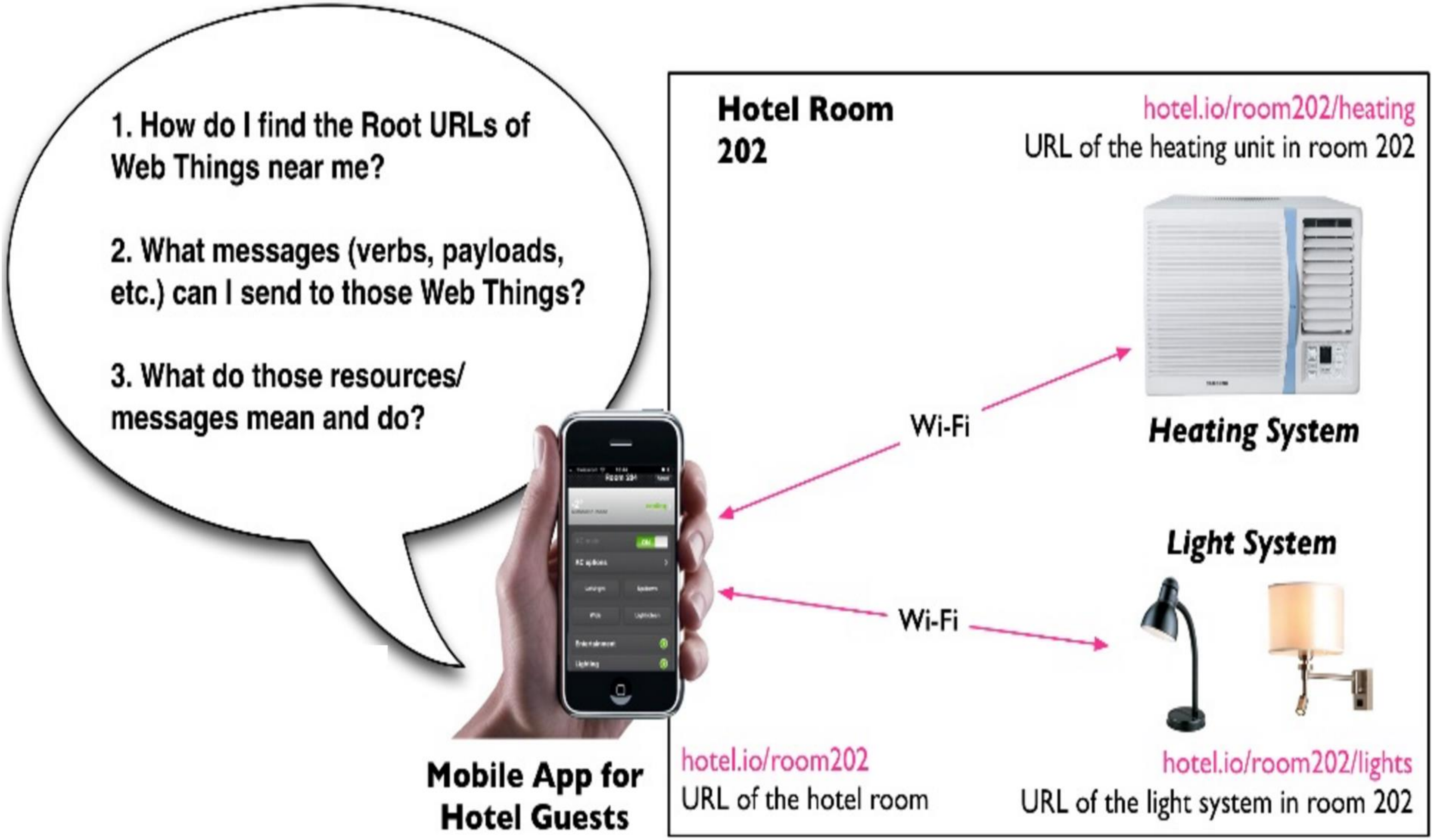
IoT – Find Layer



Web protocols cover the "How" not the "What"

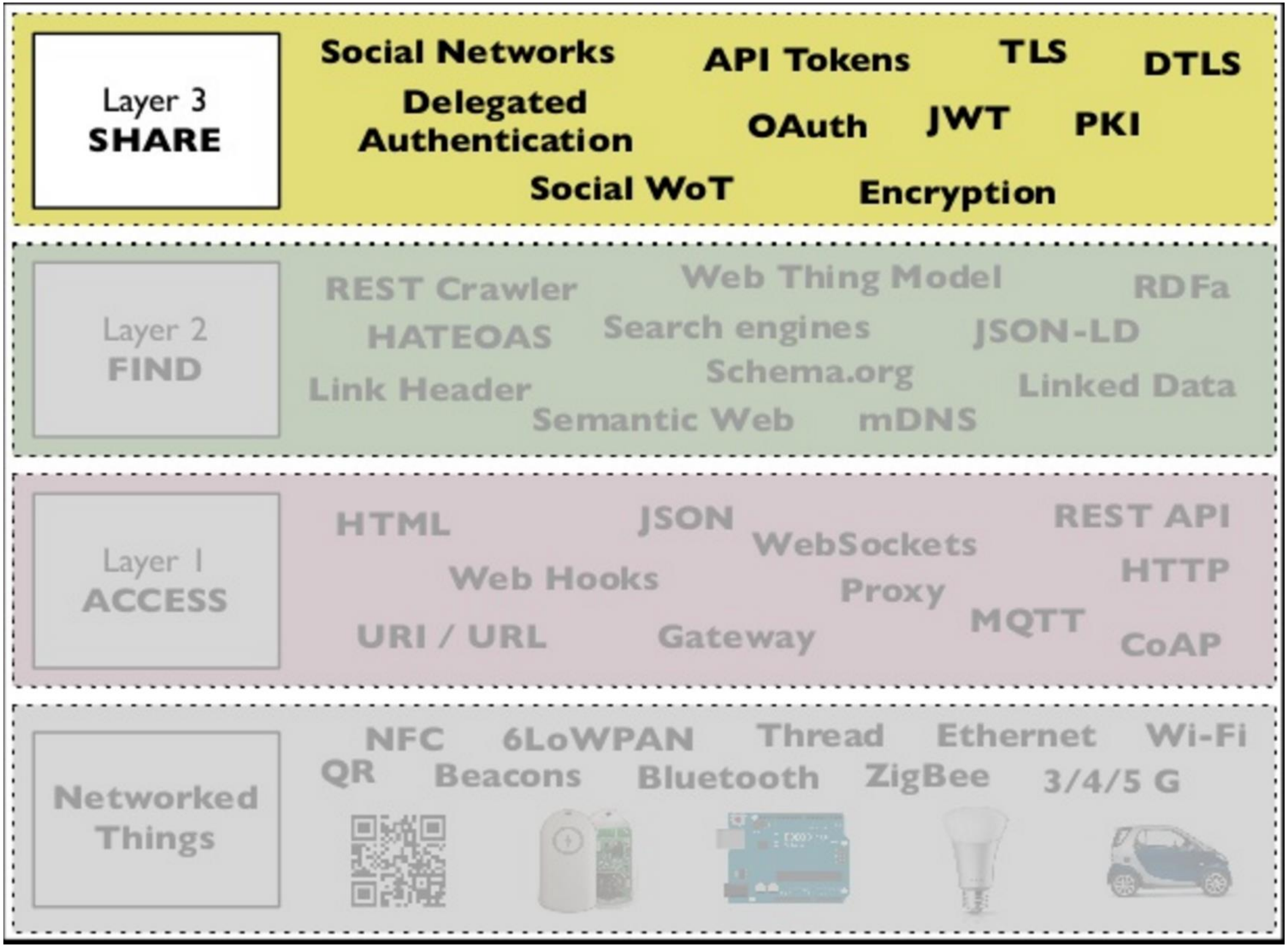
The findability problem: describe and discover the Things !

IoT – F.L



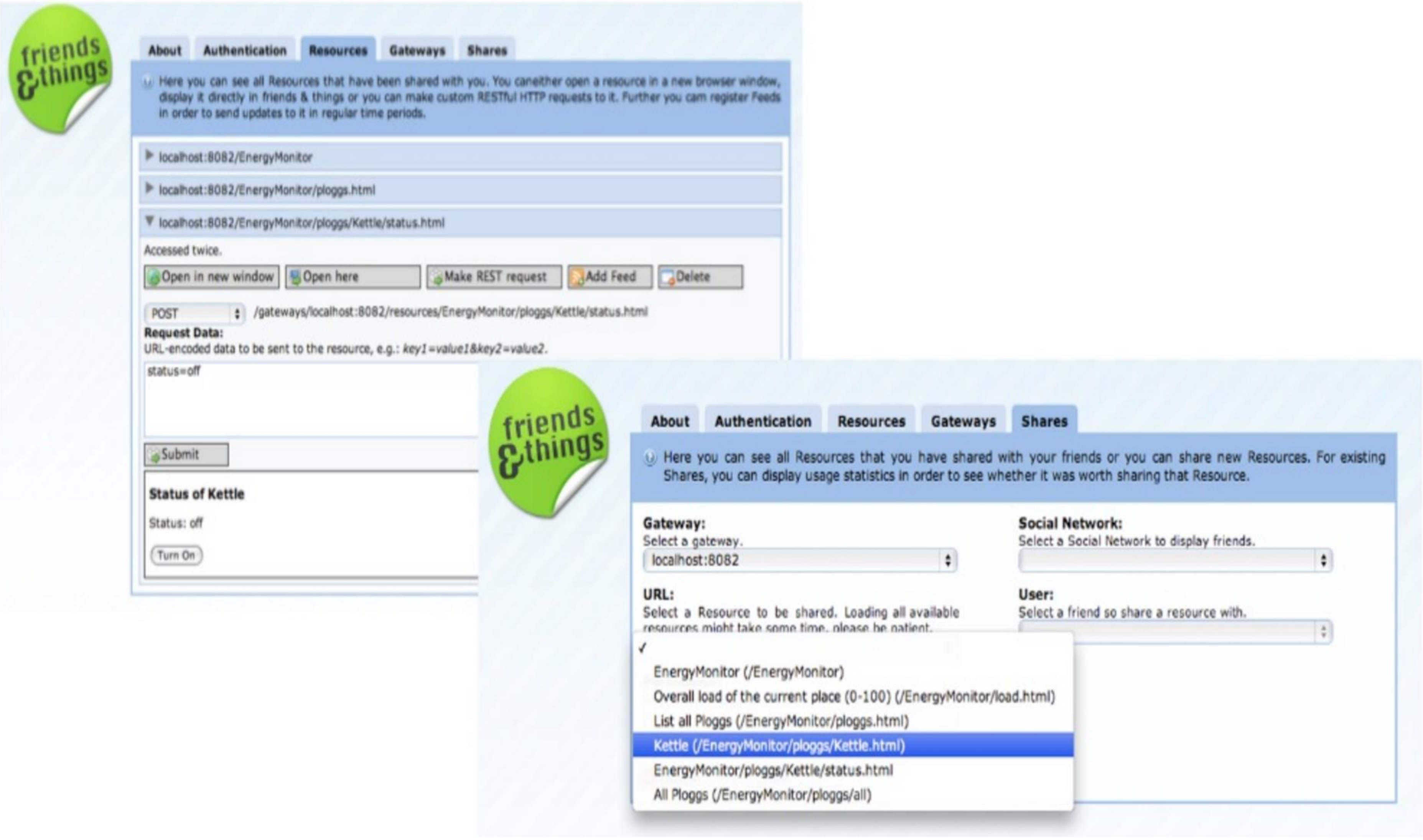
1. How do I find the Root URLs of Web Things near me?
2. What messages (verbs, payloads, etc.) can I send to those Web Things?
3. What do those resources/ messages mean and do?
Hotel Room 202
hotel.io/room202/heating
URL of the heating unit in room 202
Wi-Fi
Heating System
Light System
Wi-Fi
Mobile App for Hotel Guests
hotel.io/room202
URL of the hotel room
hotel.io/room202/lights
URL of the light system in room 202

IoT – Share Layer



Securing and sharing Things !

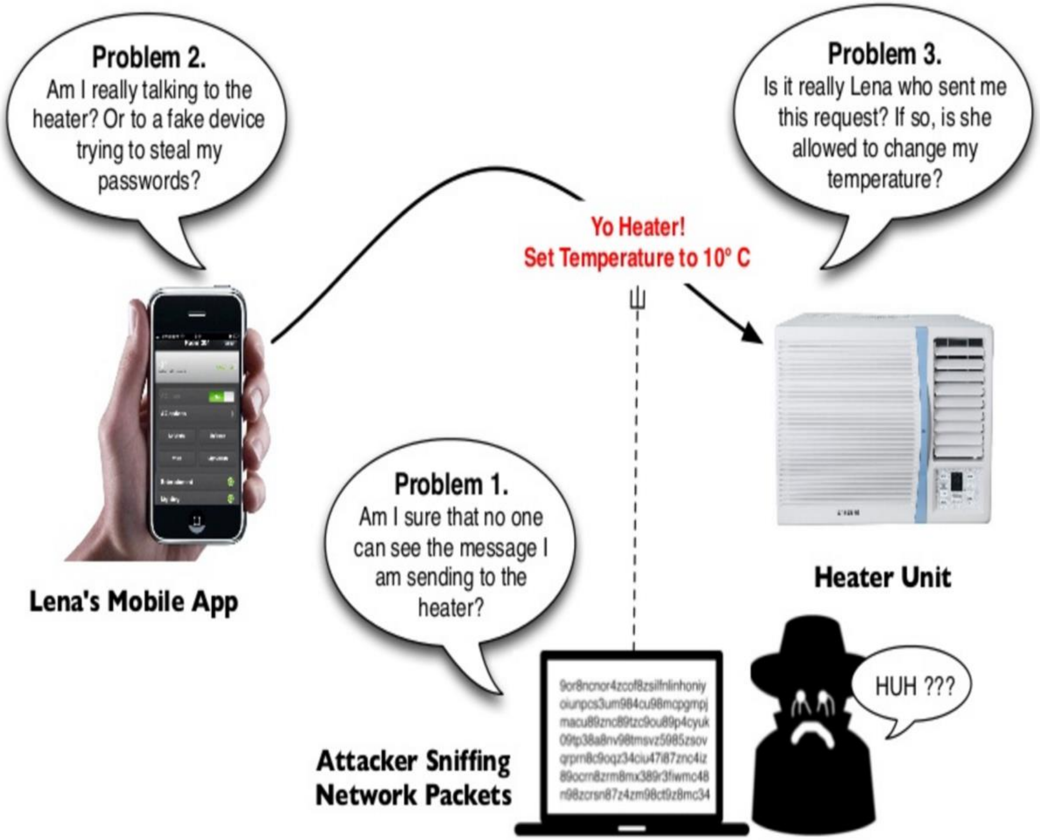
IoT: Sh. Layer – The Social Web of Things



IoT: Sh. Layer – The Social Web of Things

UniPadova MobileLab Research Group

IoT: Sh. Layer - Security



Security by obscurity never helps

- Better off with open protocols!

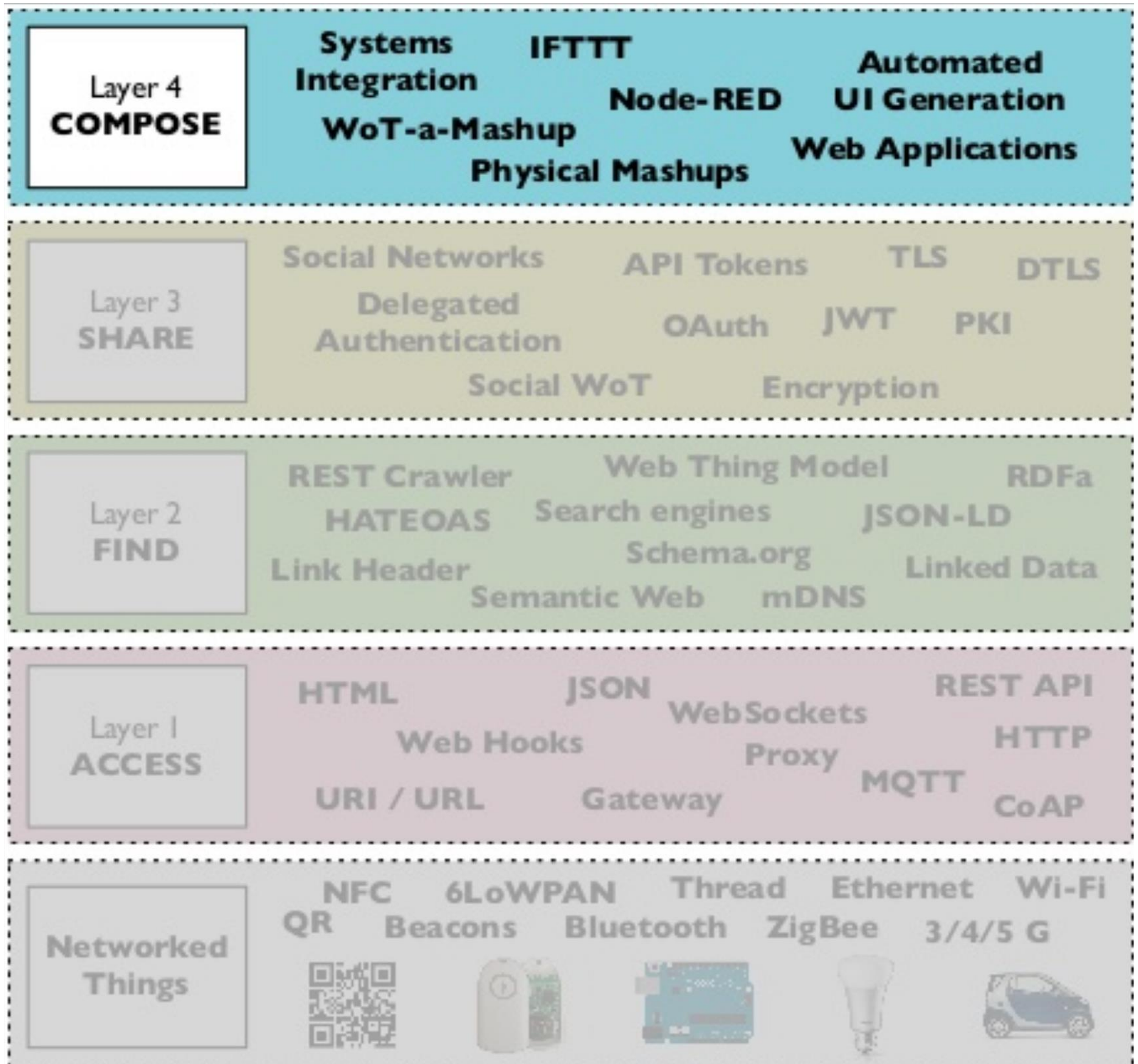
Technical challenges

- TLS can be heavy for resource constrained devices
- DTLS, TLS on UDP for constrained devices

Things on the Web = Things on the Web!

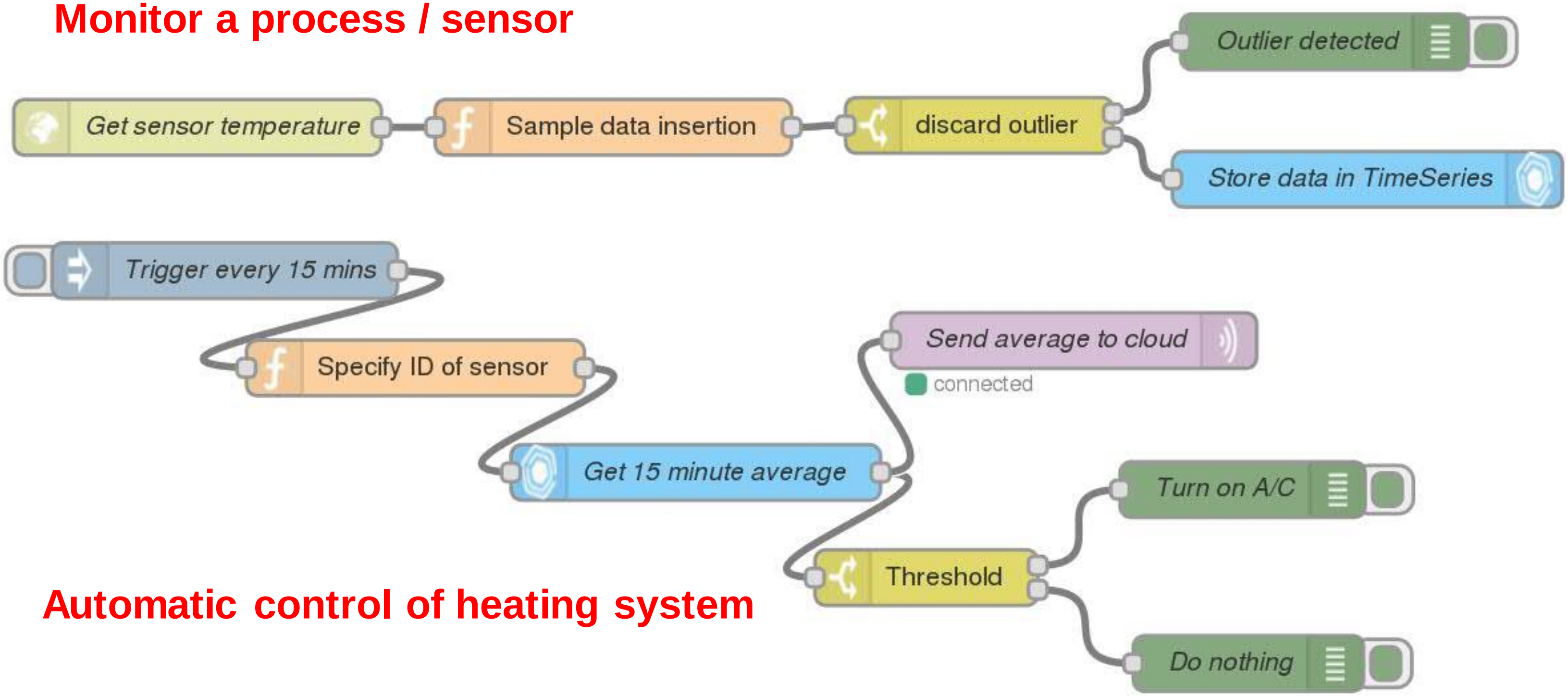
- DDoS attacks
- UDP flooding / TCP SYN attacks
- Hacking the physical world
  - e.g., **Shodan**, Baby Monitors

IoT – Compose Layer



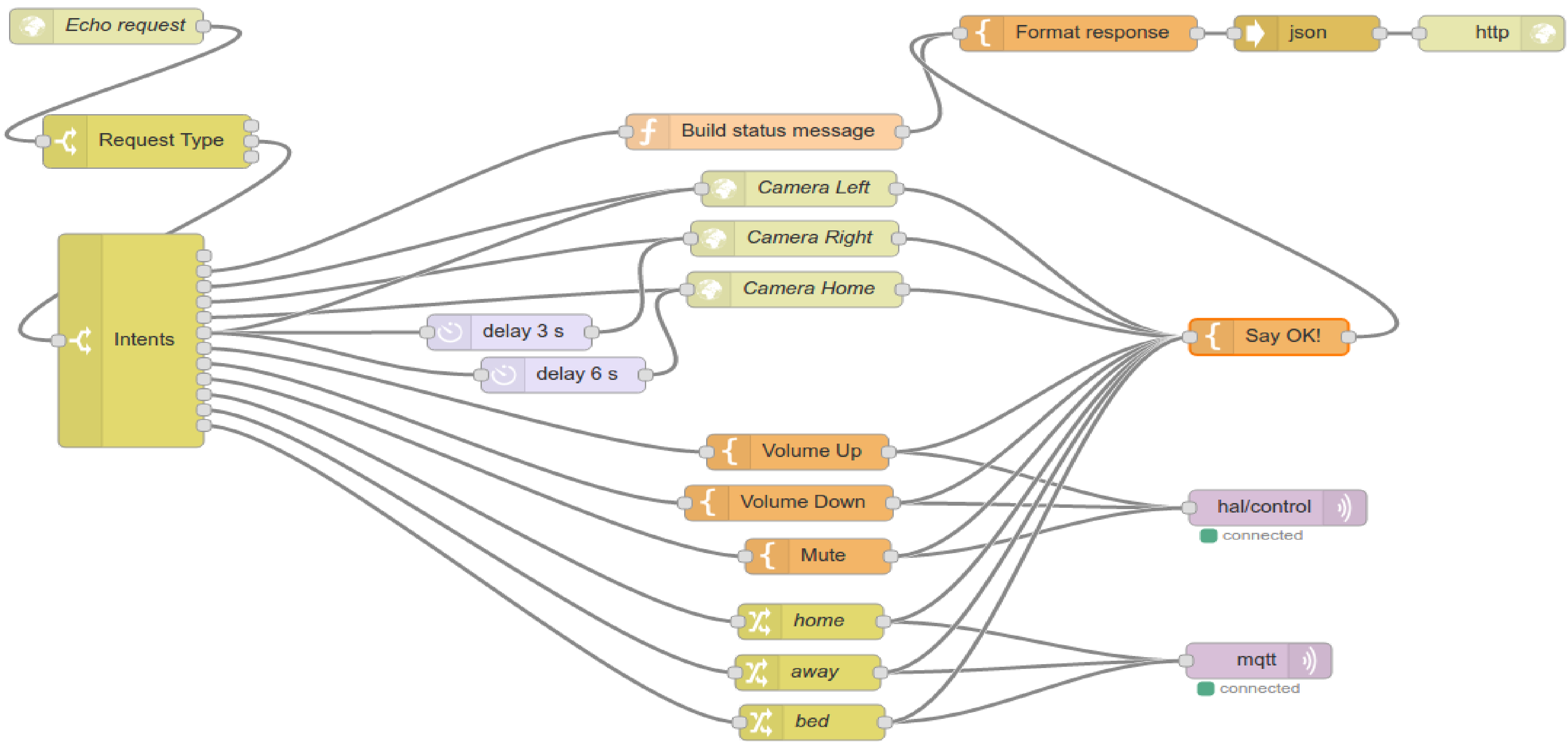
IoT – Layer 4

Monitor a process / sensor



Automatic control of heating system

IoT – Layer 4



- **Node-red**: tool for composing together hardware devices, APIs and online services
- And a lot of other interesting frameworks…

The S.C.A.L.E Taxonomy

(Challenges)

The S.C.A.L.E scheme

Major UC challenges, on a very high level:

S – SCALABILITY
- how to support cooperation of "zillions" of components?
- how to support nomadic users around the globe?

C – CONNECTIVITY
- how to "easily" connect these zillions? Several levels of abstraction:
  - wireless networks – a blessing and a curse (unreliable!)
  - most issues come *above* wired/wireless net (note: overlap with scalability):
    - how to find/understand your peers? How to enable zero configuration
    - how to design networks for zillions^2 of connections, without central-server bottleneck

A – ADAPTABILITY
- usage during daily work, surrounded by 100s of components: need *minimal* interaction
- major approach: context-aware computing – use it to automate tasks & reduce options
- why "adaptability"? adapting-to-particular-user (user *modeling)* focused beyond context-awareness

L- LIABILITY
- term indicates: we must go beyond today's IT security solutions (not goals), since
  - today's solutions do not scale (centralized components?), are not "humane" (see below), …
  - … & don't flexibly consider conflicting (privacy, traceability) & related goals (dependability etc.)

E – EASE-OF-USE
- adaptability permits "minimal" …, ease-of-use means "optimal" interaction (related!)
- issue: optimal use & combination of modalities, advancement of specific modalities
- issue: "understanding" natural input: a) xxx-to-text; b) text-to-meaning; "intelligence"?

S.C.A.L.E - Scalability

- **S – SCALABILITY**
  (is a "top priority" challenge → reflected in acronym: scale)
  A. Network Scalability: UC leads to (potential) cooperation of "zillions" of devices
     - thus, solutions need to work efficiently with zillions of components

  most relevant areas (basically, *alternatives* for addressing technical scalability):

  1. bionics i.e. bio-analog computing
     - neural networks, cooperating robots: huge fields, only marginal importance for UC
     - ant colonies – often simulated / executed on single computer today; swarms, autonomous computing …
  2. Future communication/cooperation (pub/sub; P2P, Grid) – see further below (C – connectivity)
  3. Locality of data and content
     - Not everything needs to be available and accessible globally
     - Data aggregation at intermediate points

An example - Localized, aggregate data

Qualcomm’s LTE-Direct presentation

S.C.A.L.E - Connectivity

Global interconnection of UC components is related to the following (and to "scalability" above):

A. Scalable Communication

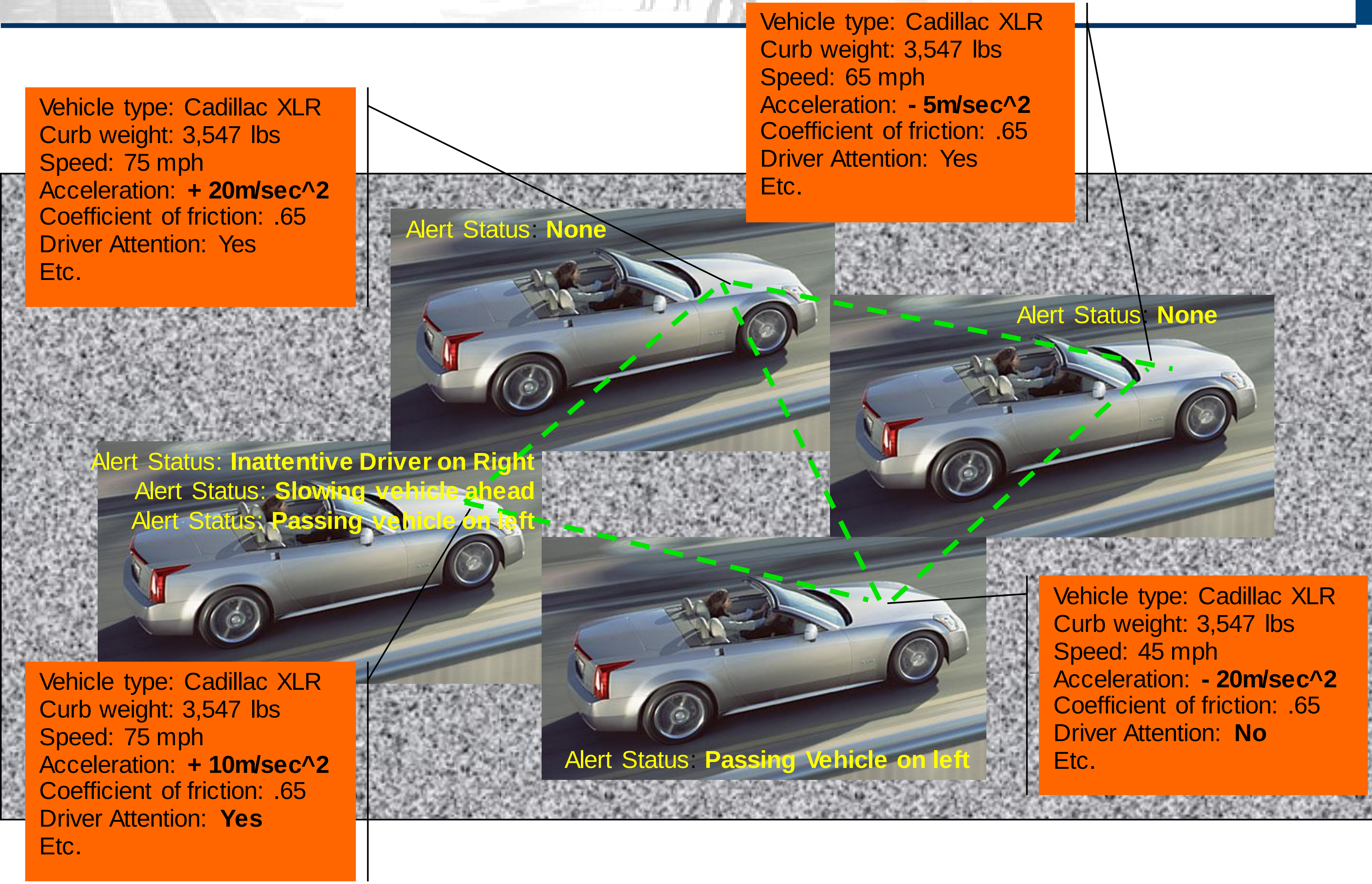
1. wireless networks: (often!) a prerequisite for higher layers. 5G the solution?
2. event based communication: praised as *the* UC connectivity approach

- means "push" paradigm, a prerequisite for scalable open cooperation of components (supersedes client/server!);
- remaining problems (advertising, openness, integration of other paradigms)
- plus: what else is needed in UC middleware (e.g., disconnections are a norm rather then an exception)

B. Scalable Cooperation

1. Overlay Nets: overlay networks in the Internet; at least 3 classes:
   a. Peer-to-Peer Networks: no centralized bottleneck, scale well?
   b. Opportunistic Networks: ad hoc net (node proximity) parallels global human "network"
   c. Cloud Computing: dynamically available resources parallel fluctuating resource demands
2. Service Discovery: prerequisite for zero configuration

An Example – V2V communication



An example – CarFi Demo

Enabling V2X in Urban Landscapes

S.C.A.L.E - Adaptability

A. Context Awareness (adaptation to "situation of use")

- sensed context: what sensors can measure (temperature, shock, location, …)
- modeled context: info held in "other" software/DB: tasks & activities etc.
- inferred context: built from (several?) sensed or modeled contexts, e.g., GPS→street … co-located chemicals → dangerous!, is always modeled
- note: context "ages", is "probabilistic"/maybe contradictory (sensor imprecise? calendar entry gives different location than GPS sensor?)
- most investigated context: location
  - maybe absolute or relative, outdoor or outdoor

B. User Awareness (adapt to user(s) - and, mid term, provider?)

- technology? "usual suspects": user models, profiles&preferences, user agents
- *great challenge:* the huge crowd of "new" users
  - *unexperienced, hands/eyes free, little attention*
  - *understand their actions → support them!*

S.C.A.L.E - Liability

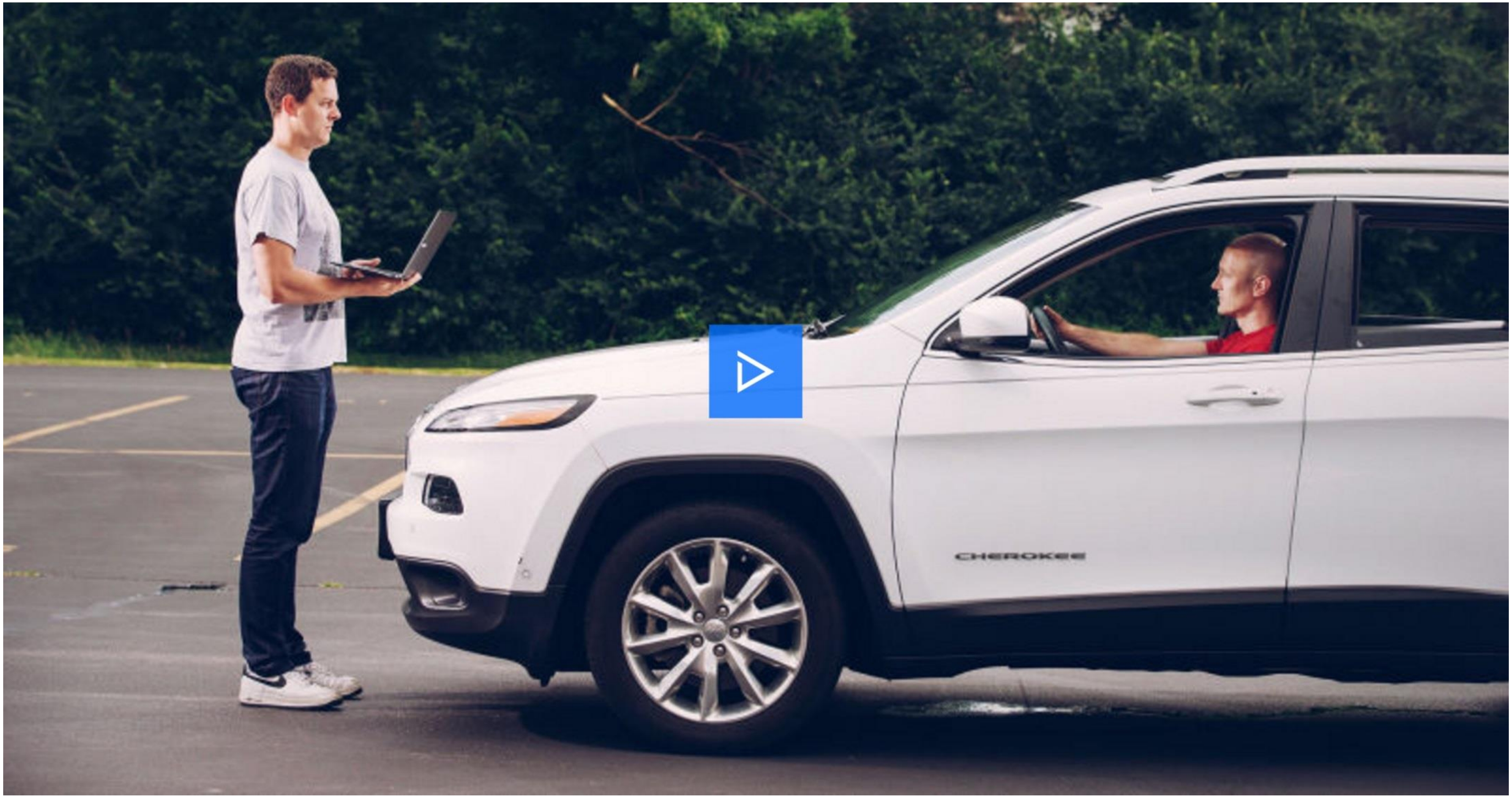
Liability :== protection of actors *and* those concerned by actions (peers, third parties, society) through "right" mix of protection/prosecution – all in presence of zillions of peers; liability = "security and beyond"

A. Scalable security:

- Machine-2-machine communication, ad hoc "encounters": PKI not viable
  - cannot check certificate chain with (central!) roots zillions of times per second!
  - even if so: a party may change (e.g., due to virus) zilliseconds after check
  - maybe: not always/reliably connected!
  - early approaches: resurrecting duckling++, TCI, … : → viable overall solution?
- there ain't no end-2-end encryption (cf. https-connection vs. "frontend" password-spyware)

An example – what can possibly go wrong???

Wired – Car hijacked remotely



How ?

- " by sending carefully crafted messages on the vehicle's internal network known as a CAN bus"
- Which was the "attack vector" ?
- Controller Area Network(CAN)-bus
  - Message-based for the vehicle-bus designed to microcontrollers to communicate with each-other
  - No security features in the standard
  - applications are expected to deploy their own security mechanisms
- Read This if curious

S.C.A.L.E – Ease-of-Use

remember: optimal use & combination of modalities (UI-adaptability may be considered a subset of ease-of-use)

A. **"multimodal interaction"**

simple distinction: hands&eyes- vs. mouth&ears-interaction →

1. advanced hands&eyes interaction: GUIs predominant, but further developments needed
   - examples: focus + context-displays, 3rd dimension (VR), 4th dimension (dynamic displays), immersion, narration
2. mouth&ears interaction: voice underdeveloped today, great potential! → nomadic (hands-/eyes free) operation
   - but: needs speech understanding, AI recent improvements
3. integration of HCI and SWE(ng): the grand challenge!
   - today: HCI before & after SWE – but "incompatible"

- Check This

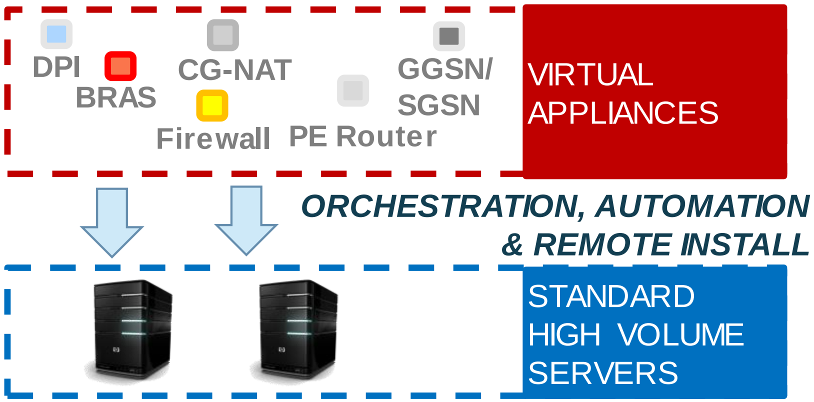
The NFV Concept

A means to make the network more flexible and simple by minimising dependence on HW constraints

Traditional Network Model: APPLIANCE APPROACH

- Network Functions are **based on specific HW&SW**
- **One physical node per role**

Virtualised Network Model: VIRTUAL APPLIANCE APPROACH



- Network Functions are **SW-based over well-known HW**
- **Multiple roles** over **same HW**

Source: Adapted from D. Lopez Telefonica I+D, NFV

5G – Network Slicing Concept