An introduction to the Internet of Things (IoT)

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MdF version 1.7 2022-02

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Course objectives - Summary

- The main objective is this lecture is to give the audience an opportunity of understanding what the Internet of Things is about, what has been done (sample architecture design, protocols, proposed solutions) and what still remains to be addressed, as well as which are the enabling factors of this evolutionary process and what are its weaknesses and risk factors.
- Section 1: Introduction
- Section 2: we introduce and compare the different visions of the IoT paradigm, which are available from the literature.
- Section 3: IoT main enabling technologies, IoT reference architecture. What makes IoT architecture and projects specific?
- Section 4: IoT applications design concepts. Example of IoT application development with Rasperry Pi and integration with cloud-based IoT platform.
- IoT mini-project team exercise
- Section 5: Real-life IoT project examples
- Section 6: open issues on which research is focusing such as addressing, networking, security, privacy, and standardization efforts.
- Conclusion

An introduction to the Internet of Things - Agenda

I. Internet of Things introduction (1/2)

- **The Internet of Things (IoT) is a paradigm that has rapidly gained ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as sensors, actuators, Radio-Frequency IDentification (RFID) tags, smartphones, etc. – which through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals.**
- **The IoT idea has a high potential impact on several aspects of everyday-life and behavior of potential users.**
  - From the point of view of a private user, the most obvious effects are (will be) visible in both working and domestic fields. In this context, domotics, assisted living, e-health, enhanced learning are only a few examples.
  - From the perspective of business users, the most apparent consequences are in fields such as, automation and industrial manufacturing, logistics, business/process management, intelligent transportation of people and goods.
  - IoT is included by the US National Intelligence Council in the list of six "Disruptive Civil Technologies" with potential impacts on US national power. (*)

(*) <http://www.dni.gov/nic/NIC_home.html>

I. Internet of Things introduction (2/2)

- **still faces many challenges, both technological as well as social issues**
- **Central issues :**
  - full interoperability of inter-connected devices possible
  - higher degree of smartness by enabling their adaptation and autonomous behavior
  - guarantee trust, privacy, and security.
- **New problems concerning**
  - the networking aspects.
  - low resources in terms of both computation and energy capacity.
  - scalability

  Thus the proposed solutions need to pay special attention to resource efficiency besides the obvious scalability problems.
- **Several industrial, standardization and research bodies are currently involved in the activity of development of solutions to fulfill the highlighted technological requirements.**

Internet of Things – Market facts

- **The Western Europe market for internet of things (IoT) solutions will grow $507.7 billion in 2013 to $2.1 trillion in 2020 (a 22.8% CAGR)**
  - Source: **IDC**, Date published: **05/29/2014**
- **The Western Europe installed base of internet of things (IoT) will grow from 2.4 billion units in 2013 to 8.3 billion units in 2020 (a 19.4% CAGR)**
  - Source: **IDC**, Date published: **05/29/2014**
- **In 2020, spending on security related solutions and services will account for 6% of the total spending on Internet of Things (IoT)**
  - Source: **IDC**, Date published: **03/19/2014**

An introduction to the Internet of Things - Agenda

IoT perspectives - a first "thing-oriented" definition

- **"Internet of Things" is composed of two terms:**

→ The first one pushes towards a network oriented vision of IoT

→ The second one moves the focus on generic ''objects" to be integrated into a common framework.

- Differences, sometimes substantial, in the IoT visions raise from the fact that stakeholders, business alliances, re-search and standardization bodies start approaching the issue from either an ''Internet oriented" or a ''Things oriented" perspective, depending on their specific interests, finalities and backgrounds.

IoT perspectives - a first “thing-oriented” definition

Definition 1 (Things-oriented): **“a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols”.**

→**This implies a huge number of (heterogeneous) objects involved in the process.**

→**Most challenging issues: the object unique addressing and the representation and storing of the exchanged information**

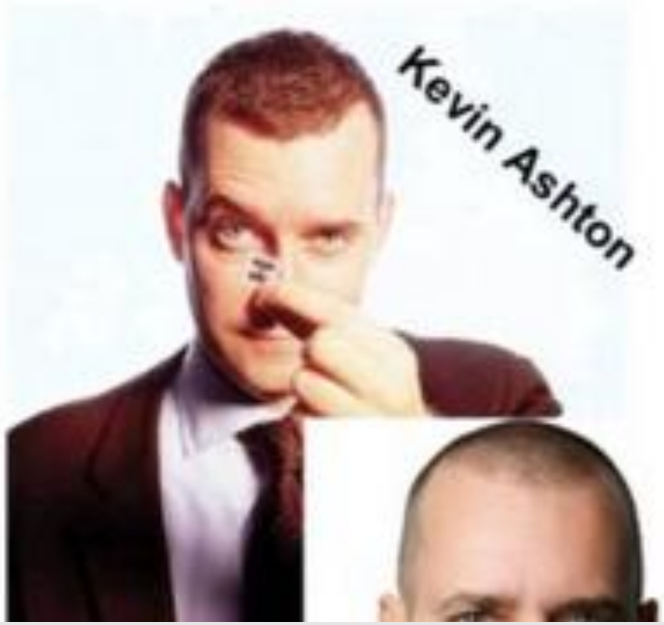
→The terms “Internet of Things” is attributed to the Auto-ID Labs, a world-wide network of academic research laboratories in the field of networked RFID and emerging sensing technologies.

IoT Initial definitions

Photo credit: Wikipedia

- ✓ 1832 - In the Beginning, there were… Things… Paul L. Schilling's "Electromagnetic Telegraph"[1]
- ✓ 1991 - Mark Weiser, chief scientist at Xerox Park, publishes "The Computer for the 21st Century" – 'making the computer disappear'[2]

The "Father" of the Term - Internet of Things



1999 - Concept

Title of a presentation he gave at Proctor & Gamble where he described the potential impact of linking RFID in P&G's supply chain to the Internet[3].

2009 - Clarification

"We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory[3].

2013 – Celebration

April 9th International Internet of Things Day

Tweet – "Happy Internet of Things Day! #IoT"

(*) Kevin Ashton (born 1968) is a British technology pioneer who cofounded the Auto-ID Center at the Massachusetts Institute of Technology (MIT), which created a global standard system for RFID and other sensors. He is known for inventing the term "The Internet of Things" to describe a system where the Internet is connected to the physical world via ubiquitous sensors. Source: Wikipedia

Current definitions and decriptions related to the IoT

- **Machine to Machine** - describes any technology that enables automated wired or wireless communication between mechanical or electronic devices

  Whatis.com

- **Internet of Things** - the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

  Gartner

- **Pervasive Computing** - the idea that almost any device, from clothing to tools to appliances to cars to homes to the human body to your coffee mug, can be imbedded with chips to connect the device to an infinite network of other devices.

  WEBOPEDIA[tm]

- **Ambient Intelligence** – where computers are used as proactive tools assisting people with their day-to-day activities, making everyone's life more comfortable

  International Symposium on Ambient Intelligence

IoT perspectives and Internet-oriented definitions

ITU vision of the IoT: (*)

"from anytime, anyplace connectivity for anyone, we will now have connectivity for anything".

A similar vision and definition from the European Commission: (**)

"IoT involves things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts".

"a world where things can automatically communicate to computers and each other providing services to the benefit of the human kind".

Internet oriented approach proposes a vision of IoT as a global infrastructure which connects both virtual and physical generic objects and highlights the importance of including existing and evolving Internet and network developments in this vision.

(*): ITU International Telecommunication Union is the United Nations specialized agency for information and communication technologies – ICTs.
(**): http://ec.europa.eu/digital-agenda/en/internet-things

IoT perspectives and Semantic-oriented definitions

- The Semantic-oriented approach recognizes that the number of items involved in the Future Internet is to become extremely high.

→ **how to represent, store, interconnect, search, and organize information generated by the IoT?**

→ **semantic technologies could play a key role can exploit appropriate modeling solutions for:**

- o things description,
- o reasoning over data generated by IoT,
- o semantic execution environments and architectures that accommodate IoT requirements and scalable storing and communication infrastructure.

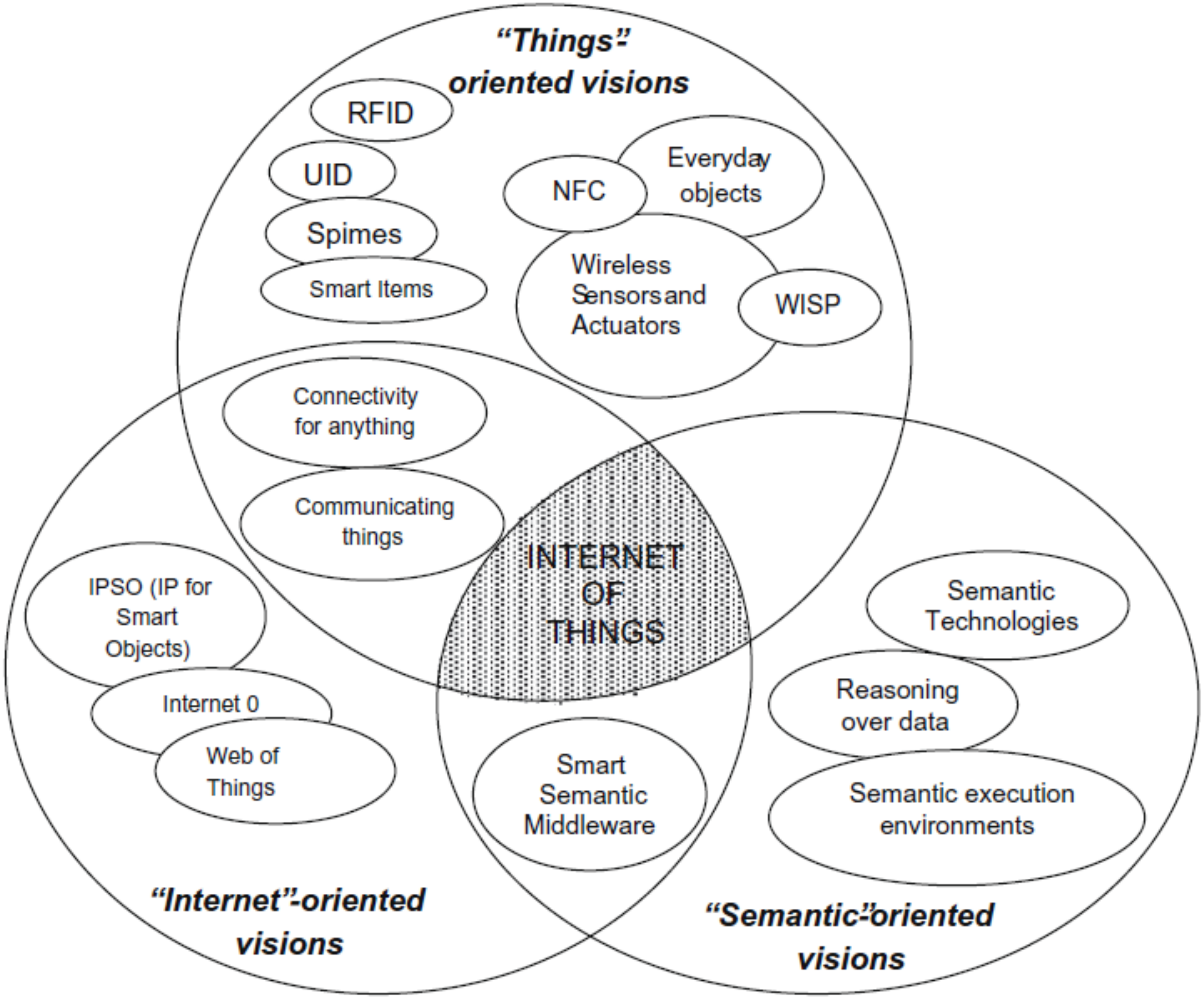
- "Web of Things": **Web standards are re-used to connect and integrate into the Web everyday-life objects that contain an embedded device or computer.**

IoT perspectives and definitions: 3 main visions

The IoT paradigm is the result of the convergence of the three main visions addressed above.

IoT becomes the **enabling architecture** for the **deployment** of independent federated **services and applications,** characterized by a high degree of **autonomous data capture, event transfer, network connectivity and interoperability.**

The "Internet of Things" is a paradigm resulting of the convergence of different visions.



An introduction to the Internet of Things - Agenda

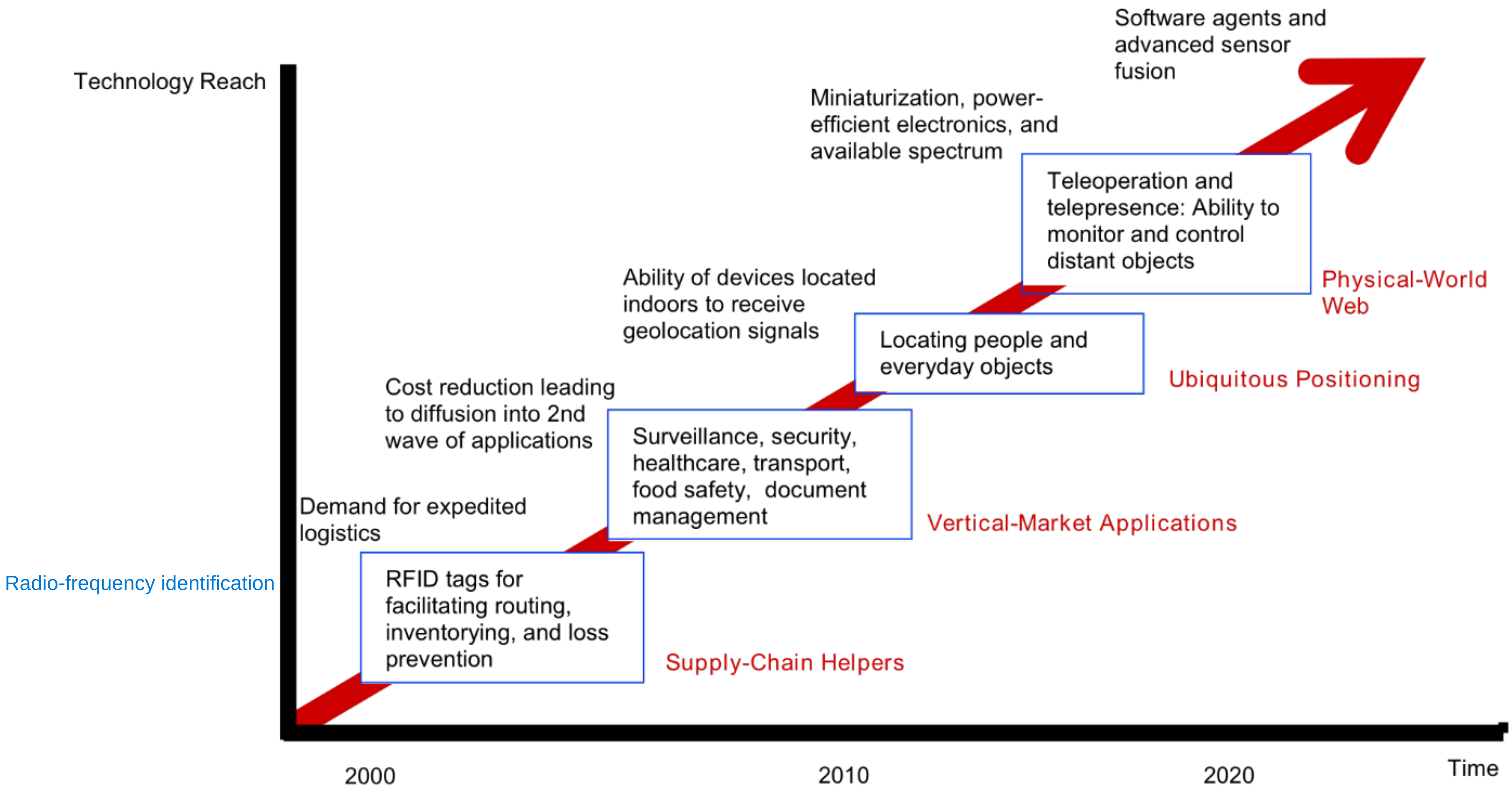
IoT Enabling technologies

- **The implementation of the IoT concept in the real world is possible through the integration of several enabling technologies:**
  - **Identification, sensing and communication technologies**

- The reduction in terms of size, weight, energy consumption, and cost of the radio will allow us to integrate radios in almost all objects.
- The wireless communications allowed us to deliver and deploy the vision of "anywhere, anytime, any media". Now "anything" can be added to the above vision, which leads to the IoT concept.

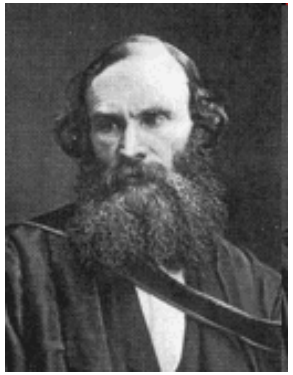
IoT technology Roadmap

TECHNOLOGY ROADMAP: THE INTERNET OF THINGS



Source: SRI Consulting Business Intelligence

IoT enabling technologies: Sensors
Lord Kelvin



- **"In physical science the first essential step in the direction of learning any subject is to find principles of numerical reckoning and practicable methods for measuring some quality connected with it. I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of *Science*, whatever the matter may be."**

- *[Popular Lectures and Addresses (1891-1894, 3 volumes) , vol. 1, "Electrical Units of Measurement", 1883-05-03]*

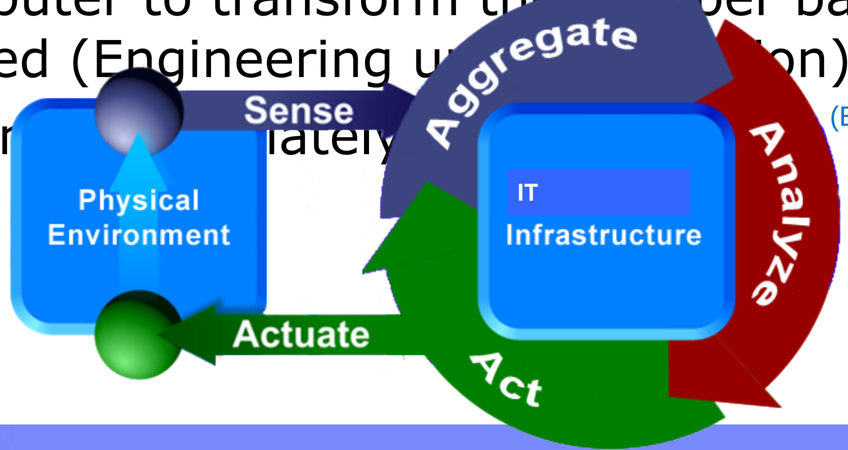
IoT enabling technologies: Sensors & actuators

Sensors are devices that measure real world conditions – like temperature, flow or position.

Actuators are devices that take actions in the real world – like valves, thermostats, or robots.

- In general, **how do sensor data integration work** ?
  - Find a phenomena that changes an electrical property when the physical property changes
  - Convert that electrical parameter in to a digital form
    - Analog to Digital Converter
  - Transmit the digital data to a computer
  - Apply an equation in the computer to transform the number back in to the physical quantity you measured (Engineering u... ...on)
  - Use the engineering unit datu... ...iately

    use the engineering unit datum appropriately



(Engineering uints converision)

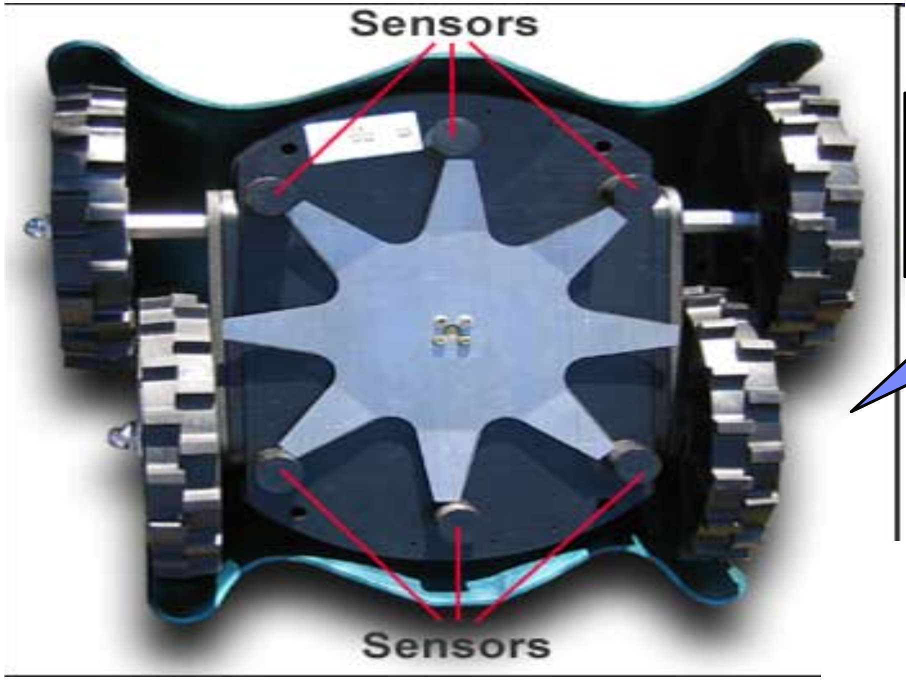
IoT enabling technologies: Sensors

- **Classic sensors**
  - Measure a physical property
    - Temperature
      - RTD (Resistance Temperature Detector), Thermocouple
    - Pressure
      - Direct
      - Strain gauges
    - Flow
    - Electrical Voltage and Current
- **Light sensors**
  - Light beam weighs very little, thus little impact on measured item
  - Often needs more local preprocessing
  - Examples
    - Embedded sapphire fiber optic in metal
      - Optical properties changed by heat, stress
    - Electricity passing through optical fiber loop
      - Faraday effect

IoT enabling technologies: Sensors (cont'd)

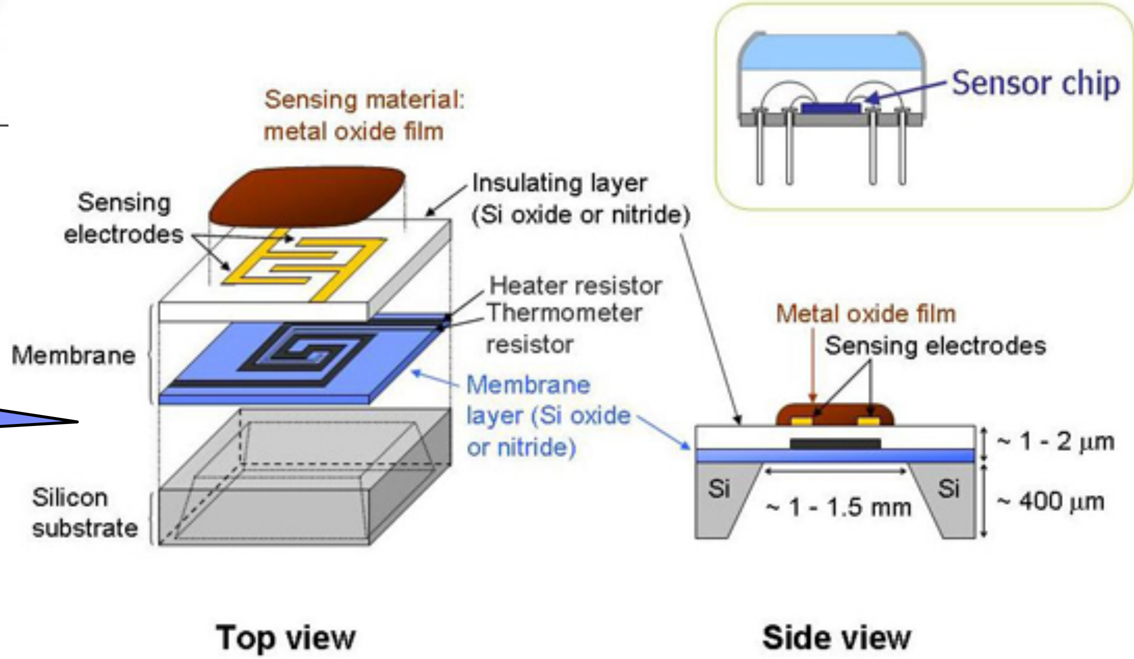
- **Biological**
  - Embedded
  - Implanted
  - Swallowed
- **Network of accelerometers**
  - used for computer hard disk drive protection also used for global earthquake sensing
- **Cameras / Imaging**
- **Motes:** Wireless Mesh Low Power Sensor Node, in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network

Sensor Examples



Lawn mowing robot

Gas sensor



IoT enabling technologies:
Why IoT network is different from “traditional” IP networks?

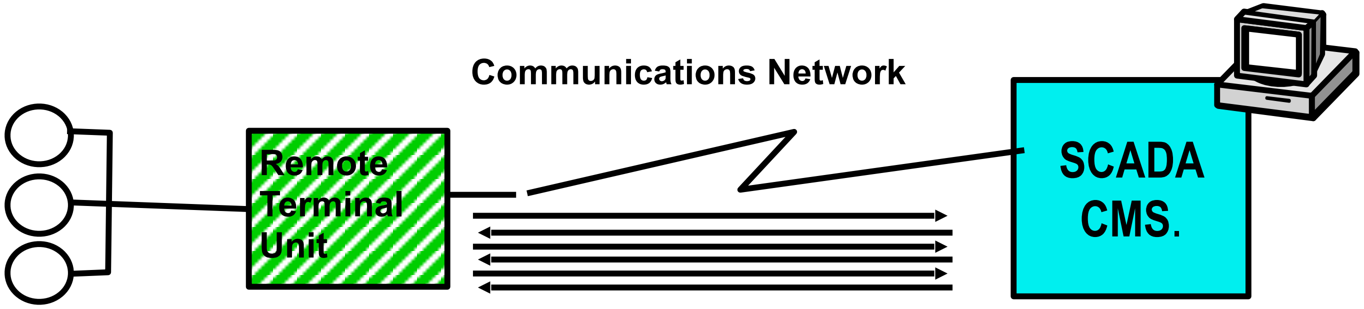
- Bandwidth constraints
  – x 100 less than WiFi
- Highly unreliable networks
  – x 10^{-12} error rate on an optical fiber compared to 30-40% loss rate
- Limited ressources (power, memory, CPU processing)
  – x 125 k less memory than a basic PC/Mac
- Extremely high scale network
  - N x 100 M of devices . eg. 2M devices for smart metering in the city of Vancover

Need to innovate - Design a new distributed architecture for the network, new protocols.

IoT enabling technologies: Sensor networks

- Sensor networks play a crucial role in the IoT.
  - can cooperate with RFID systems to better track the status of things, i.e., their location, temperature, movements, etc.
  - act as a bridge between physical and digital world.
- Sensor networks consist of a certain number (which can be very high) of sensing nodes communicating in a wireless multi-hop fashion.
- Usually nodes report the results of their sensing to a small number (in most cases, only one) of special nodes.

Need to enhance existing SCADA Implementations (Supervisory Control and Data Acquisition)



The RTU (Remote Terminal Unit) connects to physical equipments

- reads status data such as the open/closed status eg from a switch or a valve, reads measurements such as pressure, flow, voltage or current.
- controls equipment by sending signals to equipment, such as opening or closing a switch or a valve, or setting the speed of a pump.

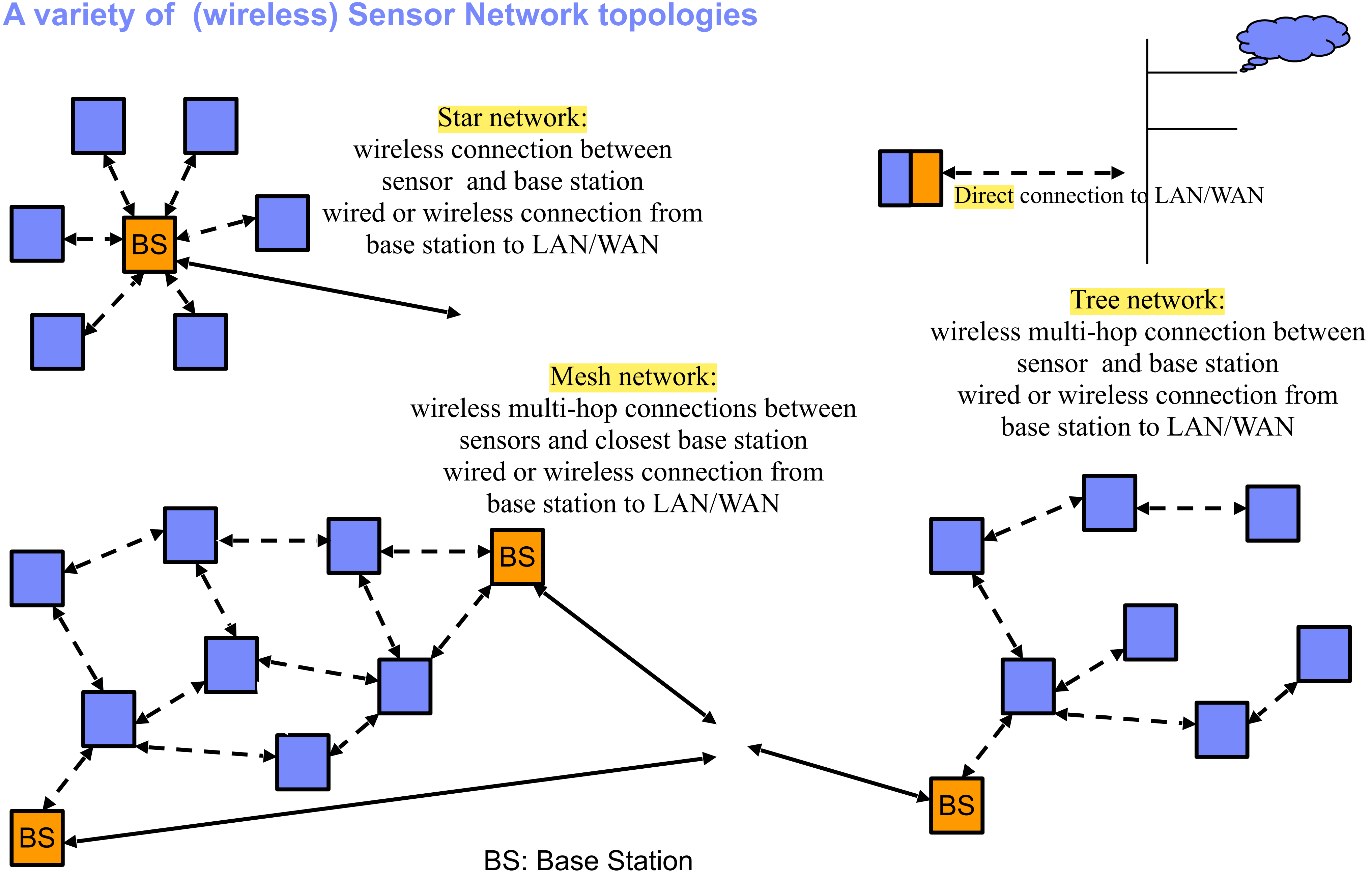
Need to enhance existing SCADA Implementations (Supervisory Control and Data Acquisition)

- Poll/Response Protocol performance paradigm: uses 100% of available bandwidth
- "Transport" is the "application". You cannot break them apart.
- One protocol for all field equipment limits new/mixed technologies
- It is not a "managed" network
- When SCADA system goes down... monitoring is down
- End point is normally a terminal or user monitoring data

→ Typically, these systems are not connected, or not easily connected, to back end e-business / Web-based applications:

- One-to-one data relationship between the host and field equipment
- Custom applications are required to access data for other apps.
- If data is needed for multiple applications, multiple custom connections are needed

A variety of (wireless) Sensor Network topologies

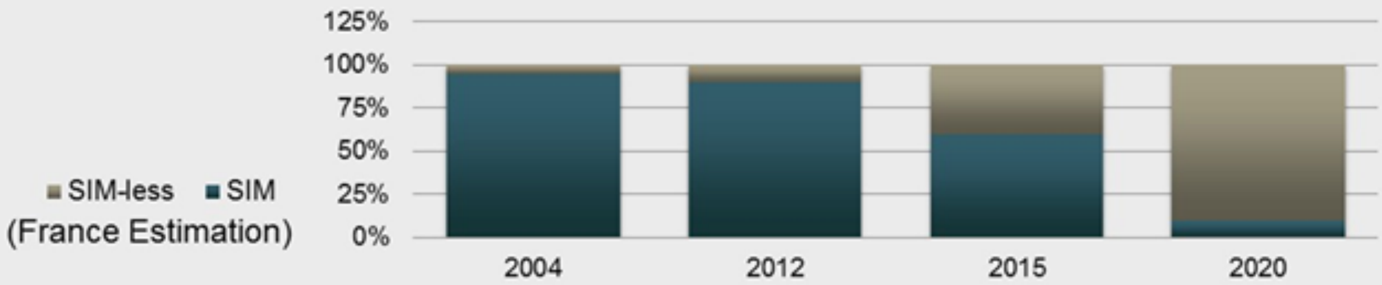


IoT enabling technologies: Sensor networks

- Design objectives **of the proposed implementations are**
  - **energy efficiency** (which is the scarcest resource in most of the scenarios involving sensor networks),
  - **scalability** (the number of nodes can be very high),
    - Common Transport
  - New communications options leveraging TCP/IP
    - Security with Authentication and Encryption
    - New networks - including wireless, always on
    - New network hardware (e.g. wireless modems)
  - reliability (the network may be used to report urgent alarm events),
  - robustness & flexibility (sensor nodes are likely to be subject to failures for several reasons) using proven Wireless IT architectures
    - Middleware Products eg Micro-Broker, Message Queing for Telemetry, …
    - Supervision Tools
  - **New Applications, distributed intelligence**
    - Predictive maintenance
    - Performance Optimization

How to connect all these devices?

- GSM/GPRS?
  - ✓ high data rates, bidirectional
  - ✓ long range, broadly available as infrastructure service
  - - requires SIM card for each end-device
  - - not particularly energy-efficient
  - - coverage is insufficient for specific types of applications
  - - cost is (prohibitively) high for specific types of applications
- WiFi, Bluetooth, ZigBee, 6LoWPAN?
  - ✓ high data rates, bidirectional
  - ✓ no SIM card required for each end device
  - - not universally available as infrastructure service
  - - short range requires complex mesh networking to cover larger areas



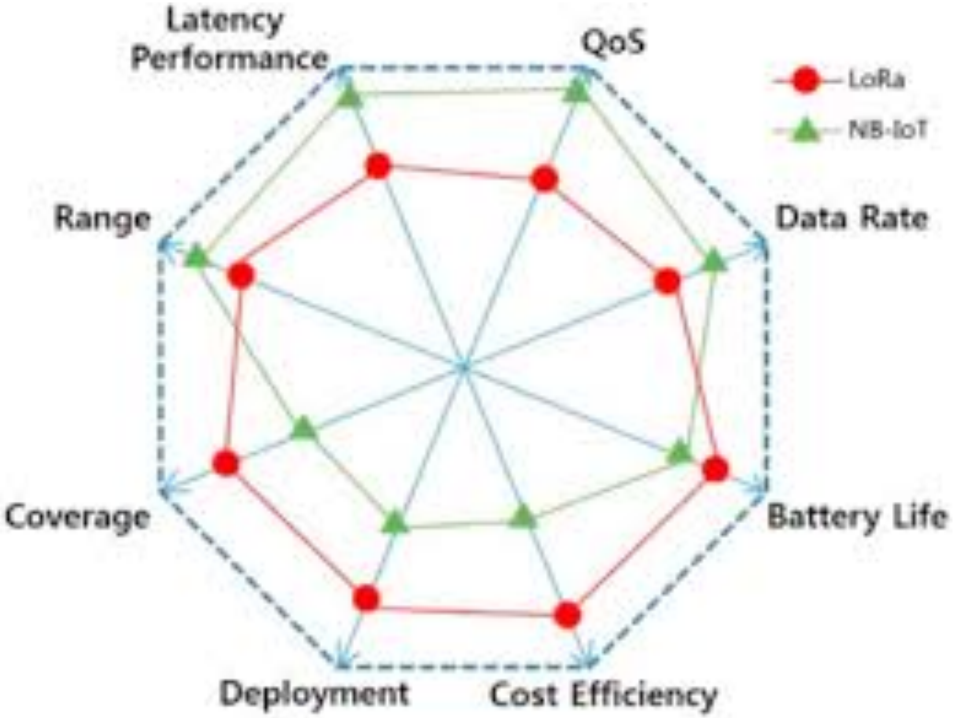
Building the Internet of Things – Example Standards

- **Networking**
  - IEEE - 802.15.4 (e-g) - Low-Rate Wireless Personal Area Networks (LR-WPANs)/
  - IETF - Internet Engineering Task Force
  - IETF - 6LowWPAN - IPV6 over low power wireless personal area network
  - IETF- ROLL – Routing over low power and lossy networks
  - IETF - CORE – constrained restful environments
- **Information and Data**
  - OGC SWE - Sensor Web Enablement
  - OGC PUCK - standard instrument protocol to store and automatically retrieve metadata
  - OASIS - MQTT – MQ Telemetry Transport (M2M)
  - DPWS – Devices Profile for Web Services
  - RFD – Resource Description Framework
  - MQTT – MQ Telemetry Transport IBM.
- **Identification and Tagging**
  - EPC TDS – Tag Data Standard
  - EPC TDT - Tag Data Translation machine-readable version of the EPC Tag Data
  - EPC LLPR - Low Level Reader Protocol specifies an interface between RFID Readers and Clients

OGC: Open Geospatial Consortium

How to connect all these devices? Choosing among various technologies

Considering the “link budget”



Considering multiple parameters

IoT enabling technologies: Sensor networks & IEEE 802.15.4

- **Most Sensor networks solutions are based on IEEE 802.15.4**
  - standard, which defines the physical and MAC layers for low-power, low bit rate communications in wireless personal area net-works (WPAN)

➢ **Basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s**. Tradeoffs are possible to favor more radically embedded devices with even lower power requirements. 100 kbit/s rate is being added in the current revision.

➢Even lower rates can be considered with the resulting effect on power consumption.

➢The main identifying feature is the importance of achieving extremely low manufacturing and operation costs and technological simplicity, without sacrificing flexibility or generality.

➢**Important features**:

- real-time suitability by reservation of guaranteed time slots,
- Physical media accessed through CSMA/CA protocol (Carrier sense multiple access with collision avoidance)
- integrated support for secure communications.
- Devices also include power management functions such as link quality and energy detection.

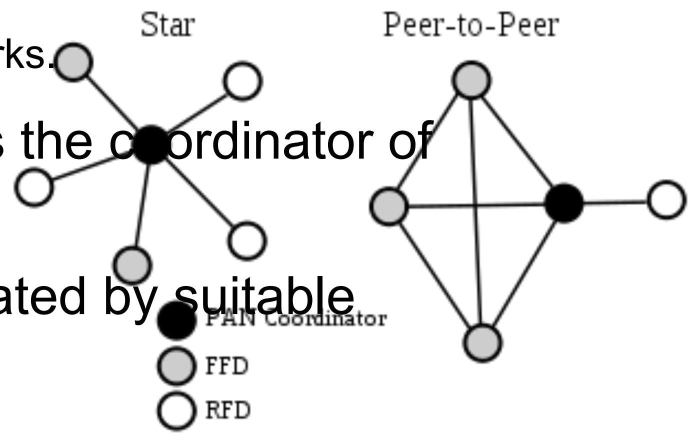
➢IEEE 802.15.4-conformant devices may use one of **three possible frequency bands** for operation.

- 868.0-868.6 MHz: Europe, allows 3 communication channels
- 902-928 MHz: North America, up to 30 channels
- 2400-2483.5 MHz: worldwide use, up to 16 channels

IoT enabling technologies: Sensor networks & IEEE 802.15.4

- The standard defines two types of network node.
  - **full-function device** (FFD). It can serve as the coordinator of a personal area network just as it may function as a common node. It implements a general model of communication which allows it to talk to any other device: it may also relay messages, in which case it is described as a **coordinator** (PAN coordinator when it is in charge of the whole network).
  - **reduced-function devices** (RFD). These are simple devices with very modest resource and communication requirements; due to this, they can only communicate with FFDs and can never act as coordinators

- **Topology**: Networks can be built as either peer-to-peer or star networks.
  - every network needs at least one FFD to work as the coordinator of the network.
  - networks are formed by groups of devices separated by suitable distances.
  - Each device has a unique 64-bit identifier.



IoT enabling technologies: Sensor networks & IEEE 802.15.4 (cont'd)

IEEE 802.15.4 does not include specifications on the higher layers of the protocol stack, which is necessary for the seamless integration of sensor nodes into the Internet. This is a difficult task for several reasons, the most important are given below:

- Sensor networks may consist of a very large number of nodes. This would result in obvious problems as today there is a scarce availability of IP addresses.
- The largest physical layer packet in IEEE 802.15.4 has 127 bytes; the resulting maximum frame size at the media access control layer is 102 octets, which may further decrease based on the link layer security algorithm utilized. Such sizes are too small when compared to typical IP packet sizes.
- In many scenarios sensor nodes spend a large part of their time in a sleep mode to save energy and cannot communicate during these periods. This is absolutely anomalous for IP networks.

Building a network ideal for Internet of Things (IoT)

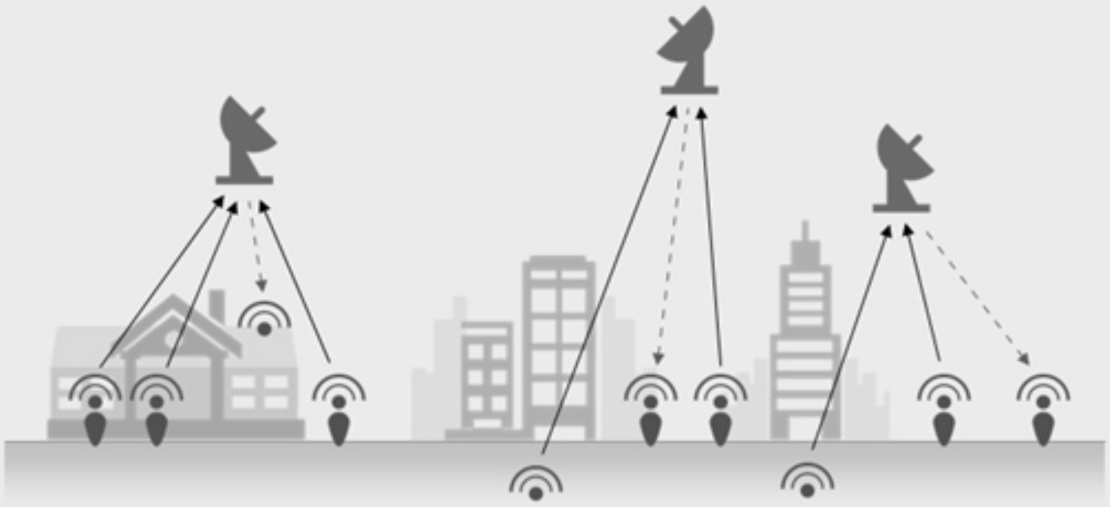
A 2-way wireless solution that:

- complements M2M cellular infrastructure,
- provides a low-cost way to connect battery operated and mobile devices to the network infrastructure.
- combining transceiver products with concentrator gateway, you can create networks with longer ranges and the capacity to handle millions of devices. You can also improve the battery lifetime of end-user devices, while minimizing signal interference.

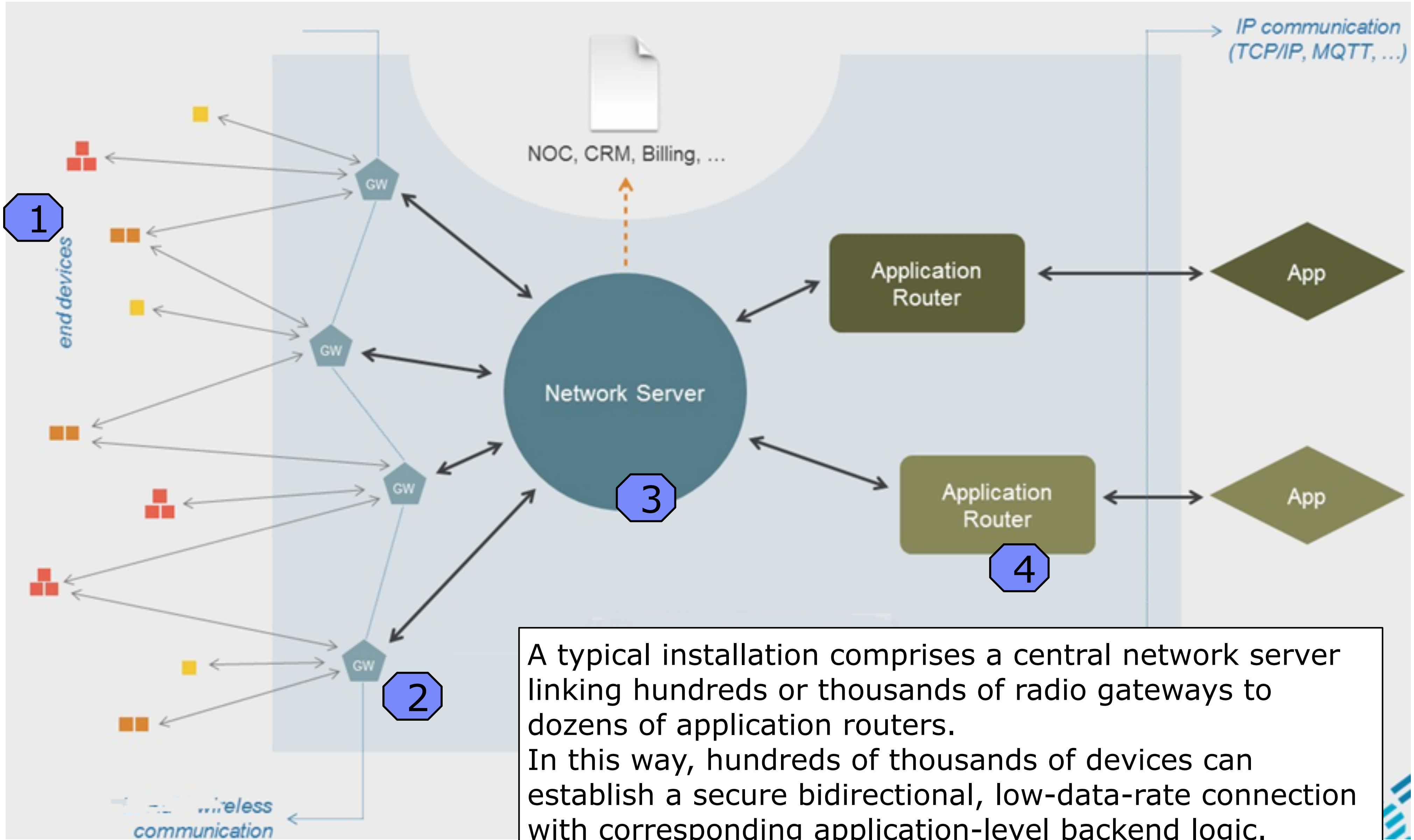
More than 22 billion devices will be connected by 2020. Given that this number far outstrips mobile (GSM) subscription estimations for 4G networks, there is one key question to be answered: How can this be made possible in a sustainable and scalable manner, e.g., without deploying 2–3 times more GSM base stations or routing billions of new machine-to-machine (M2M) interactions over private WLAN hotspots?
One answer to this question is by using a long-range, low-data-rate communications infrastructure that needs fewer base stations to serve more simple devices like online smoke detectors, temperature sensors or smart electrical heating controllers.

Taking into account IoT specific characteristics and requirements

- end-device characteristics
  - mobile, nomadic, or fixed
  - possibly located underground (e.g., smart meters) out of reach of existing wireless infrastructure
  - possibly battery-powered w/ a life time of years on a single set of batteries
- communication requirements
  - low data rate w/ traffic being uplink-biased
  - relaxed latency constraints
  - high interference robustness
- operator focus
  - ease of maintenance
  - cost-effectiveness
  - reliability and security

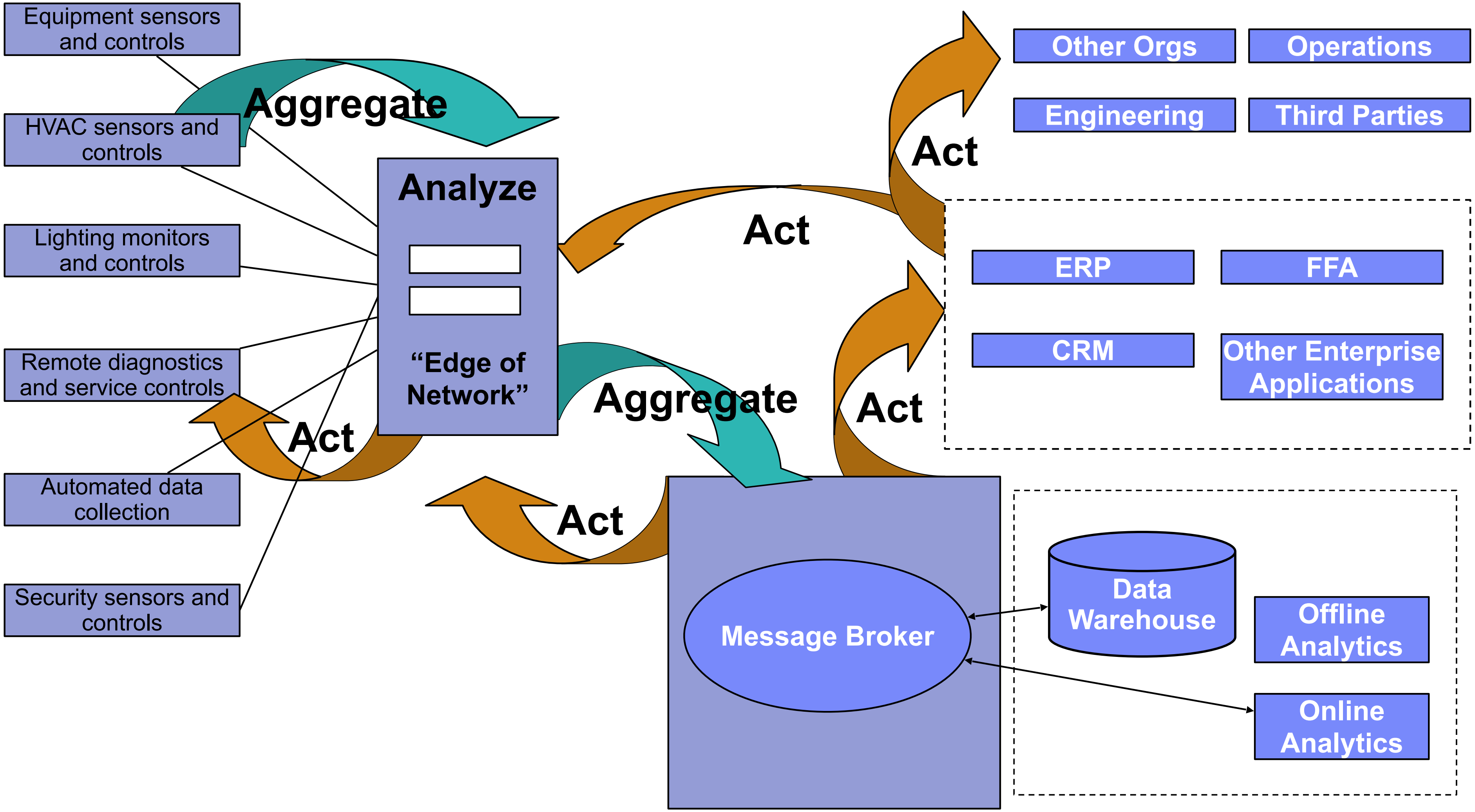


IoT architecture – Infrastructure overview



A typical installation comprises a central network server linking hundreds or thousands of radio gateways to dozens of application routers.
In this way, hundreds of thousands of devices can establish a secure bidirectional, low-data-rate connection with corresponding application-level backend logic.

Base Requirements: Aggregate – Analyze – Act
Where should the data be located? Centralized or at the edge of the network?



IOT architecture – Gateway functions and characteristics

- sends beacons time-synchronously
  - channels available for random access, GPS timestamp, GPS location information
- relays traffic between end devices and the network server (bi-directional)
  - adds timestamp and metadata to messages received from end devices
  - sends messages to end devices following a schedule set by the network server
  - may compensate for latency fluctuations on the link to the network server
- security
  - communicates with pre-configured network server via TLS, certificate-based authentication
  - cuts off traffic from “foreign” well-behaved end devices
  - limits impact on network server caused by traffic from malicious end devices
- fault tolerance
  - manual replacement of faulty gateways by operator
  - end devices are typically in the reach of more than one gateway or may (temporarily) extend their reach to regain connectivity

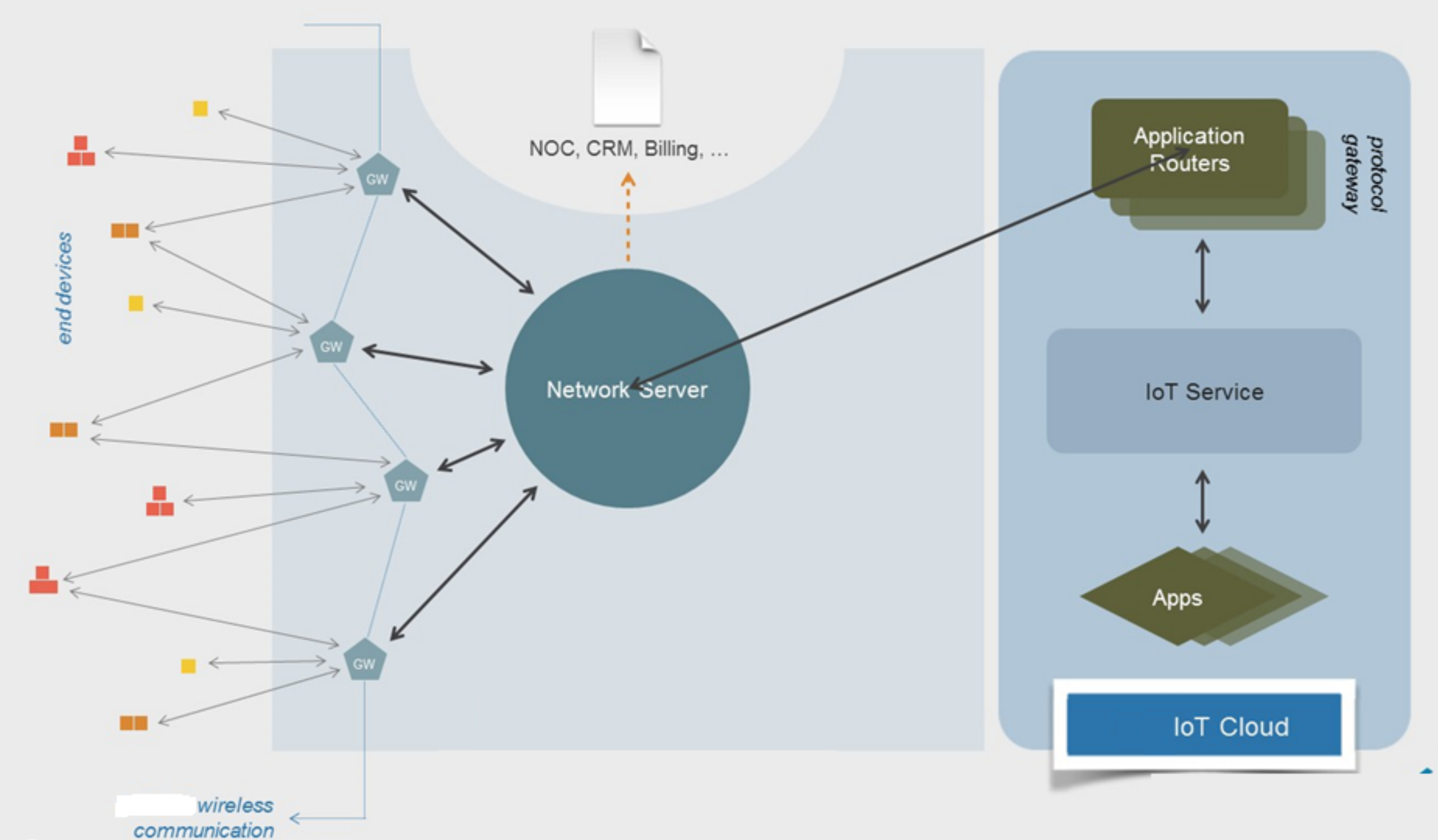
IoT architecture – Network Server

- operates the network
  - relays traffic between gateways and application routers
  - schedules all communication (uplink and downlink)
  - collects usage data for network operation and billing
  - provides maintenance interface to gateways (e.g., for software updates)
- requirements
  - rack-mountable appliance w/ Red Hat Linux
  - single multi-core blade with sufficient resources to handle tiered traffic
- security
  - communicates with gateways and application routers via TLS, certificate-based authentication
  - end-to-end verification of messages between end device and network server
  - end-to-end encryption of MAC layer interactions between end device and network server
- fault tolerance
  - warm stand-by on a remote secondary node that takes over based on regularly mirrored data
  - recovery within a few minutes

IoT architecture – Application Router functions and characteristics

- relays traffic between network server and application server
  - one per application, typically (but not necessarily) “owned” by the application provider
  - authorises join requests from end devices, accepting traffic charges for these end devices
  - requests certain levels of QoS per end device from the network server
  - maps between network-internal traffic and IPv6/MQTT traffic
  - implements protocols for interaction with the application server
- security
  - communicates with network server and application server via TLS, certificate-based authentication
  - end-to-end encryption of application payload exchanged between end device to application router
  - end-to-end verification of application payload has to be done on the application level (if required)
- fault tolerance
  - warm stand-by on a remote secondary node that takes over based on regularly mirrored data
  - recovery within a few minutes

For cost and speed of deployment reasons, it will become more and more common to deploy and host IoT applications in the Cloud.



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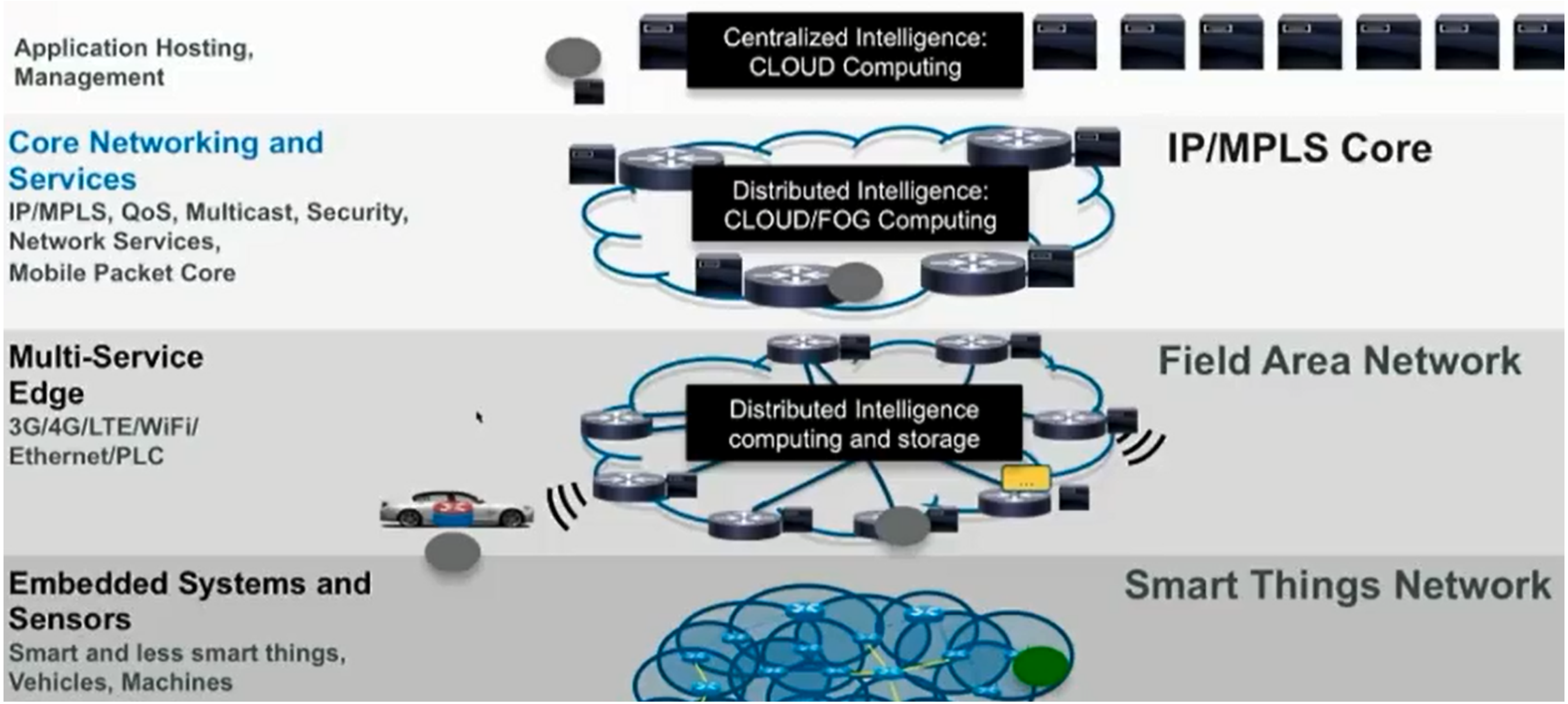
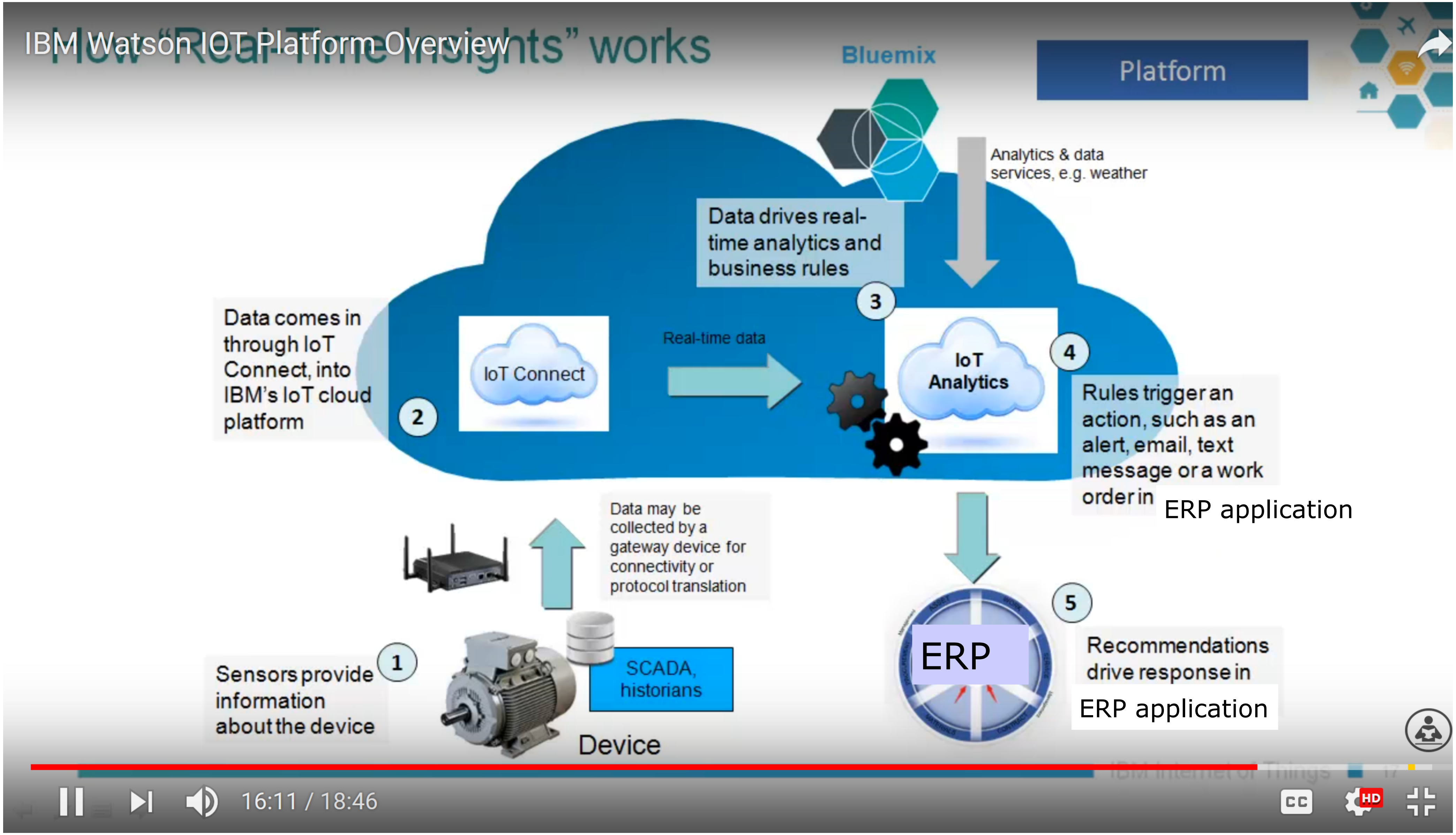


Example IBM Watson IoT Platform overview



IoT is both similar to and different from the Internet

- **What is in common or similar:**
  - Business processes
  - Data Analytics
  - Data Stores
  - IT connexions, from devices to systems via networks
  - Mobile devices

- **What is unique to IoT**
  - Non traditionnal devices
  - Industrial equipments (machines, vehicles), consumer appliances
  - Specific operating environments (eg RTOS, SCADA), embedded operating systems
  - Security mostly based on « trusted approach »
  - Non traditionnal protocols
  - Physical systems / sensors

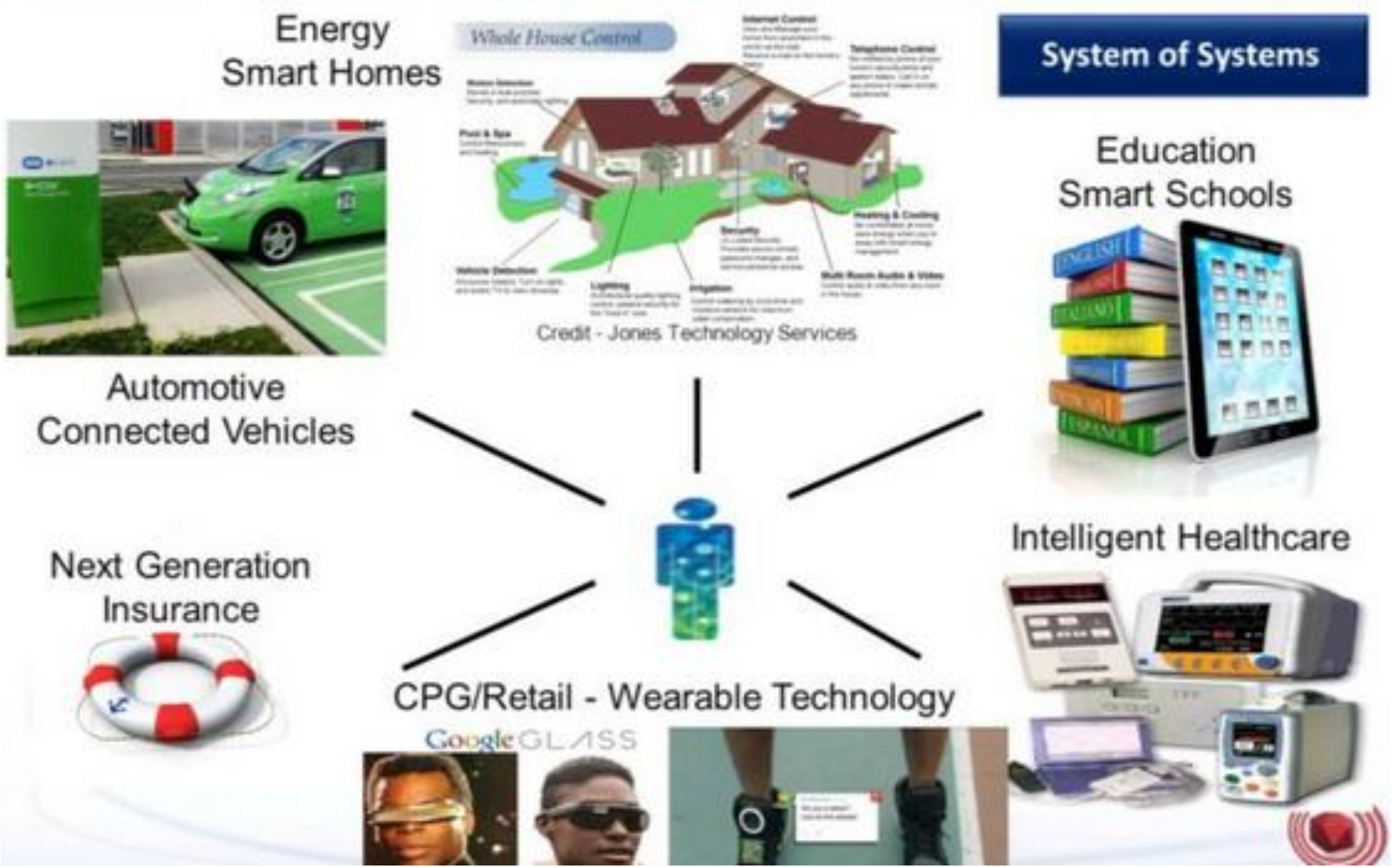
1. Automation for verification, including requirements analysis and test generation
2. Development practices that respond to cyber resilience and autonomy assurance challenges
3. Certification evidence generation, integrated with development practice
4. Promoting higher design quality with fewer escapes; reduced time to market and costs; product differentiation in emerging technology areas
5. Engaging with and often serving as liaison among customers and regulators

5 minutes break

Come back at 10:30 !

An introduction to the Internet of Things - Agenda

Building the IoT – Operational Concept



- Building blocks are used to create systems, which are then combined to create a system of systems. The distinction in an Internet of Things world is defined by the operational scenario that is being supported.

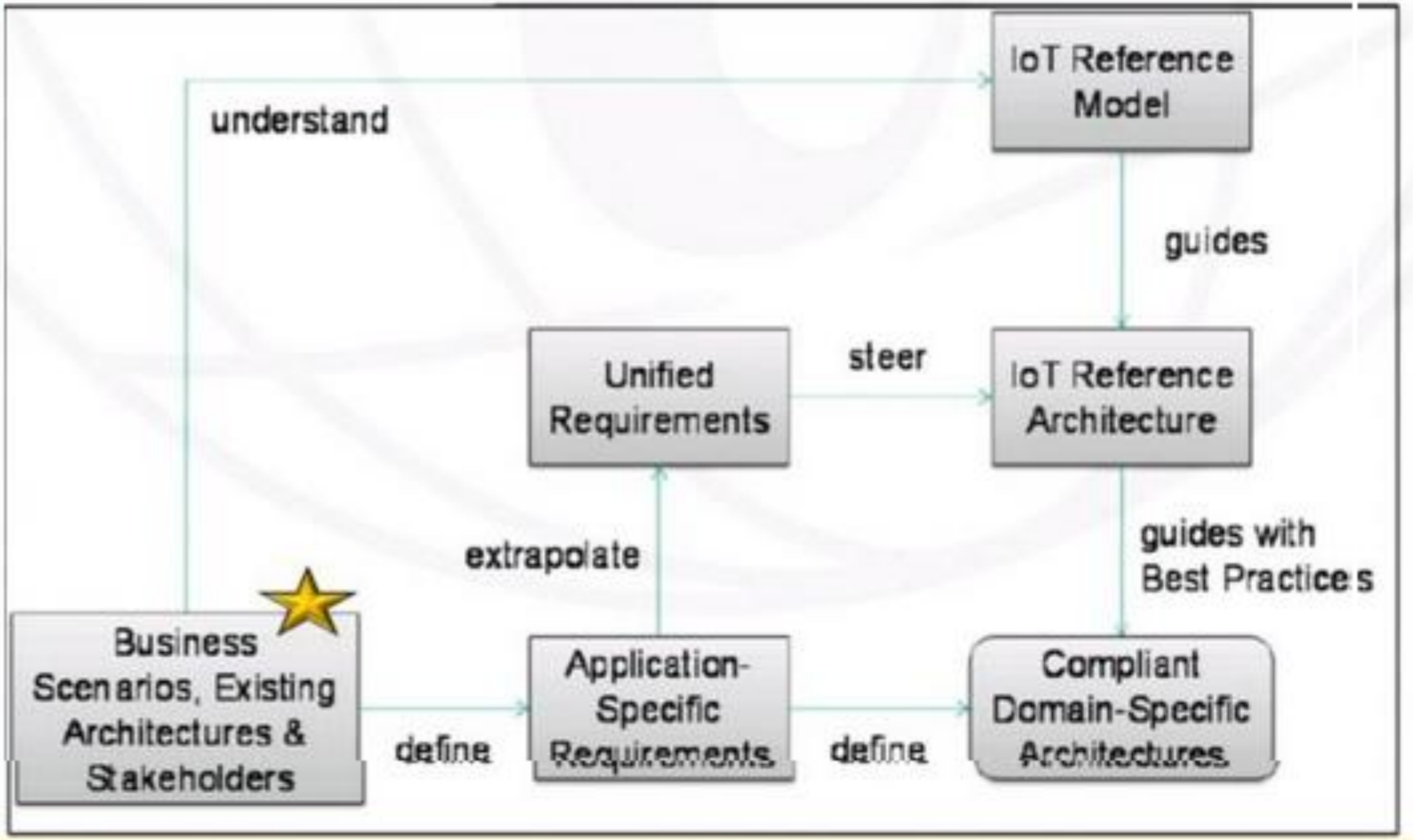
Building the IoT – Operational Concept

For example, a car is a system that consists of multiple building blocks and components.

- In city traffic, the car and driver interact with the city traffic systems to navigate directions and traffic flow as a type of city-traffic system of systems.
- For an automobile manufacturer, the context switches to customer support systems. The information that is gained on driving conditions, driving habits, security, and maintenance records is fed to the manufacturer’s customer support systems, forming a customer-care system of systems.

➔ In both scenarios, the Internet-of-Things solution is the coordination and interaction of many smaller systems, each with levels of autonomy, dependence, and interaction.

Realizing IoT solutions – Architecture Reference Model

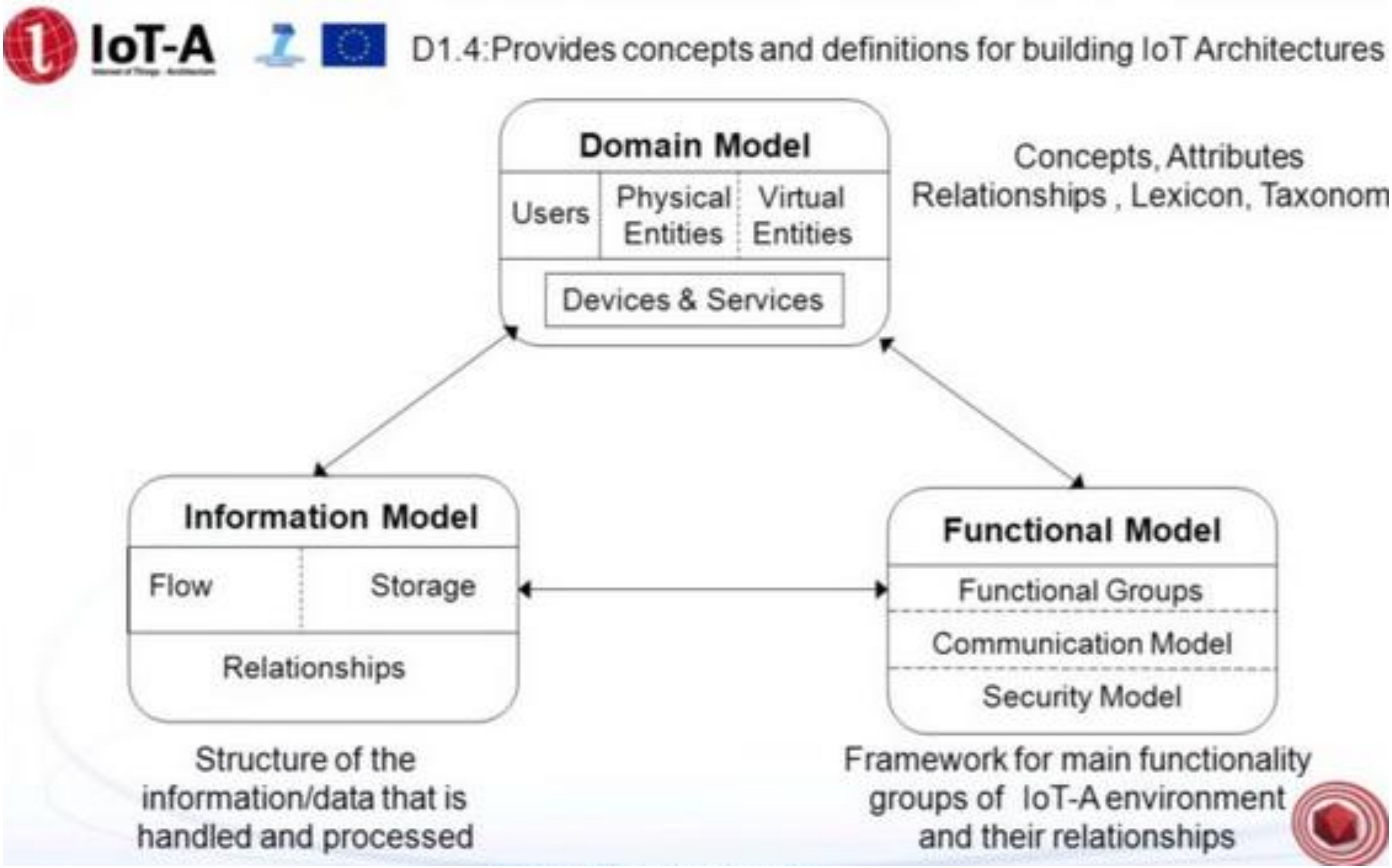


Understand the challenges and approaches to consider in an Internet-of-Things-centric ecosystem.

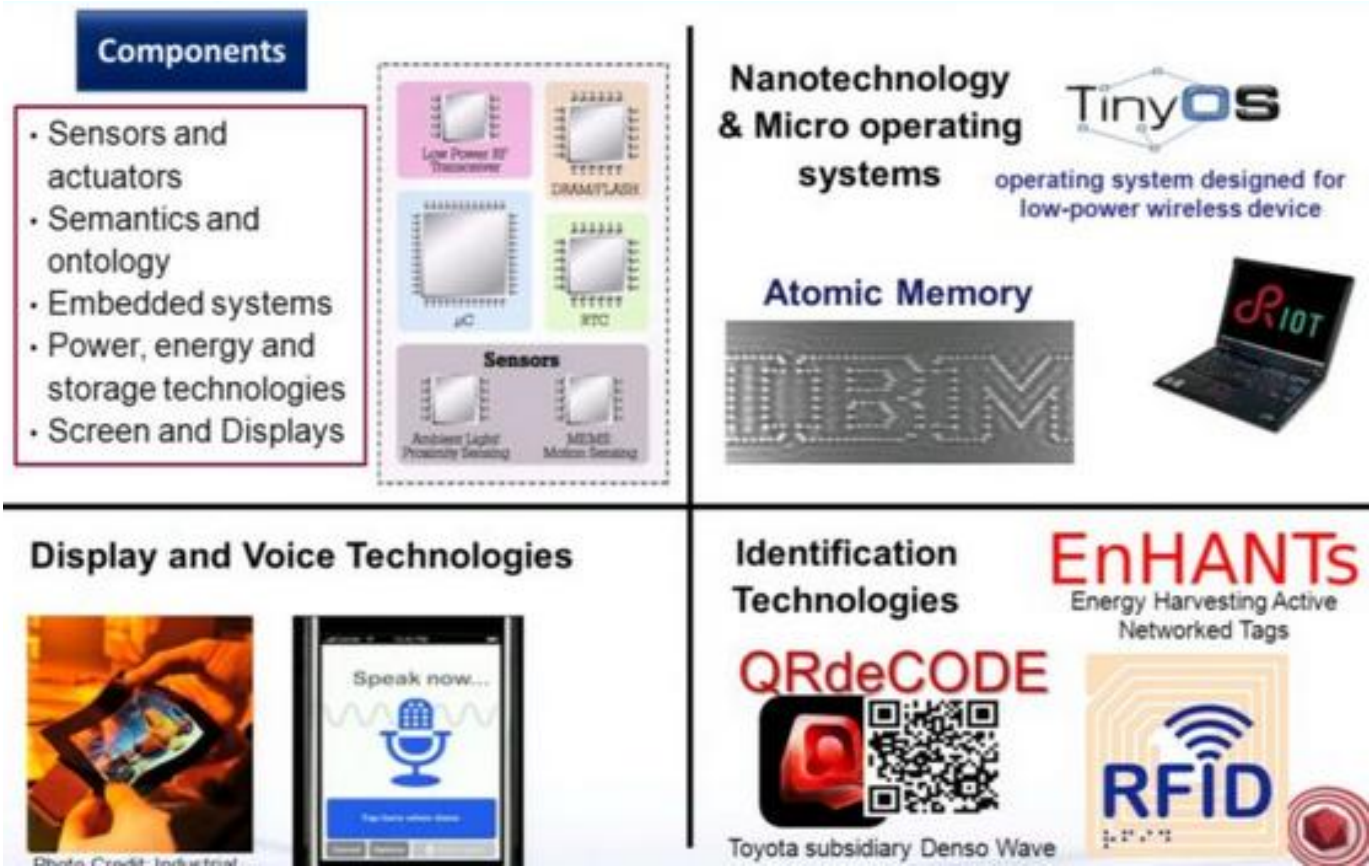
- The primary focus must on critical operational considerations, such as
  - scalability
    - The first scalability issue is based on the number of connected devices. The second issue is based on the volume of generated data.
  - availability,
  - manageability,
  - data management,
  - security,
  - and usability.

- These considerations are in the context of a hybrid environment where many aspects of a deployment are not within the control of the corporation.

Realizing IoT Solutions – Reference Model



Building the IoT – Physical Entities



Building the IoT – Physical Entities

IoT Strategic Areas of Interest for business scenario

IOT-i Internet of Things Initiative

D2.1: Initial report on IoT applications of strategic interest
D2.3: Final report on IoT applications of strategic interest

4 point Rating Scale
1. **Interest** –attract significant interest, private person, professional.
2. **Quality of Life**: improves the quality of life for individuals and/or society.
★ 3. **Societal Need:** needed by society to overcome current and future societal challenges.
$$ 4. **Business Value:** generate new value for business.

Categories
$$ ★ • **Health Care**
$$ ★ • **Smart Factory**
$$ ★ • **Emergency**
$$ • **Retail**
★ • **Environment**
• Transport
• Smart Home
• Smart City
• Supply Chain
• Lifestyle
• Agriculture
• Culture and Tourism
• User Interaction
• Energy

ISEP – Internet of Things

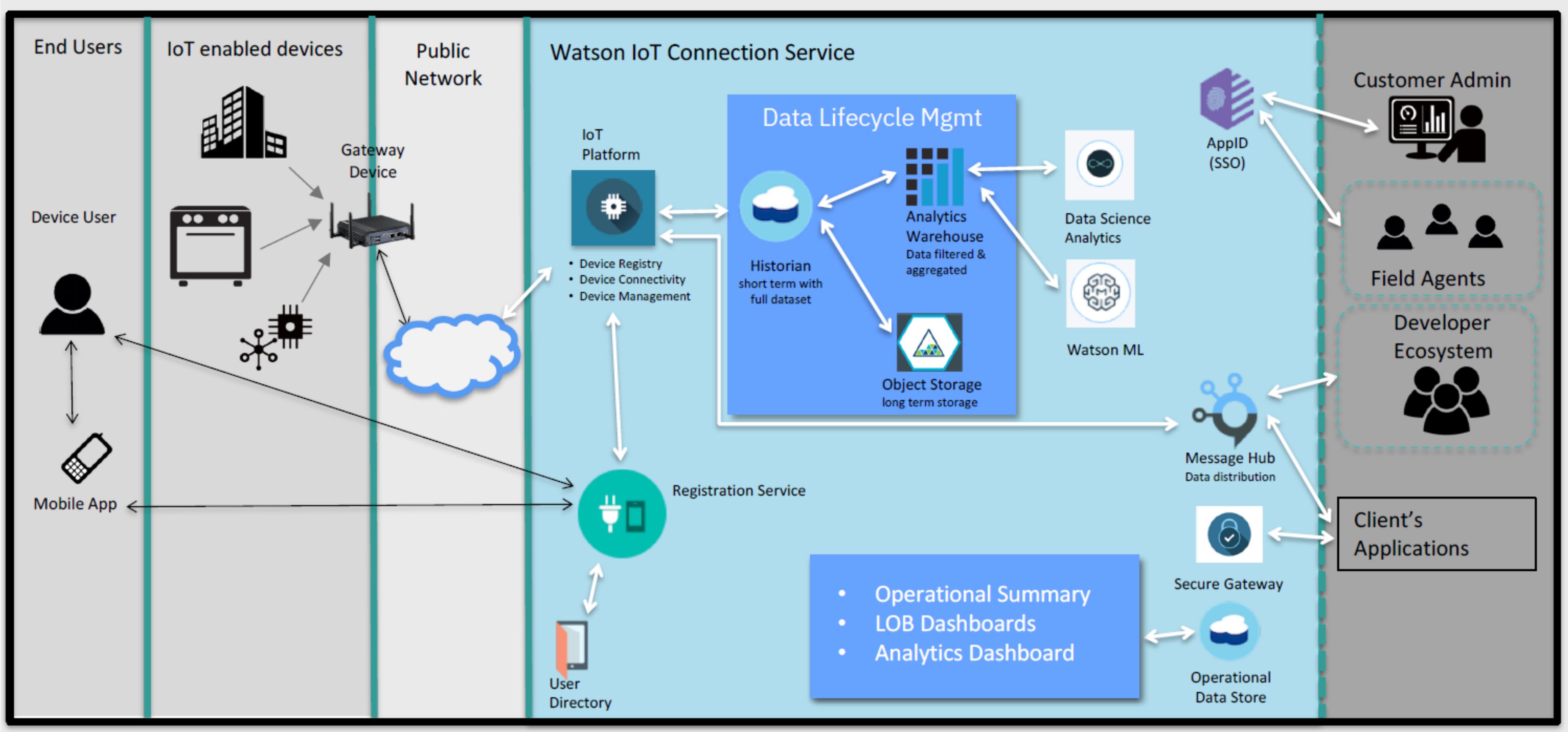
An introduction to the Internet of Things (IoT)

Developing an IoT application by the example

ISEP
Institut Supérieur d'Electronique de Paris

MdF version 1.3 2018-04

IoT solution overview



IoT do-it-yourself steps

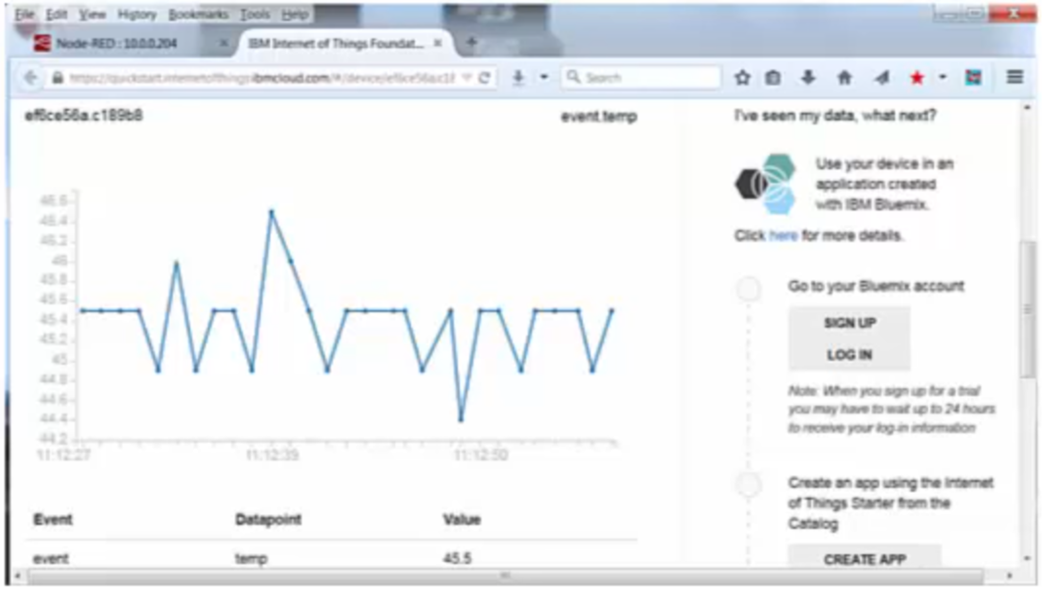
1. **Getting started**
   (setup and programming of IoT hardware)
2. **Measuring** and **manipulating**
   (physical computing: sensors and actuators)
3. **Connecting** your device **to the Internet**
   (IoT: monitoring sensors, controlling actuators)
4. **Mash-ups** with Web-enabled devices
   - ✓ A **mash-up** combines two or more Web services
   - ✓ Once **devices** have APIs, they **become scriptable**
   - ✓ **Logic moves** out of device, **into the Cloud**, e.g. Web-enabled LED + Yahoo Weather API = ambient weather notification

Internet of Things sample application:

Create an application which reports the CPU temperature of the device to the IoT platform

- Download and install Raspberry OS
- Configure the Raspberry Pi

- Connect the Raspberry Pi to the IoT Cloud platform
- Start Application flow editor



- View data from your smart device
- Use analytics tools

Internet of Things sample application

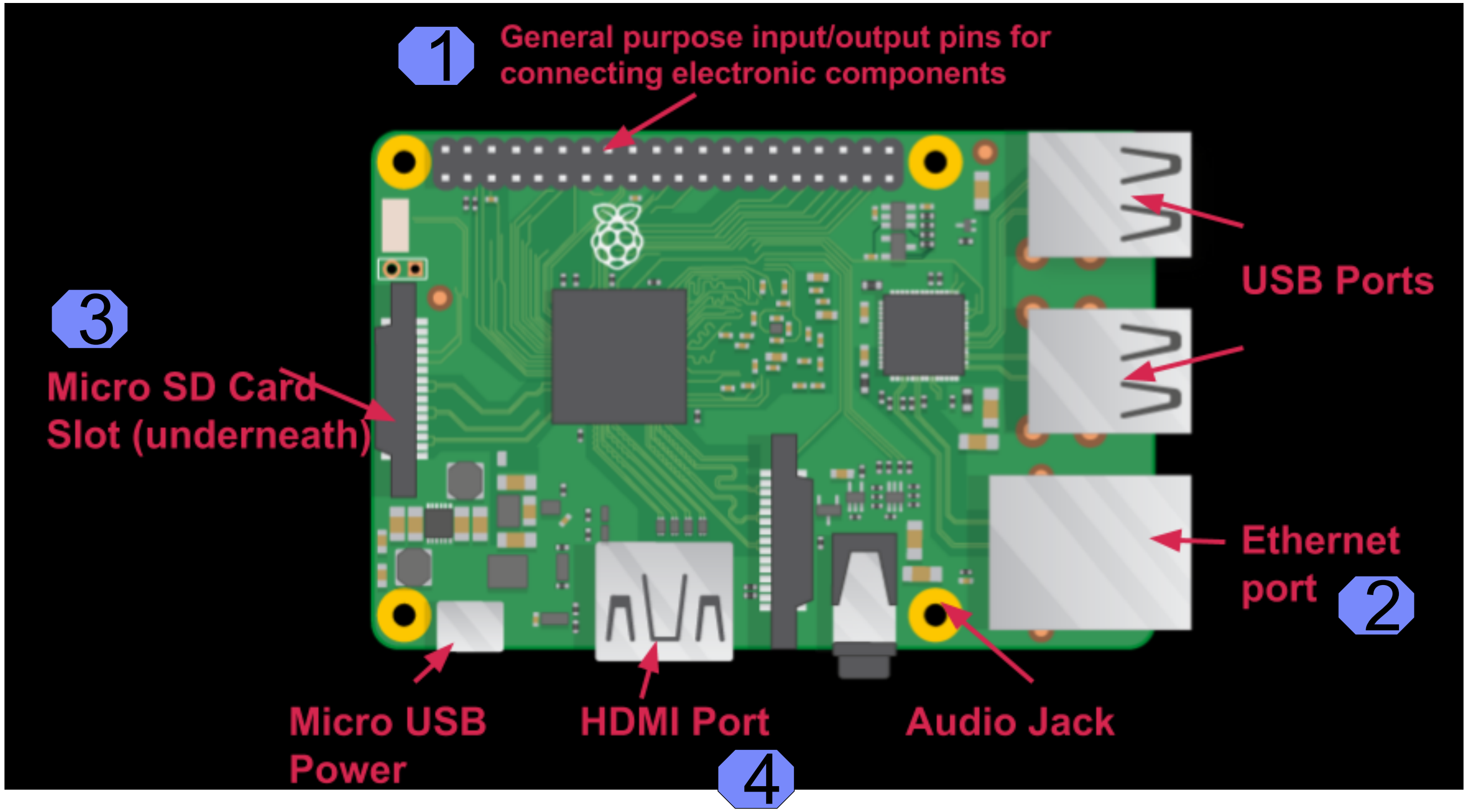
- Node-RED is a **programming tool for wiring together hardware devices, APIs and online services**
- Originally developed as an open source project at IBM in late 2013
- Browser-based editor that makes it easy to wire together the wide range of nodes (predefined code blocks) available in the palette to create flows that can be deployed to its runtime in a single-click
- **Flow-based programming model:** messages representing events flow between nodes, triggering processing that results in output. The flow-based programming model maps well to typical IoT applications which are characterized by real-world events that trigger some sort of processing which in turn results in real-world actions.

• https://nodered.org/

• http://noderedguide.com

- Raspberry Pi is a series of small single-board computers
- The Raspberry Pi Foundation provides Raspbian, a Debian-based Linux distribution for download, as well as third-party Ubuntu, Windows 10 IoT Core, RISC OS, and specialised media centre distributions. It promotes Python and Scratch as the main programming language.

Meet the Raspberry Pi:



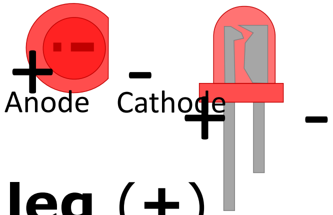
1: **GPIO**: allows you to connect electronic components such as LEDs and buttons
Measure: read sensor value from input pin
Manipulate: write actuator value to output pin
Inputs and outputs can be digital or analog

2: Connect to a network via cable (or wireless LAN)

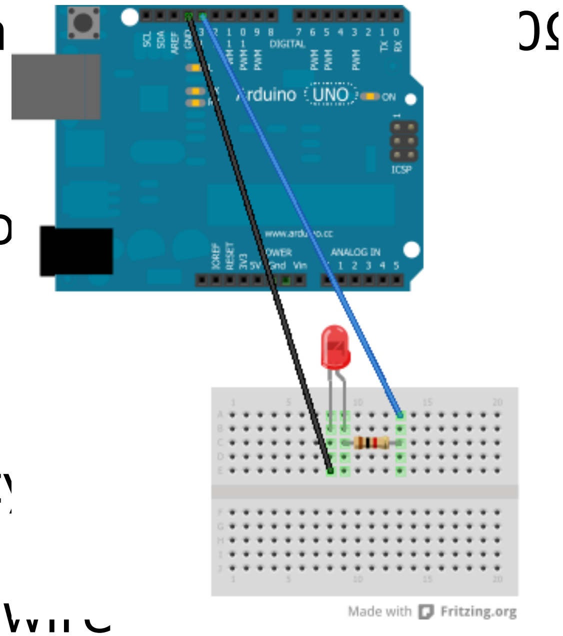
3: This is where the operating system software and your files are stored

4: Where you connect the monitor to display the output from the Raspberry Pi

Example: connecting sensors with a micro-controller



- Resistors
- LED: is a simple, digital **actuator**
    - LEDs have a **short leg** (**-**) and a **long leg** (**+**)
    - it matters how they are oriented in a circuit
    - To prevent damage, LEDs are used together with a
      2KΩ)



- Breadboard: lets you wire electronic components witho
    - Its holes are connected "under the hood"

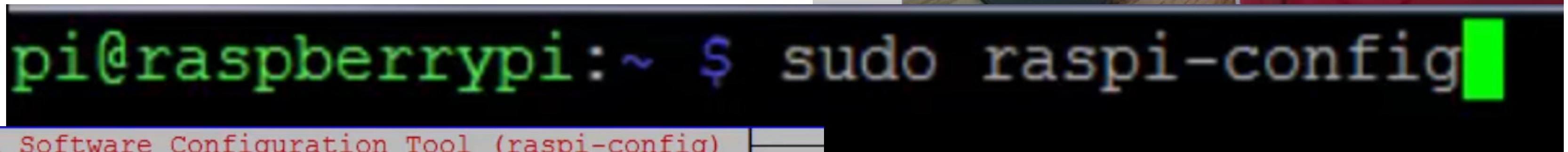
- Photo resistor pr LDR(**l**ight **d**ependent **r**esistor)
    - resistor whose resistance depends on light intensit
- Switch: a simple, digital **sensor** n different forms,
    - all of them in some way **open** or **close** a gap in a
    - The **pushbutton** switch has four legs for easier mounting

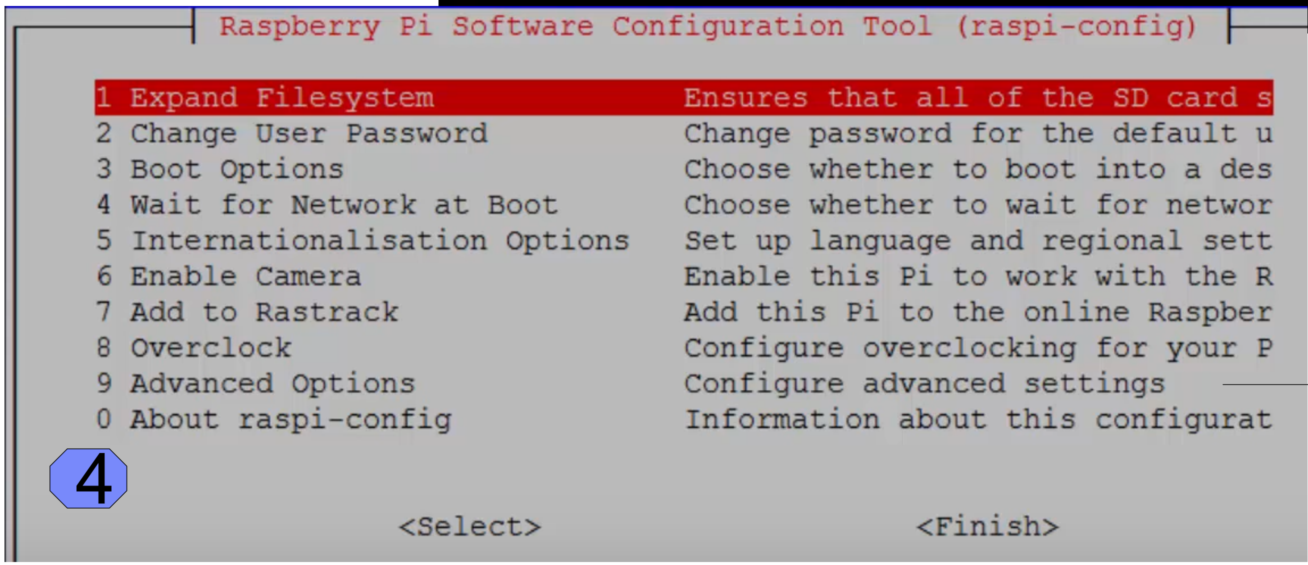
Download OS

1

2

3





4

- Hostname for Pi
- Enable I2C automatic load
  - Reboot

5

Check updates and upgrade:

- $ sudo rpi-update
- $ sudo apt-get update
- $ sudo apt-get –y upgrade
- $ sudo apt-get –y autoremove

Getting started

Use an **IDE** (**I**ntegrated **D**evelopment **E**nvironment) allows you to **program** your board

You **edit** a program on your computer, then **upload** it to your board where it's stored in the program memory (flash) and **executed** in RAM

Note: Once it has been programmed, your board can run on its own, without another computer

- **Get the IP adress of the device**:

$ hostname –I

Eg IP_adress_of_your_PI:1880

- Get the temperature of the device:

$ vcgencmd measure_temp

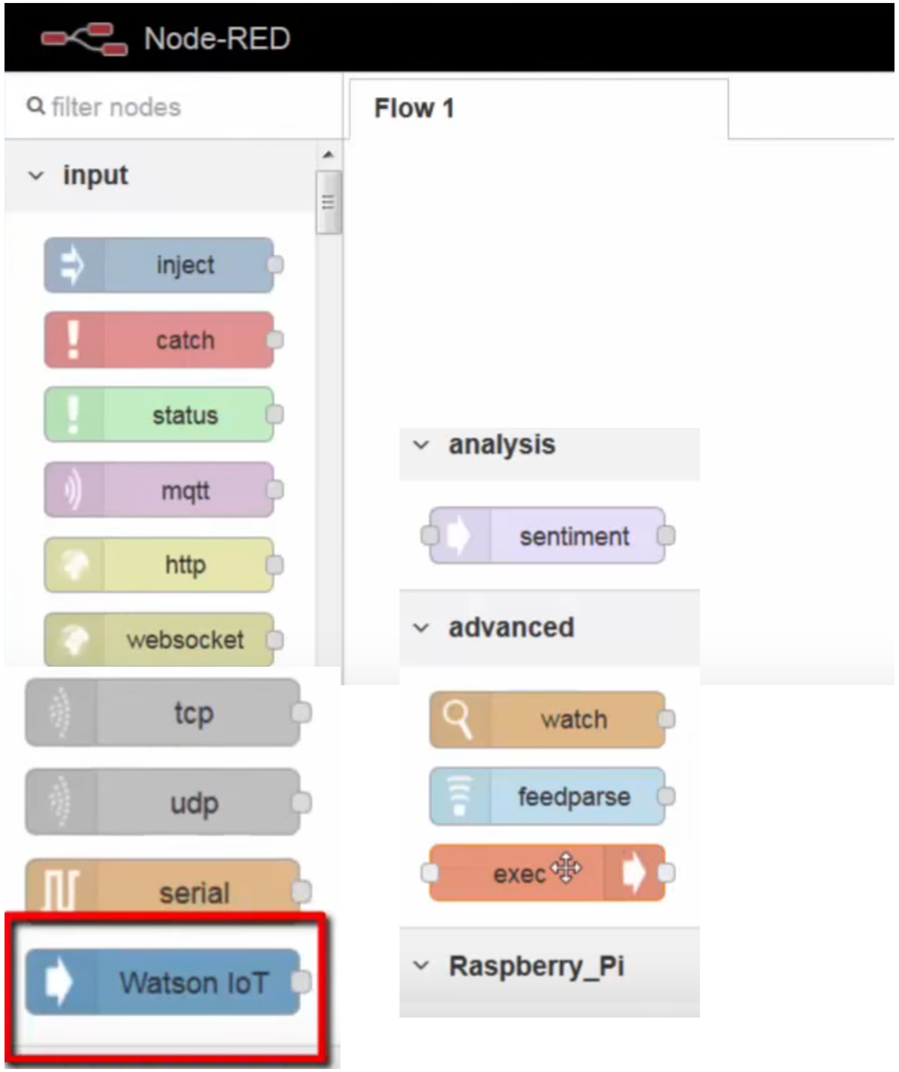
temp=45.5°C

- **Launch Node-RED editor**: $ node-red-start

- Use a Web brower on your desktop computer:

The Function node allows JavaScript code to be run against the messages that are passed in and then return zero or more messages to continue the flow.
The message is passed in as an object called msg.

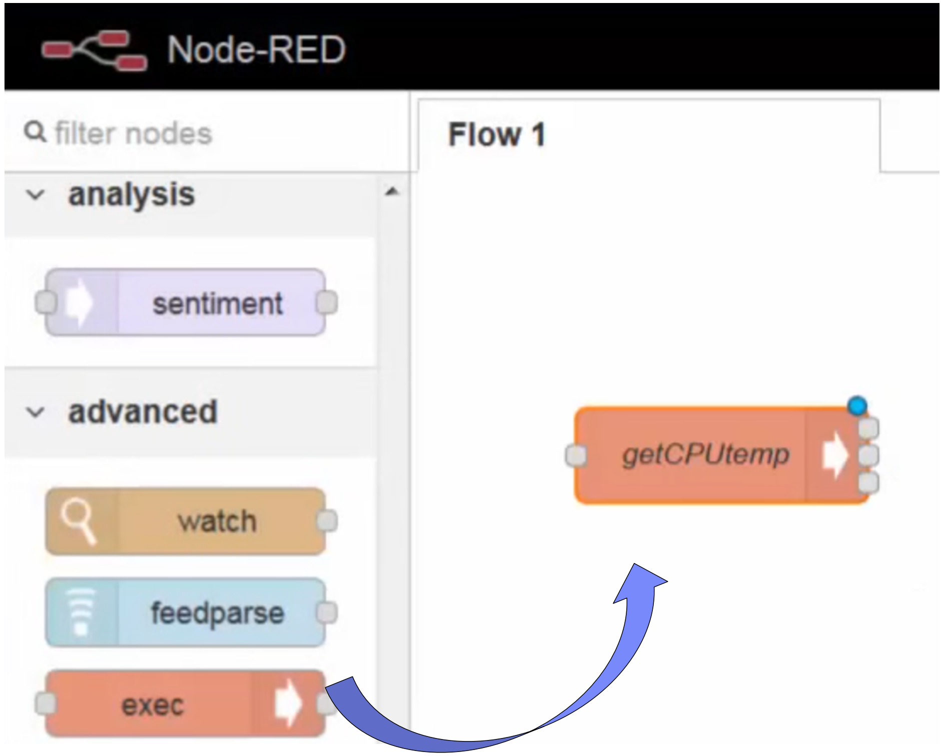
By convention it will have a msg.payload property containing the body of the message.



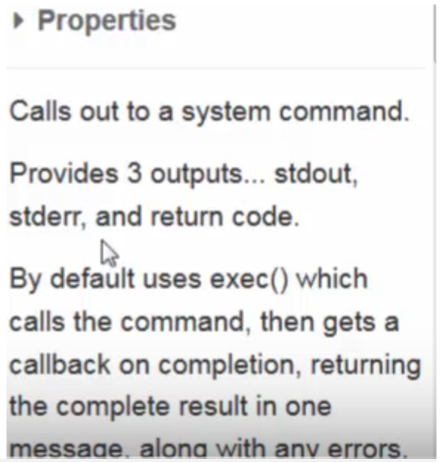
Note: Watson IoT is an example of a **managed, cloud-hosted service designed** to make it simple to derive value from your Internet of Things devices

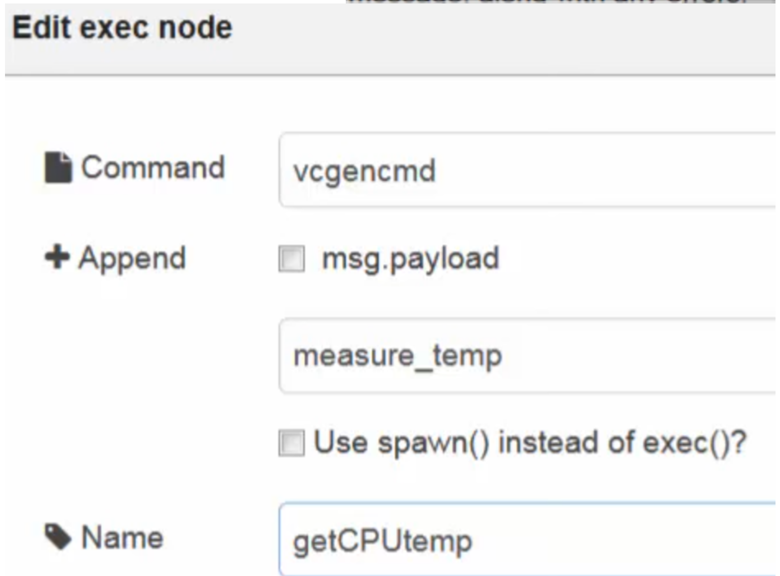
Using the flow editor

Drag the « exec » node from the advanced section and edit it

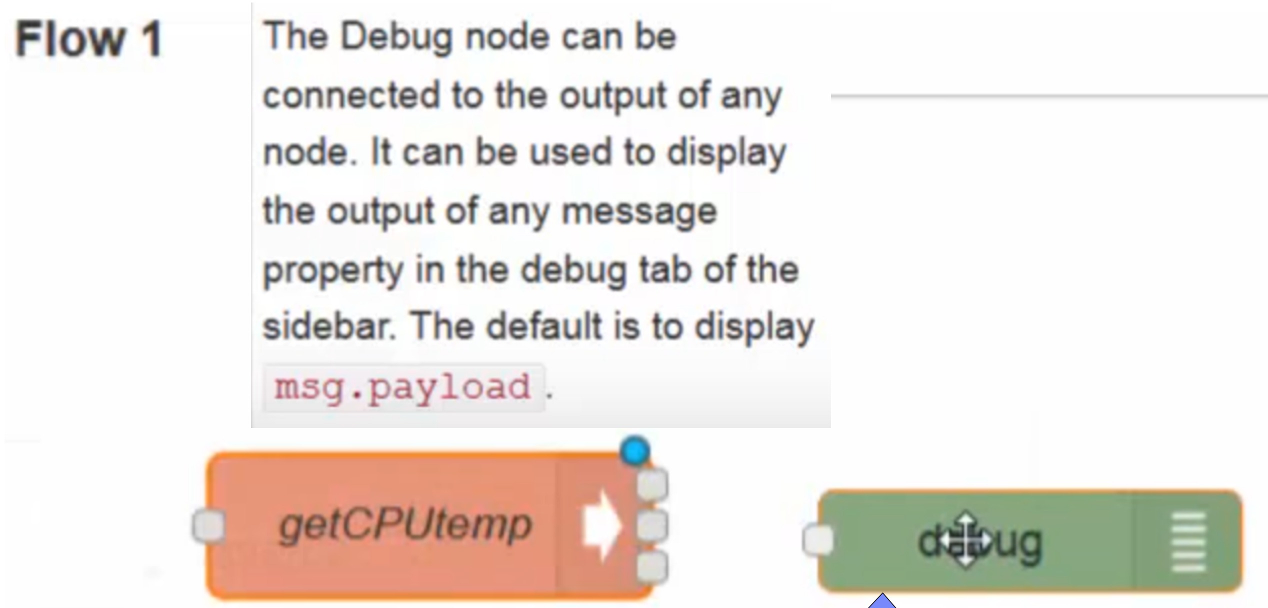


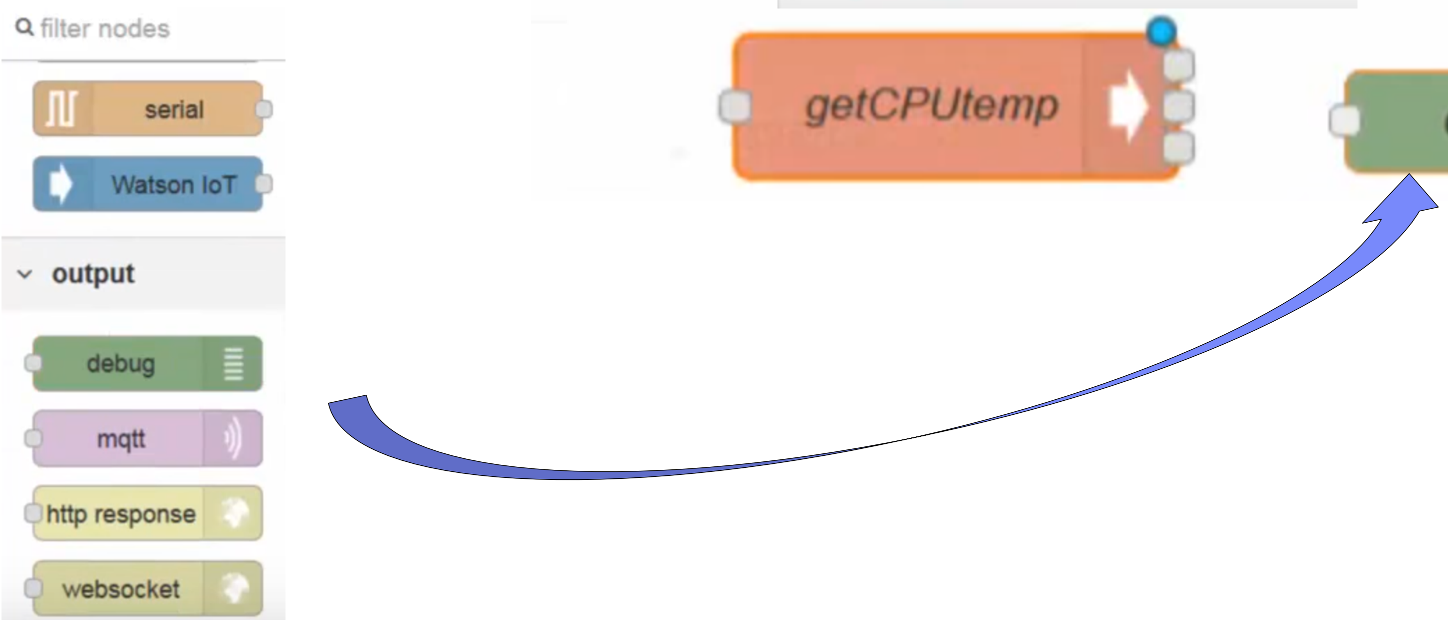
Exec node:



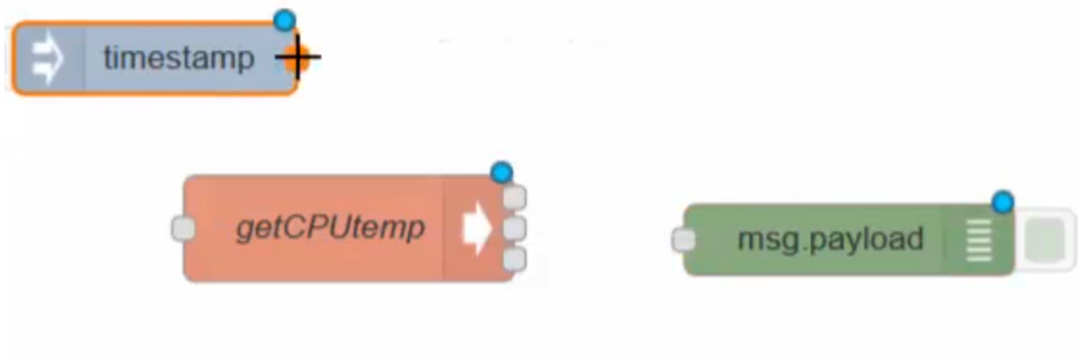


Add a debug node from the output section to display the result of the exec node in the debug window

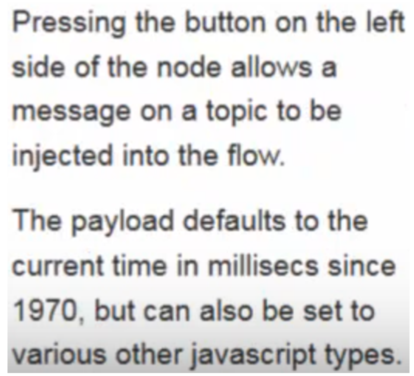




Add « inject » node from the input section to specify when (timestamp) to take the temperature from the device



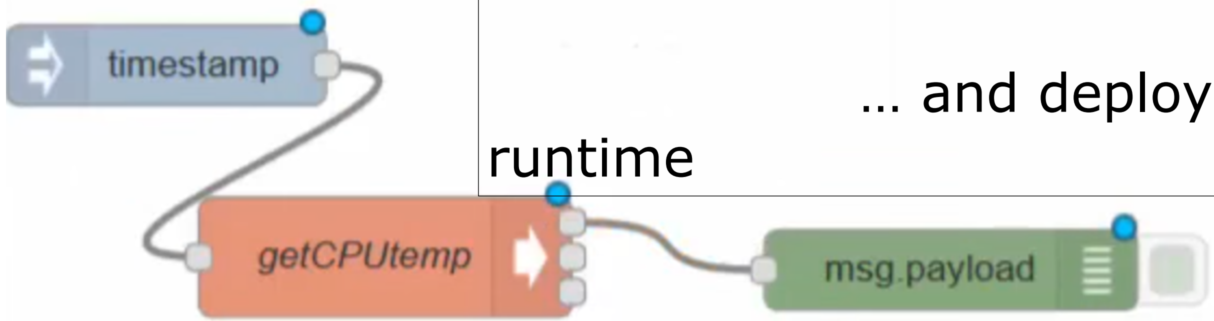
Inject node:

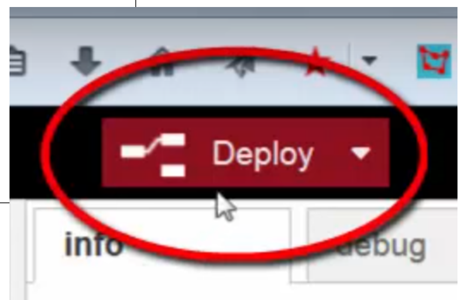

Pressing the button on the left side of the node allows a message on a topic to be injected into the flow.

The payload defaults to the current time in millisecs since 1970, but can also be set to various other javascript types.

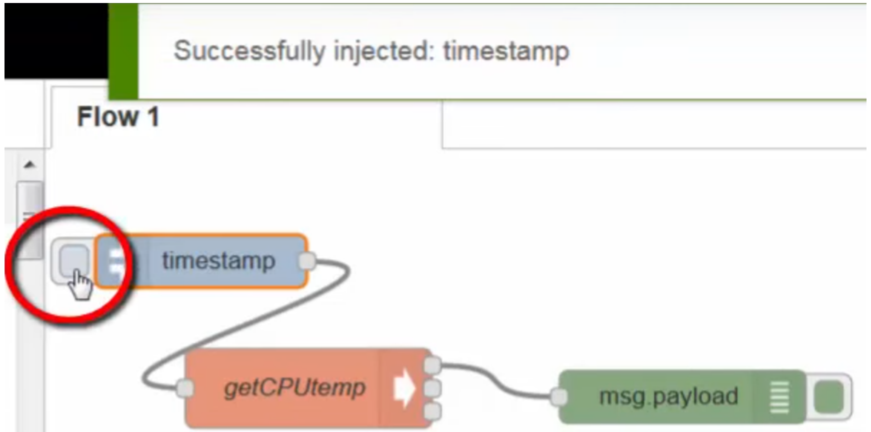
Connect the nodes to create a flow…

… and deploy the runtime





The message is displayed in the debug window



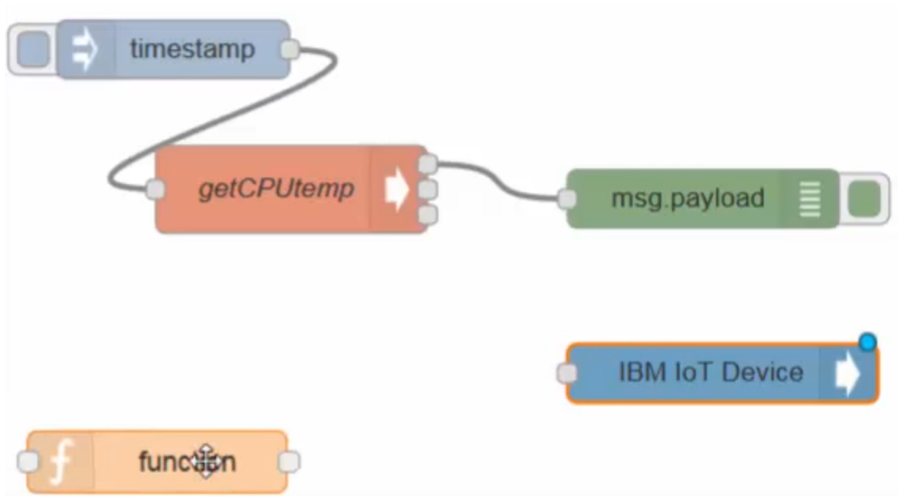
Sending the device data to the IoT platform to create an « IoT data »

Use “wiotp” Node-RED node for connecting to the IBM Watson Internet of Things Platform:

- Send device events to the Cloud-based IoT platform
- Receive device commands from the centralized IoT platform eg IBM Watson Internet of Things Platform.

The node can connect as either a Device or Gateway, in registered mode or using the Quickstart service.

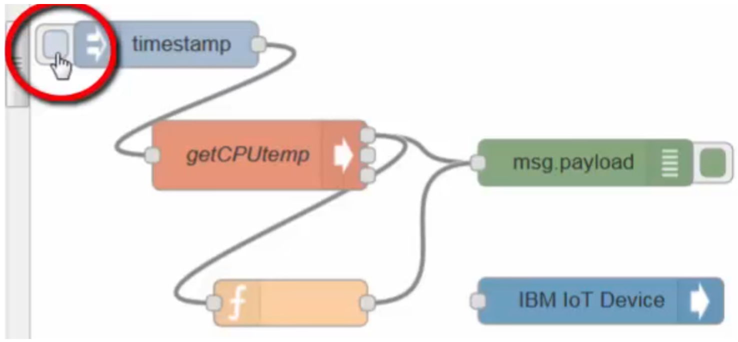
Word of caution:
Make sure that the data format sent by the Raspberry Pi is the format expected by the IoT platform, or replace as appropriate.

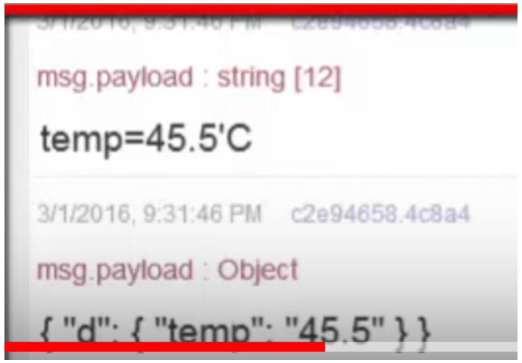


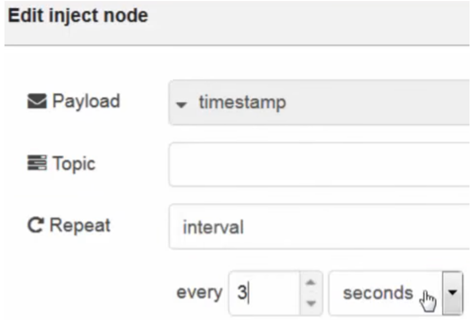

```
msg.payload={'d' : {'temp':msg.payload.replace("temp=", "").replace("'C\n","")}}
return msg;
```

We have to change the string output from the PI (« **temp=45.5’C** ») to the format expected by the IoT platform

Test with inject node and set measure interval every 3 seconds







Final flow

- Re-deploy
- Connect to the Cloud

… and automatically visualize your data in the Cloud from a Web browser (pre-packaged function in the Cloud-based IoT platform)

Next: Store the ingested data in the appropriate database. Then perform filtering, analytics, create dashboards, …