Mobile and Cyber Physical Systems - Appunti

Francesco Lorenzoni

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Contents

Course info

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Part I

Stefano Chessa

Chapter 1

Internet of Things

The main topics addressed aside from **IoT** itself are how it relates to *Machine Learning* and *Cloud* computing processes, but also *IoT interoperability*, known *Standards*, and the *security* concerns about IoT.

1.1 IoT introduction

Cyber and Physical Systems (CPS) operate in both the Physical and Cyber worlds, thus we can see IoT as an embodiement of CPSs.

In a *smart environment*, smart objects are both physical and cyber, hence they are subject to "physical experiences" such as being placed, moved, damaged and so on.

But actually...
What is a *smart environment*?

The answer actually ain't trivial; a journal on IoT reports:

"smart environments can be defined with a variety of different characteristics based on the applications they serve, their interaction models with humans, the practical system design aspects, as well as the multi-faceted conceptual and algorithmic considerations that would enable them to operate seamlessly and unobtrusively"

1.2 Platforms for IoT

Sensors and actuators are the edge of the cloud. In general the purpose of IoT is to gather and send data, send it somewhere where it gets transformed into information ultimately used to provide some functionality for an end user, or it simply presented to them.

A **Platform for IoT** is essentially a —complex— software hosted on the cloud, which, first of all, **collects** data gathered by IoT devices, but *not* only that:

- ◇ Identification
- ◇ Discovery
- ◇ Device Management
- ◇ Abstraction/virtualization
- ◇ Service composition
  Integrating services of different IoT devices and SW components into a composite service
- ◇ Semantics
- ◇ Data Flow management
  - *sensors* $\longrightarrow$ *applications*
  - *applications* $\longrightarrow$ *sensors*
  - Support for aggregation, processing, analytics

1.3 No-SQL Databases

No-SQL DBs address the problem of the several changes of data formats, sources, cardinality and so on, which happen throughout time.

A common example is **MongoDB**, which stores records in JSON-like objects called *documents*, which are stored in *collections*, the entity corresponding to tables in relational DBs, with the key difference that multiple documents in a single collection may be structured differently.

1.4 IoT Issues

- ◇ Performance
- ◇ Energy Efficiency
- ◇ Security
- ◇ Data analysis/processing
  - – Adaptability/personalization

  The course will cover the basics of signal processing, with mentions to machine learning
- ◇ Communication/brokerage/binding
- ◇ Data representation
- ◇ Interoperability

  Standard discussed will be ZigBee, MQTT, and IEEE 802.15.4 (?)

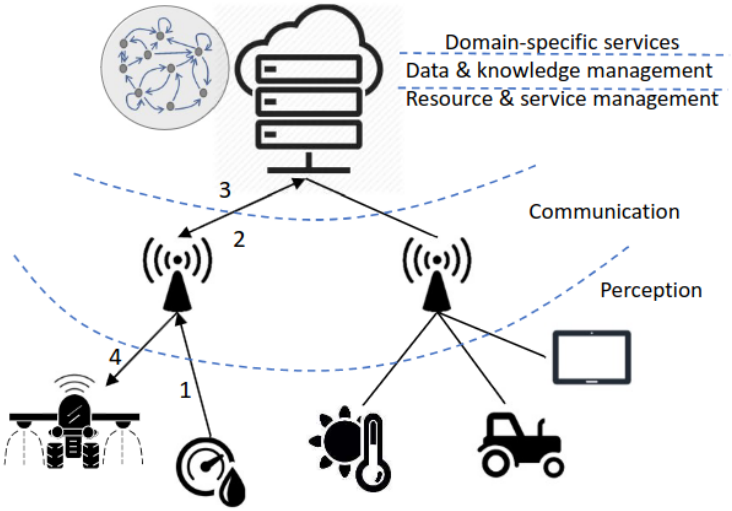


Figure 1.1: Communication outline in IoT
IoT systems are distributed, and servers may be dislocated around the globe, making room for **latency** and **reliability** issues.

To confine the problem displayed in Fig. 1.1 there are proposal to move the ability to make a decision on the data closer to the edge, but this in general isn't trivial.

Key Issues

1. Producing and handling fast-streaming heterogeneous sensed data
2. Make devices context-aware & allow them for continuous adaptation
3. Handle strong computing and energy constraints

1.4.1 Edge and Fog computing

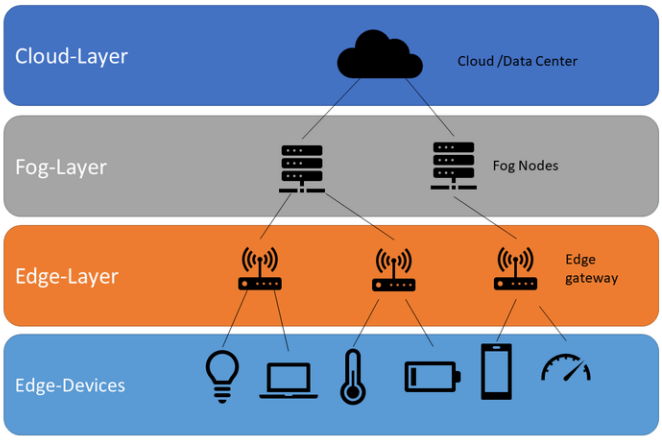


Figure 1.2: Layers scheme

A solution forsees to split the network in 4 layers, allowing for different response times and decisional capabilities.

A gateway on the **edge** interconnects the IoT-enabled devices with the higher-level communication networks, performing protocol translations.

A basic task performed at the fog layer is aggregating and collecting data, and then flushing it to the cloud periodically.

However, some decisions on the aggregated data may be taken at the fog node without querying the cloud, for instance determining where is a nest of tortoises, whether an explosion has occurred (by analyzing data from multiple sensors), and —maybe, one day in a not-so-far future— recognize human language.

prof. Chessa developed an 8 bit controller implementing a model for determining where is a nest of tortoises.
Alexa and *Google Home* currently send audio samples to the cloud for processing, but in the futurue this may be done locally.

1.4.2 Artificial Intelligence

AI splits into **Machine Learning** and **Curated Knowledge**.

ML focuses on mimicking how humans *learn* on new knowledge, while *curated knowledge* focuses on mimicking how humans *reason* on a known set of data.

Machine Learning reveals itself to be particularly useful in aggregatin multiple heterogeneous time-series sensed data about the same environment.

Supervised and Reinforcement learning are more promising than

1.4.3 Blockchain & IoT

A **blockchain** may act as a shared ledger between companies in a supply chain, with IoT devices to track goods and to monitor their quality along the chain, i.e. production stages, shipping and distribution.
With a blockchain each actor along the supply chain can query the ledger to check the —certified— state of the goods.

1.4.4 Interoperability

Vertical Silos

Developing a straight implementation of an IoT solution, starting from physical up to the application layer, is not a problem by itself.
In this way solution you implemented will work only on your devices, making your intervention needed for any change or update; besides, products by other vendors will be incompatible.

Vertical Silos business model leads to **vendor lock-in**s, which basically are service limitations which prevent the users from purchasing and using products from other vendors.

The solution to avoid —or limit— such issues is to introduce **standards**. Standards require common interests and agreements among different manufacturers, they are usually motivated by a reductino of the costs for development of a technology. There must be "*coopetition*" among manufacturers.

There is coopetition usually when a technology becomes **mature**:
- ◇ Big revenues are somewhere else
- ◇ No interest in investing big money in developing the technology

⇒ Without these conditions the standards will most likely fall

For what concerns wireless communication, standards are mainly differentiated by *Range* and *Data Rate*.

However, interoperability may be an issue not strictly related to vertical silos, but also to standards, in case there are *too many*.
The problem of interoperability shifts from low-level to application level.
To solve the problem, **gateways** are introduced, which translate different protocols.

- In type C configuration, how many mappings from one protocol to another (at the same level) the integration gateway should be able to manage?
- What about in type D configuration?

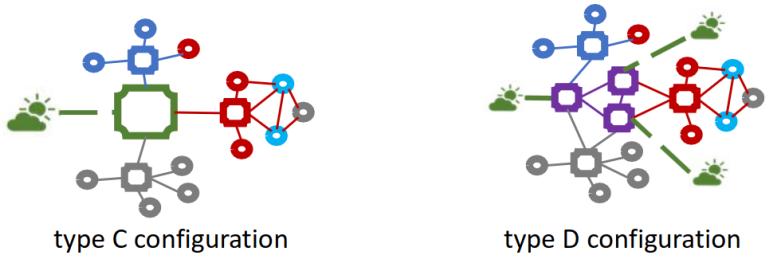


Figure 1.3: Gateway configs

Considering Fig 1.3 and assuming n protocol standards, the gateway in config C must be able to manage a mapping for every possible pair of standards, resulting in $n * n = n^2$ mappings. In configuration D instead evey gateway translates *from* and *to* an **intermediate language** (purple in figure), resulting in a double translation process, but only $2 * n$ mappings, which is much less.

1.5 Security in IoT

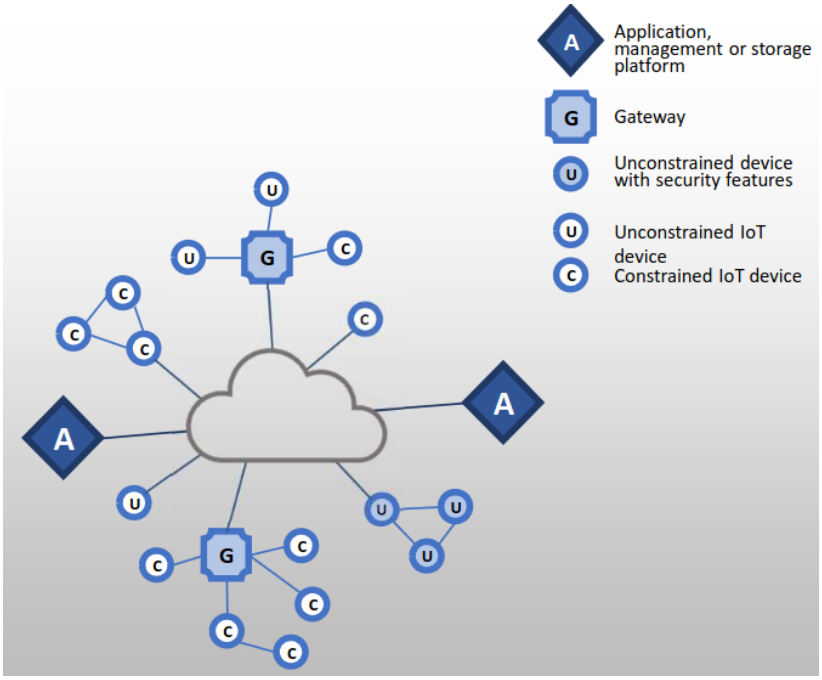


Figure 1.4: Security elements of interest

In an IoT environment there are various elements, each with its characteristics and vulnerabilities.

In general there are many issues concerning **patching vulnerabilities**, which poorly —or not at all— addressed.

- ◇ There is a crisis point with regard to the security of embedded systems, including IoT devices
- ◇ The embedded devices are riddled with vulnerabilities and there is no good way to patch them
- ◇ Chip manufacturers have strong incentives to produce their product as quickly and cheaply as possible
- ◇ The device manufacturers focus is the functionality of the device itself
- ◇ The end user may have no means of patching the system or, if so, little information about when and how to patch
- ◇ The result is that the hundreds of millions of Internet-connected devices in the IoT are vulnerable to attacks
- ◇ This is certainly a problem with sensors, allowing attackers to insert false data into the network

Not so critical for wristbands, but potentially harmful for water quality sensors, even worse for uranium enrichment, or aircraft sensors

- ◇ It is potentially a graver threat with actuators, where the attacker can affect the operation of machinery and other devices

What about **confidentiality**? Is it necessary?
The lecturer provided an example:
Assume that a wristband records the heartbeat without enforcing confidentiality, and assume that such heartbeat indicates a risk of heart disease in the owner. The owner may want to have a life insurance, but if a company had bought the unconfidential data on the black market, and recognized that the owner may suffer from a heart disease. Then the company could rise the price of the insurance for the unconfidential wristband owner.

Aside from these, laws introduce many requirements concerning security, which may be critical to satisfy in an IoT environment. In particular, The `IUT-T` standard Recommendation `Y.2066` includes a list of security requirements for the IoT, which concern the following points, but note that the document does **not** define how to enforce and satisfy such requirements:

- ◇ Communication security
- ◇ Data management security
- ◇ Service provision security
- ◇ Integration of security policies and techniques
- ◇ Mutual authentication and authorization
  It it crucial for the authentication to work both directions, from the gateway to the device, and from the device to the gateway. It is needed because wireless networks are easily trickable by intruders.
- ◇ Security audit

Considering the points mentioned above, we must consider what is the role of **gateways** about security.

Sometimes instead of mutual one, weaker *one-way authentication* may be enforced: either the device authenticates itself to the gateway or the gateway authenticates itself to the device, but not both.

Also the security of the data is not trivial to achieve, especially if constrained devices are used, because they may not be able to enforce task such as encryption or authentication.

This makes **privacy** concers arise especially regarding homes, cars and retail outlets, because with massive IoT, governments and private enterprises are able to collect massive amounts of data about individuals.

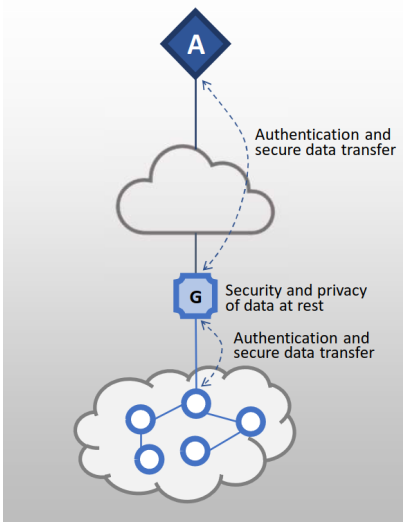


Figure 1.5: Gateways security functions

Chapter 2

MQTT

Things must be connected to the Internet to become *"IoT"* devices, and thus to adopt the internet protocol suite (TCP/IP + application, usually HTTP). However, the Internet stack is thought for *resource-rich* devices, not for IoT ones.
These led the canonical protocol stack to be modified

MQTT is a publish-subscribe application protocol.

Part II

Federica Paganelli

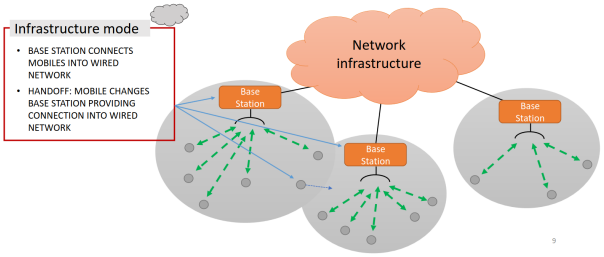
Chapter 3

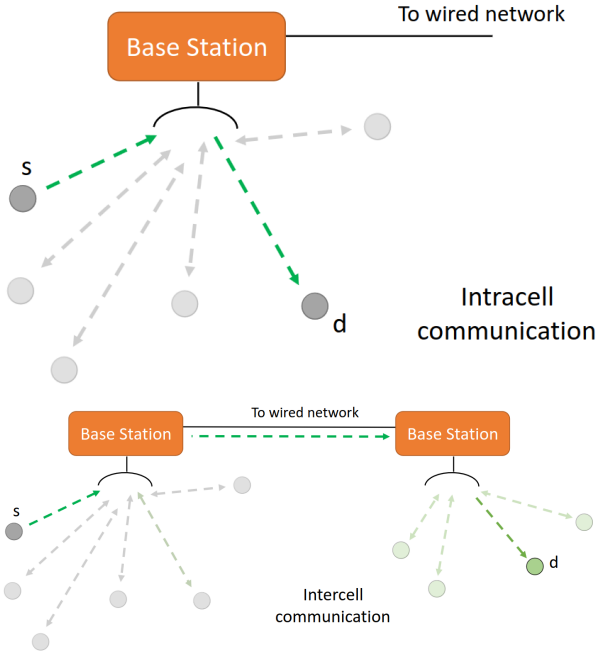
Wireless Networks

Wireless Networks are composed of **hosts**, which are end-system devices that run applications, typically battery powered.

Recall that *wireless* $\neq$ *mobility*

In general Wireless Networks may be based on the interaction *hosts* $\longrightarrow$ *base station* —or access point— or *hosts* $\longrightarrow$ *hosts*. The two resulting functioning modes are called *Infrastructure* and *Ad hoc networking*.





3.1 Link Layer

3.1.1 CSMA/CD

Basic idea of CSMA/CD:

1. When a station has a frame to send it listens to the channel to see if anyone else is transmitting
2. if the channel is busy, the station waits until it becomes idle
3. when channel is idle, the station transmits the frame
4. if a collision occurs the station waits a random amount of time and repeats the procedure.
   Refer to the slides of 21 February for more in depth usage examples

In short: CSMA/CD performs poorly in wireless networks. Firstly because CSMA/CD detects collisions while transmitting, which is ok for wired networks, but not for wireless ones. Secondarily, what truly matters is the interference at the *receiver*, **not** at the *sender*, causing the two problems known as *hidden* and *exposed terminal* problems; to

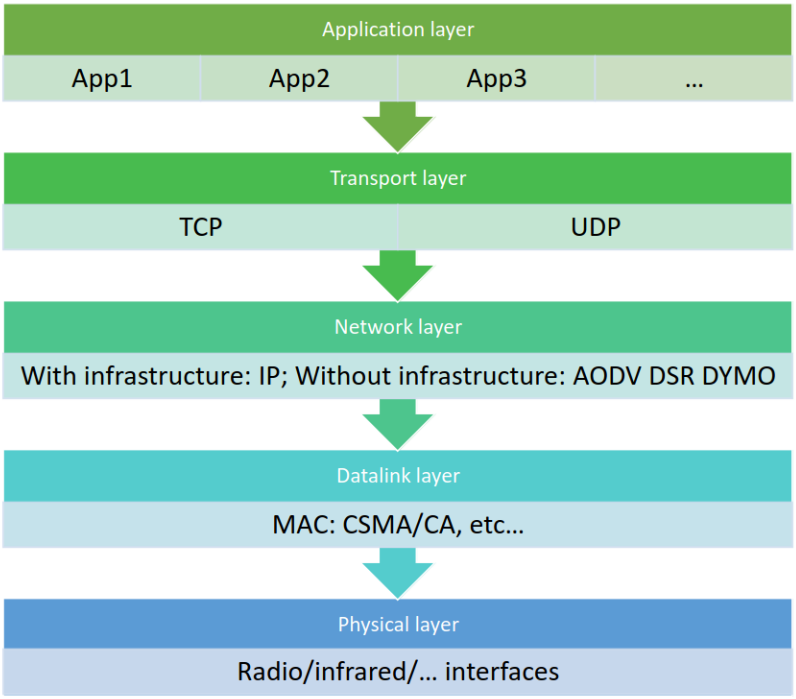


Figure 3.1: Protocol stack

better understand this point, look at the following figure, consider that at the sender, the signal strength of its own transmission (self-signal) would be too strong to detect a collision by another transmitter, making collisions happen at the receiver.

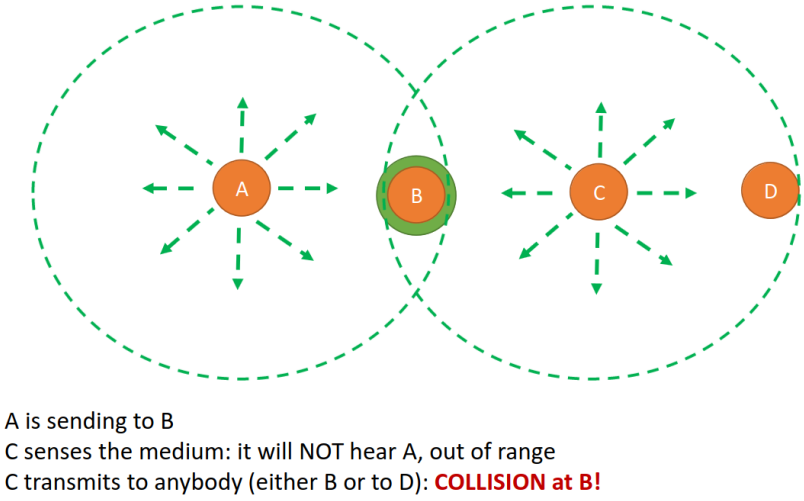


Figure 3.2: **Hidden Terminal** problem
Two or more stations which are out of range of each other transmit simultaneously to a common recipient

3.1.2 MACA

MACA stands for *Multiple Access with Collision Avoidance*

1. stimulate the receiver into transmitting a short frame first
2. then transmit a (long) data frame
3. stations hearing the short frame refrain from transmitting during the transmission of the subsequent data frame

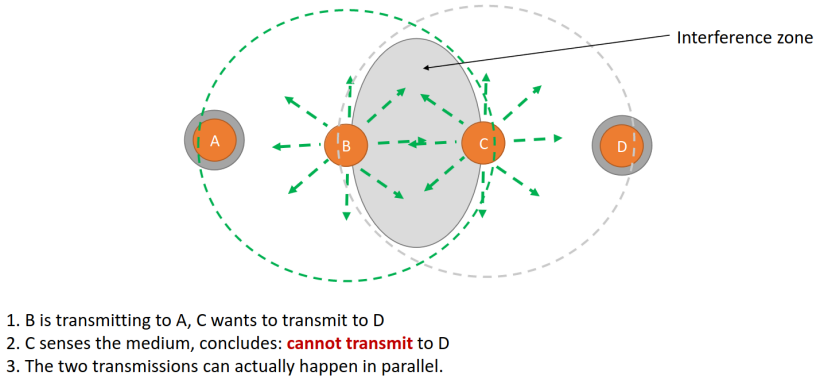


Figure 3.3: **Exposed Terminal** problem
A transmitting station is prevented from sending frames due to interference with another transmitting station

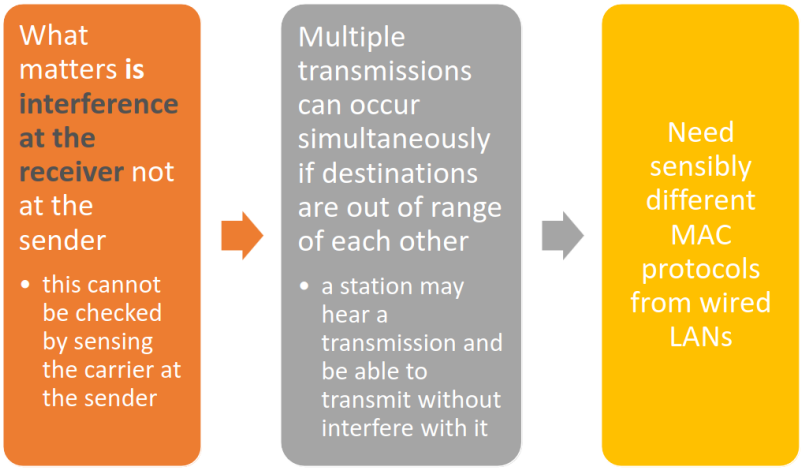


Figure 3.4: MACA Motivations