IoT: THE CHALLENGES AHEAD TO BRING IT FROM HYPE TO REALITY

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Agenda

• What IoT is and its several challenges
  
  IoT … the T means Things

  IoT and Data

  IoT and Communications

  A Few Remarks
Context: the Rise of Softwarization

Key drivers towards softwarization

<table>
<thead>
<tr>
<th>Commodity of HW, i.e., general purpose HW is becoming more and more powerful and cheap. Cloud computing evolving towards the a Fog of very powerful terminals (smartphones)</th>
<th>Virtualization, i.e., the capability to execute functions and services on virtual computational environments</th>
<th>Autonomics and Self-Organization, i.e., the ability of large system to adaptively and autonomously optimize their behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commoditization of communications, i.e., the ubiquitous availability of communications means</td>
<td>Availability of Application Programming Interfaces for several resources and functionalities (pertaining to the Comm, Stor, Proc, Sens/Acting realms)</td>
<td></td>
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<tr>
<td>Open Source, i.e., the ability to model resources and functions by means of software communities that share results and tools</td>
<td>Big data, i.e. the capability to collect data in real time that describe a phenomenon associated with a resource or a person (or groups of them)</td>
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Softwarization instantiations

- **Softwarization of the Telcos**
  - Software Defined Networks (SDN)
  - Network Functions Virtualization (NFV)
  - Integration of SDN, NFV with Cloud

- **Emergence of new Services paradigms and Biz Models**
  - Servitization: Anything as a Service (e.g., IoT, IwT)
  - Pervasive sensing and actuating

- **Virtual Continuum**
  - Creating new Virtual Worlds bridging the Physical
  - WorldMetaverse: Integrating of the Physical and Virtual Worlds
  - Micro-Manufacturing: 3D Printers

- **Big Data**
  - Real Time Data management
  - The Bank of User Data
  - Electronic Money

- **Edge as Point of Intelligence Accumulation**
  - Smart Terminals
  - Different connectivity options
  - Smart environment
  - ....

**Processing, Storage and Communication resources will be interchangeable.** Their composition will allow to provide high quality services, while virtualization and autonomics will allow for system optimization (aggregating resources where they are needed the most)
What IoT is: two different views

The Internet of Things (IoT) envisions systems made out of networked sensors and smart objects whose purpose is to measure/control/operate on an environment in such a way to make it intelligent, usable, and programmable and capable of providing useful services to humans.

• **Single Administrative Domain**
  - In a single administrative domain Internet of Things envisions a system comprising sensors/actuators, aggregators and gateways, service control. These components use Internet protocols and/or specific sensor protocols to communicate.
  - These systems could be quite large in size and complex in technologies (even if they will tend to use a few of them), but they are homogeneous from a management perspective (at least in processes and governance) and in ownership.

• **Multiple Administrative Domains**
  - In multiple administrative domains, the IoT envisions the integration of several heterogeneous systems (i.e., networks of networks), each one using different technologies, interfaces and protocols and governed/managed by different Actors by means of different processes and managements functions.
  - The Internet of Things (IoT) in a multi domain envisions a self-configuring and adaptive complex system made out of networks of sensors and smart objects whose purpose is to interconnect “all” things, including every day and industrial objects in such a way to make them intelligent, programmable and more capable of providing useful services to humans.
IoT implies a lot of Challenges

- Definition of Things and «Identity of Things» Challenge
- Complexity Challenge
- Communication Paradigms Challenge
- Data Challenge
- The Software Platform Challenge

- Silos vs. Horizontal Application Domains
- The revenue challenge
  - Per device
  - Connectivity
  - Data
- The Value Chain Challenge
- New Biz Model Challenge

- Privacy Challenge
- Ownership Challenge
- Security Challenge
- Easiness of Use Challenge
- Social Cooperation Challenge
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What IoT is and its several challenges

IoT ... the T means Things

IoT and Data

IoT and Communications

A Few Remarks
“Things” refer to any physical object with a device that has its own IP address and can connect & send/receive data via a network.
How Many Things?

The Internet of Things
An Explosion of Connected Possibility

- 2020: 50.1 Billion
- 2018: 34.8 Billion
- 2016: 22.9 Billion
- 2015: 18.2 Billion
- 2014: 14.4 Billion
- 2013: 11.2 Billion
- 2012: 8.7 Billion
- 2003: 0.5 Billion
- 1993: 1,000,000

## What are Internet-Connected Things?

<table>
<thead>
<tr>
<th>Generic Info</th>
<th>Contextualized Info</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passive Objects</strong></td>
<td>A Tag, A pointer to some information</td>
</tr>
<tr>
<td><strong>Reactive Objects</strong></td>
<td>A switch at home (turn it on/off), A smart meter</td>
</tr>
<tr>
<td><strong>Autonomous Objects</strong></td>
<td>A Vending Machine, An Intelligent Fridge</td>
</tr>
</tbody>
</table>
Sensors: Example in E-Health

Each Object can be a “Smart Thing”

- Each Resource is representable in the Cloud
- Each resource can be made programmable
- Each Resource can be functionally augmented
Dealing with Billions of smart and independent things?

Billions of smart objects cannot be managed in a traditional manner.

There is the need to move towards zero-configuration and autonomic systems.
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# How much Data (and traffic)?

**Table 3. Summary of Per-Device Usage Growth, MB per Month**

<table>
<thead>
<tr>
<th>Device Type</th>
<th>2014</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsmartphone</td>
<td>22 MB/month</td>
<td>105 MB/month</td>
</tr>
<tr>
<td>M2M Module</td>
<td>70 MB/month</td>
<td>366 MB/month</td>
</tr>
<tr>
<td>Wearable Device</td>
<td>141 MB/month</td>
<td>479 MB/month</td>
</tr>
<tr>
<td>Smartphone</td>
<td>819 MB/month</td>
<td>3,981 MB/month</td>
</tr>
<tr>
<td>4G Smartphone</td>
<td>2,000 MB/month</td>
<td>5,458 MB/month</td>
</tr>
<tr>
<td>Tablet</td>
<td>2,076 MB/month</td>
<td>10,767 MB/month</td>
</tr>
<tr>
<td>4G Tablet</td>
<td>2,913 MB/month</td>
<td>12,314 MB/month</td>
</tr>
<tr>
<td>Laptop</td>
<td>2,641 MB/month</td>
<td>5,589 MB/month</td>
</tr>
</tbody>
</table>

Source: Cisco VNI Mobile, 2015

- = 2.33 MB /Day
- = 12.2 MB /Day
- = 27 Byte /s
- = 141 Byte /s

IoT Data and ... Identity of Things

Things have Identities (and Owners)

People have Identities and use Things

Identity Relation

Functional Relation (events and cmds)

“My” Smart Thing

Raw data to be transformed into Info

Functional Profiling

Personal Profiling

Who, Where, When, What, Why, ...

Third Parties
What to do with data?

Based on https://securityledger.com/2014/04/will-not-big-data-create-darwinian-struggle-for-insurance-carriers/

Profile Engines
- User Profiling
- Community Profiling
- Service/App Profiling
Aggregating Data per Identity ...

"OUR" Smart Things

Raw data to be transformed into Info

Events and commands

Functional Profiling

Personal Profiling

Who, Where, When, What, Why, ...

Who is the Owner of all these Data?

Who has the right to extract info?

Bigger DATA

50 B Devices

* ~ 2MB/day

(Average Aggregated Traffic of M2M Devices)

= ~ 88.81 petabytes /day
Some observation on (Big) Data

Vertical Markets Data will contribute to the Data Surge
- Many data from verticals sources and services
- Integration with different systems
- Multimedia data

Privacy of data and fair usage
- There is the need to protect the final user
- New ownership of data are to be defined (Bank of user data)

IoT and Big Data analysis will go hand in hand
- Exploitation and monetization of data sets
- Collection of data and new applications fields is essentially undiscovered
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Communication Environments

Long Range Communication (3G, 4G, 5G, ...)

Short Range Communication (WiFi, BlueTooth, NFC, ZigBee, 6LoWPAN, ...)

The Network is a commodity. Intelligence aggregates at the Edges. Network Intelligence makes no sense.

• Network as a smart, fast Pipe
• Distributed Edge Networked Platform
• Value of UpLink
• Control of Spikes of Information
• Virtualization in the Cloud of Resources
• Transactional Communication with Guarantees

Pervasiveness and high distribution of functions
Complete decentralization
New communication paradigms
Autonomic behavior
Opportunistic and dynamic usage of resources and networks
Integration of processing, storage, communication and “sensing”
Intel has unveiled a WiFi sliver of silicon that can be part of a normal microprocessor chip.

We can expect that wherever we find a microprocessor (e.g. in over 70% of toys, to name just one area) we will find embedded connectivity.

Roberto Saracco
http://www.blog.telecomfuturecentre.it/

A trend in devices: integration of communication, processing, storage and sensing/actuation capabilities

This a is a big challenge from devices: how can we take advantage in terms of services and application of this power in a single node?
Nodes will connect in unpredictable ways

- Increasing richness and complexity at the edge of networks
- D2D Communications

Node Aggregation at time $t_1$

Node Aggregation at time $t_2$
5G Slicing supporting IoT

IoT Services and Application

Virtual Infrastructure

IoT Slice

5G standards should have less than 1 millisecond (msec) of latency
An important Functionality for IoT in the 5G

- Intelligent Routing of Events and Messages thanks to SDN
- Transaction Management
- R.T. extraction of Knowledge

We need to bring Intelligence at the Edge of the Network
Takeaways on Communications

Understand the fundamental role of Terminals and Devices

The Intelligent is at the EDGE (Put in the Net only valuable functions)

5G as an enabler
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The Software Issue: What Platform for IoT Networks
(the middleware and softwarization challenge)

Vertical Markets: a choice between Vertical and specialized platforms vs. horizontal and general purpose ones

- Application Framework
- IoT Platform Services

A Framework for developing Applications
Distributed OS (comprising Local OSes)
Sensors / Actuators/ Smart Objects

Sensor as a small computer ➔ it needs an Operating System providing for basic functions

Mobile Sensor API is an example of middleware for Wireless Sensor Networks

Obviously there are many OSes for IoT (e.g., Contiki, ...)
Many European Projects are working towards this vision
Dealing with Data in a Fair Way

DataWeb (ref.: The Dataweb: An Introduction to XDI - White Paper for the OASIS XDI Technical Committee)

Networks should aggregate data but keep the users anonymous
- The Facebook example: from user data and behavior it is possible to derive the sexual orientation


Linking the data and protecting them

The goal of XDI is to enable data from any data source to be identified, exchanged, linked, and synchronized into a machine-readable dataweb using XML documents just as content from any content source can linked into the human-readable Web using HTML documents today.

User Context

Owl: Context Entity

Activity

Location

Person

Device

Time

Speaker

Computer

Lecturer

Student

hasDevice

hasActivity

isActivityLocationOf

hasDeviceLocation

isDeviceOf

hasActivityLocation

hasLocation

hasLocation

hasTimeInterval

hasBuddy

CurrentActivity

ScheduleActivity

ComputerLab

MeetingRoom

CurrentTime

TimeInterval
Many interoperability Issues

- Software Interoperability
- Protocol Interoperability
- Data Interoperability
- Processes and management Interoperability
- Reliability / Autonomics
Business Issues

- Value Chain
- Viable Business Models
- Prosumers and Users

This business model HAS to work! Because we need the money!!
Social Issues

- The Big Brother Syndrome
- Fairness to Users
- Easiness of usage
- Security and Privacy
- Disappearing Interfaces
- Providers' responsibility
- Customers' acceptance
Grazie
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