State of the Art and Related Technologies

ITEA2 11020 Project

VERSION	1.0

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Date	**15 January, 2014**
Status	**Version 1.0**
Confidentiality	**Public**

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DOCUMENT HISTORY

Version	Date	Editor	Comments
0.1 Draft 1	June, 2013	Antonio M. Ortiz	Initialization for partner contributions
0.1 Draft 2	June, 2013	Prodevelop	Data storage & aggregation
0.1 Draft 3	June, 2013	UAH	Data management
0.1 Draft 4	June, 2013	Prodevelop	Review Data management section
0.1 Draft 5	July, 2013	Alcatel-Lucent	Introduction to Data Management. Data Collection
0.2 Draft 1	July 2013	Institut Mines-Telecom	Contribution aggregation
0.3 Draft 1	August 2013	Planet Media	Physical objects contribution
0. 3 Draft 2	September 2013	Institut Mines-Telecom	Crowd-based Technologies contribution
0.3 Draft 3	September 2013	Instituto de Telecomunicacoes	LTE: Low cost M2M and the proposed D2D architecture contribution
0.3 Draft 4	October 2013	Prodevelop	Apache Mahout for Hadoop
0.3 Draft 5	October 2013	UPV	Web of Objects, Services and Applications
0.3 Draft 6	November 2013	Gemalto	ETSI architecture
0.3 Draft 9	December 2013	KoçSistem	ZigBee, 6LoWPAN, Bluetooth
0.3 Draft 11	December 2013	UPEMLV	Devices and communications, Data Management, Crowd based technologies
0.3 Draft 12	January 2014	UPEMLV	Services and applications
0.3 Draft 13	January 2014	UAH	References updated in Section 5
0.4 Draft 1	January 2014	IMT	Updated contributions
0.4 Draft 2	January 2014	IMT	Updated references in Section 4
0.4 Draft 3	January 2014	IMT	Added introduction

1.0 Candidate	January 2014	IMT	First candidate version, copyright added, homogeneous style, references corrected, list of figures and tables
1.1 Candidate	January 2014	IMT-UAH	Included Social Networks description, comments from UAH, and first global check
1.2 Candidate	January 2014	IMT-UAH-US	Included conclusions for chapters 3 and 4, comments from UAH, resource modeling section from US
1.4 Final	January 2014	IMT-US-Gemalto	Added Section 7, format check and general review

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1. Introduction

The Internet of Things (IoT) envisions a world where everything is connected, from houses to cities, going through vehicles and infrastructures, users will be able to handle millions of objects that can sense the environment and communicate through wireless links.

Nowadays, the technology is evolving so fast that the computing and storage power are becoming higher and higher, and the devices are reducing their size.

With that huge number of devices, often called “objects” or “things”, there exists the need for managing such an amount of information; services offered by ubiquitous computing, and applications derived from these services must be completely configurable and available for the users, so they can customize the system capabilities to match their needs.

Considering an enormous number of devices with a massive number of users, the interactions of the latter also play an important role in the system. Social Networks appear as a solution that models the different user capabilities and relationships that can occur when making use of the system. They also facilitate the cooperation among different users, and are a perfect environment where users can share experiences, as well as devices.

The inclusion of objects in the Social Network brings new potential to the whole system, so enhancing the interaction among users and devices, but also carrying new challenges in terms of modeling, interactivity, security and trust among others, as well as adding more complexity to the management of the whole system.

This new framework, composed by users and devices, is aimed at producing a huge amount of data that have to be efficiently managed, requiring efficient collection, aggregation and analysis mechanisms. Communications, mostly wireless, and the possibility of managing the system through different devices (smartphones, tablets, PCs, etc.) augment the complexity of the system and represent an amazing research challenge.

But how to make this system attractive for users and stakeholders may be the most difficult point; how to manage all the information, making services available, and designing interesting crowd-based applications is the main focus of the SITAC project.

SITAC project aims at creating a unifying architecture and ecosystem comprising platforms, tools and methodologies that enable the seamless connection and cooperation of many types of network-connected entities, whether systems, machines, devices or humans with handled devices. SITAC will deliver an open platform to enable such actors to monetize their products and services (whether communication infrastructures, installed sensors, data flows or labour) as well as share revenue, much in the way that cloud computing platforms do. The project will innovate by using the ‘social networking’ paradigm to facilitate and unify interactions both between people and devices and among devices. It will propose a distributed framework for enabling the Web-based service representation of smart spaces and the object they include.

To reach this goal, SITAC project mainly covers the following innovative aspects:

- Facilitating seamless connection and cooperation among devices and users through

- Facilitating seamless connection and cooperation among devices and users through the use of social networks and crowd-based applications.

- Allowing casual users to take control of such massively deployed objects in a convenient and safe manner.

- Providing a platform which enables the development of Social IoT and crowd-based applications and its relevant business-wise ecosystem.

- Enabling in-node content analysis and decision making to decrease the amount of data flows.

- Addressing technical challenges related to data analysis and recommendation techniques when leveraging the social network and crowd-based paradigms.

1.1. Organization and Deliverables

This deliverable is structured in seven main sections, which cover the main research aspects of the project. Each section is further decomposed into a number of subsections. The followings are the outline of this deliverable.

- Related paradigms, projects and architectures: as key technological domains, this section addresses the Internet of Things, and Social Networks paradigms, as well as some related European research projects.

- Devices and communications: this section, divided into physical objects and network technologies shows an overview of the related technological developments that will be the basis of the SITAC developments.

- Services and applications: how users and devices capabilities are organized and structured is detailed in this section, from service creation and composition, to application development.

- Data management: a deep review on the state of the art related to data collection, aggregation and analysis is presented in this section.

- Crowd-based technologies: some this section reviews the state of the art in the design of services and applications based on the crowd.

- Security, trust and privacy: final user trustfulness is very important for the SITAC developments. This section reviews several mechanisms related to the security, trust and privacy that will be considered during the design and development of SITAC products.

2. Related Paradigms, Projects and Architectures

This section constitutes a review of the SITAC related technological developments in terms of paradigms and architectures, as well as projects that afford similar scientific approaches. It is divided into Internet of Things and Social Networks subsections, since they represent the most relevant approaches to the SITAC paradigm.

2.1. Internet of Things

Nowadays, Internet of Things [1] represents a global network interconnecting smart objects by means of extended Internet technologies. It is built on three pillars related to the ability of smart objects to be identifiable, to communicate, and to interact, either among themselves, building networks of interconnected objects, or with end-users or other entities in the network. IoT can be described from different perspectives:

- From the conceptual point of view, IoT is about entities acting as provides and/or consumers of data related to the physical world. The focus is on data and information rather than on point-to-point communications.
- From a system-level standpoint, the IoT can be described as a highly dynamic and radically distributed networked system, composed of a very large number of smart objects producing and consuming information.
- From a service-level perspective, the main issue related to how to integrate or compose the functionalities and/or resources provided by smart objects into services.
- Finally, from the user point of view, the IoT will enable a large amount of *always responsive services*, which shall answer to users' needs and support them in everyday activities.

At present, a large number of researchers are focused on developing technologies related to IoT. Next, a description of the main IoT-related European project is provided.

2.1.1. Internet of Things Architecture (IoT-A), FP7 project

During the last years, we have witnessed the emergence of plenty of communication solutions targeted at specific domains of the Internet of Things. On one hand, this can be seen as positive as long as it helps to uncover the real potential of IoT related technologies. On the other hand, there is a risk related to the potential isolation of the developed applications: specific applications with specific architectures, which are not able to interoperate or even communicate. Unfortunately, this lack of interoperability and cooperation means that it is not possible to take full advantage of this new family of technologies. Moreover, IoT related technologies are associated to a high level of heterogeneity and as a result of that, the IoT environment is highly fragmented. Because of the previous reasons, it has been said that more than an Internet of Things, we should be talking about an Intranet of Things.

The IoT-A project (http://www.iot-a.eu/public) is focused on promoting interoperability both at the communication level and at the service and knowledge levels across different platforms established on a common grounding. IoT-A proposes an architectural reference model, providing foundations to build upon, such as unified protocols and protocol stacks and machine-to-machine (M2M) interfaces. Moreover, IoT will provide guidance to future designers on IoT protocols, in form of system calls and architecture interfaces description, so that they are able to develop their solutions in an interoperable manner.

In order to achieve this goal, the IoT-A project propose first to establish a common understanding framework, which is called Reference Model and then provide to developers a common foundation for establishing the IoT system architecture, which is called Reference Architecture.

A Reference Architecture, according to the terminology of this project, covers all the possible functionalities, mechanisms and protocols that can be used to build an architecture for the Internet of Things. Taking into account the requirements and constraints of one particular case, it would be possible to select the protocols, functional components and architectural options needed to build a concrete IoT system.

With their main focus set on interoperability, the idea behind this project is to ease down the creation of different Internet of Things systems, potentially in different application domains, that are able to cooperate. One of the main sources of heterogeneity in Internet of Things systems is related to the diversity of communication protocols (6lowpan, Zigbee, IPv6…) and device technologies. This serves as a foundation layer for different kinds of application that as they provide the applications with the ability to communicate. The combination of the Reference Architecture and the Reference Model of IoT-A project is intended to offer to system architects a set of models, guidelines, best practices, views and perspectives that can be used for the construction of fully interoperable IoT architectures and systems. The underlying idea would be to choose a minimal set of technologies and, taking into account the requirements of the application we are dealing with, choose the necessary set of enablers and building blocks using the IoT-A as a guideline. It is important to highlight the IoT-A does not propose a concrete architecture but a set of methodologies and guidelines to generate one; depending on the exact environment you are working on. The benefit of this approach is twofold; first, it is possible to automate the process to some extent and second, the generated architecture will intrinsically provide interoperability with other architectures that have been generated using this same procedure.

The approach followed by IoT-A project has been to base its work on the current state of the art. An Architectural Reference Model (ARM) is based on the main features extracted from the state of the art, in an effort to ensure backward-compatibility and to enable the adoption of existing solutions to various aspects of the IoT. This ARM also takes into account end users, organized into a stakeholders group, who will help to introduce new requirements in the model building process.

The IoT ARM consists of four parts:

- The vision: provides an explanation about how the ARM can be used, the way the methodology can help to build the architecture and how it encompasses business scenarios and stakeholders requirements.

- Business scenarios and stakeholders: it can be seen as a subset of the vision and drives the architecture work. Taking into account business scenarios and stakeholder analysis, it is possible to understand which aspects of the architectural reference model need to be addressed. Also, it allows validating concrete instances of the reference architecture.

- IoT Reference Model: it is the highest abstraction level for the definition of the IoT-A ARM. It models general aspects of the IoT domain, information and information flows and communication aspects. It conforms to OASIS reference model definition.
- IoT Reference Architecture: it is the reference for building compliant IoT architectures. It is focused on abstract set of mechanisms, which take into account view and perspectives on different architectural aspects.

As a whole, the IoT-A ARM provides best practices for the creation of IoT Architectures for different application domains. There concrete IoT-A Architectures are instances from the Reference Architectures. These instances are created from the basis of Reference Architectures along with some architectural choices, e.g. real-time requirements, security… The common basis of all reference architectures ensures interoperability. The role of the ARM is to provide transformation rules for translating the rather abstract models into a concrete architecture using the use case and the requirements.

Reference models and reference architectures provide descriptions with different level of abstraction. The IoT Reference Model provides the higher level of abstraction and it is defined taking into account stakeholder concerns, business scenarios and existing architectures. It provides a model for the common understanding of the IoT domain from different inputs and it is created by experts, which extract the main concepts and relationships from available knowledge. If we transform this into application-specific requirements and extrapolate them, we can build a set of unified requirements to be used to provide a guideline for the creation of the IoT Reference Architecture. This created dependencies between Reference Model and Reference Architectures; a change in a Reference Model can be followed and lead to changed in the Reference Architecture. This ensures the consistency of the IoT-A Architecture Reference Model.

The ARM development process consists of one process, the ARM derivation. The ARM derivation models the domain in order to construct the IoT Reference Model and also makes a functional modeling, which will be taken into account to create the IoT Reference Architecture. The main inputs for this process are the requirements, coming from the requirement-collection phase and the state of the art surveys, which are provided directly from IoT-A.

Once you have an ARM draft, you can use it for guiding the set-up of public use-case demonstrator and the technical work packages, which will review the ARM draft. This review will serve as an input for a review of the ARM. This way we are establishing a spiral design and prototyping model.

IoT-A also provides to the user of the ARM with best practices for deriving use-case and application-specific architectures. When translating the ARM into a specific architecture, potential inconsistencies can be exposed. These inconsistencies can help to point out which areas need further enhancement and the whole process help to achieve a better understanding of the IoT domain.

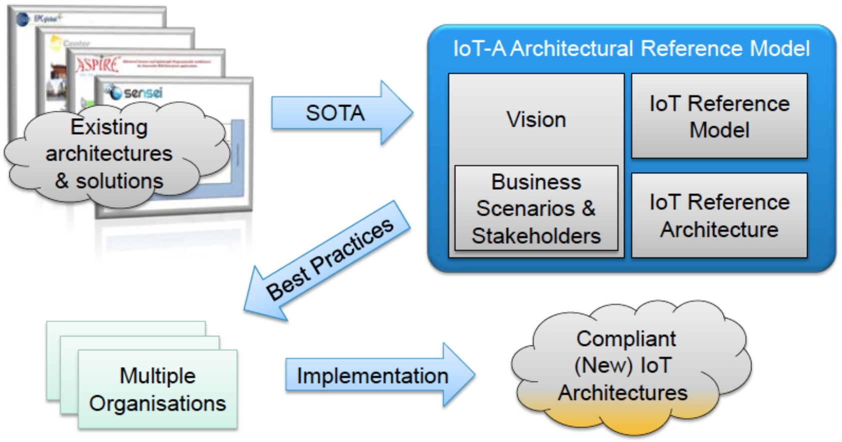

Existing architectures & solutions
SOTA
IoT-A Architectural Reference Model
Vision
IoT Reference Model
Business Scenarios & Stakeholders
IoT Reference Architecture
Best Practices
Multiple Organisations
Implementation
Compliant (New) IoT Architectures

FIGURE 1. IOT-A GENERAL VIEW.

In the next sections, we are going to focus on the main components of the ARM, the Reference Model and the Reference Architecture.

2.1.1.1. Reference Model

The Reference Model is the part of the ARM that provides the concepts and definitions on which the IoT architectures are built. Different sub-models compose it:

- The **Domain Model** is mandatory for working with IoT-A. Describes the concepts that are relevant in the Internet of Things. All other models and the Reference Architecture are based on concepts introduced in the Domain Model. This model introduces the main concepts for the Internet of Things like devices, services, virtual entities and the relations between these concepts. These concepts are independent of specific technologies and are use-case and are not expected to change over time.

- The **Information Model** defines the structure (e.g., relations, attributes) of all information that is handled in an IoT system but without discussing how it is represented. It models the information pertaining to the concepts of the Domain Model, e.g. information about devices, services and virtual entities.

- The **Functional Model** identifies groups of functionalities needed to interact with the instances of the concepts defined in the Domain Model or to manage the information related to the concepts. These functionalities model information according to the concepts defined in the Information Model.

- The **Communication Model** introduces concepts for handling the complexity of communication in heterogeneous IoT environments.

- The **Security Model** is related to the functionalities and interactions needed. Both, Communication and Security Model, constitute also functional groups in the Functional Model.

2.1.1.2. Reference Architecture

The Reference Architecture is a reference for building compliant IoT architectures suited to specific requirements. The Reference Architecture is rather abstract in order to enable many potentially different architectures.

The definition of the Reference Architecture follows the approach of views and perspectives, adapted to IoT-specific needs. The user of an architecture expects an architectural description. One way of providing this description is by means of views: system aspects that can be isolated. A view can be defined as a representation of one or more structural aspects of an architecture that illustrates how the architecture addresses one or more concerns held by one or more of its stakeholders. Unfortunately, views are not enough to describe system architectures, especially to describe stakeholder aspirations of qualitative nature, e.g. privacy. That is when the use of perspectives comes handy.

The IoT-A Reference Architecture defines the following views:

- Functional view: it is constructed using the unified requirements and the Functional Model

- Information View: based on the Information Model, provides more detailed information about how the relevant information is to be represented in an IoT system. Various representation alternatives will be considered as we are describing a Reference Architecture not a specific system architecture. This view also describes the components that handle the information, the flow of information through the system and the life cycle of information in the system.

- Deployment and Operation View: provide users of the IoT-A Reference Model with a set of guidelines to drive them through the different design choices that they have to face with designing the actual implementation of the services. This will constitute a great help to move from the service description and the identification of the different functional elements to the selection among the available technologies in the IoT to build up the networking diagram for the deployment.

Architectural decisions often affect to more than one view and even to non-functional or quality properties. In the context of IoT-A, we define a perspective as “a collection of activities, tactics and guidelines that are used to ensure that a system exhibits a particular set of related quality properties that require consideration across a number of the system’s architectural views”. Based on the stakeholder requirements, the IoT-A project identified the most important perspectives for IoT systems. These perspectives are more focused on a concrete system architecture than in a reference architecture. The most important perspectives are as follows:

- Evolution and Interoperability

- Availability and Resilience

- Security and Privacy

- Performance and Scalability

2.1.2. FI-WARE

The goal of the FI-WARE project is to advance the global competitiveness of the EU economy by introducing an innovative infrastructure for cost-effective creation and delivery of services, providing high QoS and security guarantees. FI-WARE is designed to meet the demands of key market stakeholders across many different sectors, e.g., healthcare, telecommunications, and environmental services. FI-WARE unites major European industrial actors. The key deliverables of FI-WARE will be an open architecture and a reference implementation of a novel service infrastructure, building upon generic and reusable building blocks developed in earlier research projects.

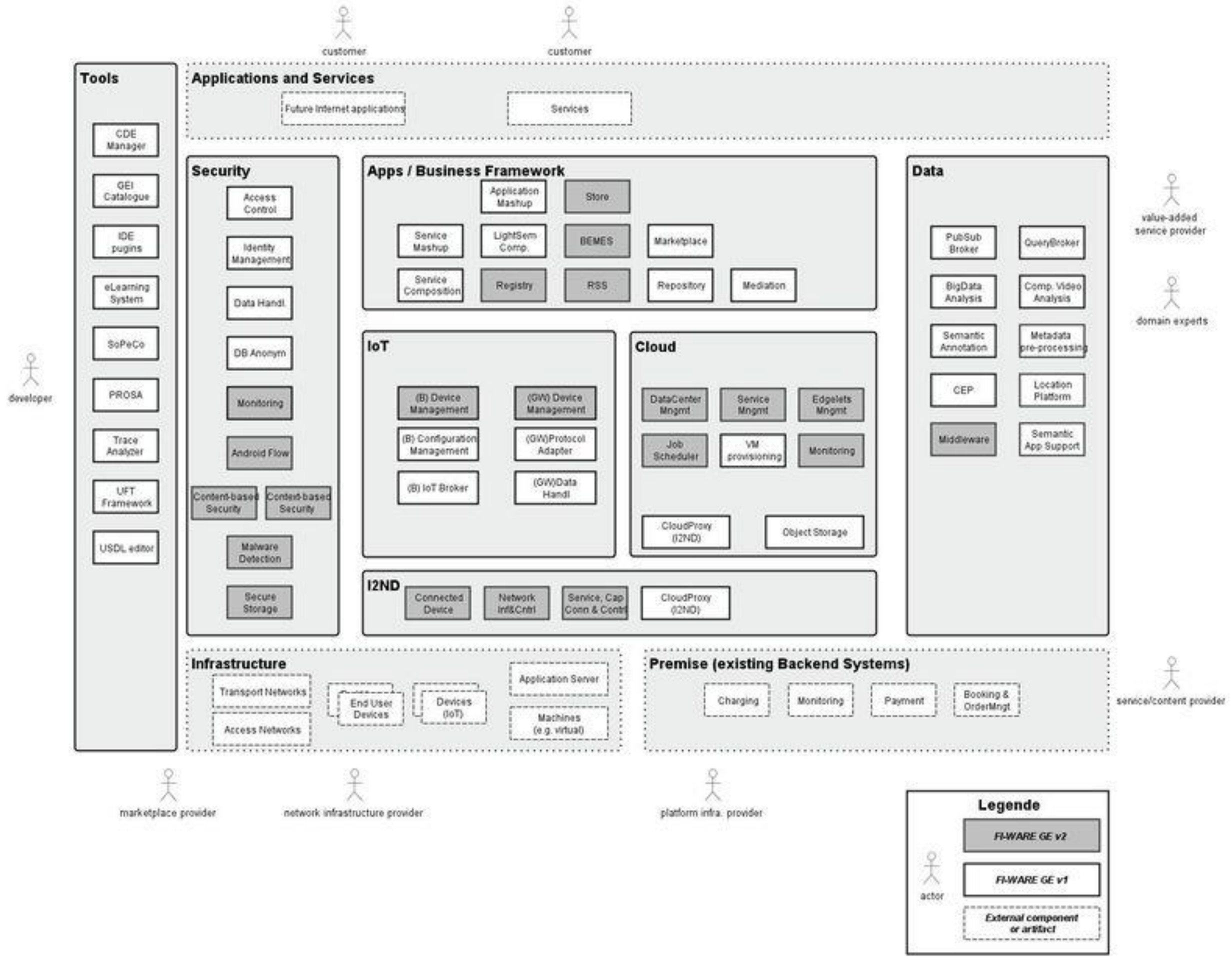


FIGURE 2. FI-WARE OVERVIEW OF CHAPTERS AND GENERIC ENABLERS.

FI-Ware proposes a set of open specification for a set of Generic Enablers classified in different chapters, including, Internet of Things, Big Data and security which are relevant for SITAC [1]. In addition, several implementations of those specifications are proposed in a service Catalog [2].

In the next section, we propose a quick walkthrough of the most relevant chapters:

2.1.2.1. *Data/Context management*

This section proposes Generic Enablers that will aims to gather, publish, process and exploit information and data streams in real-time and at massive scale.

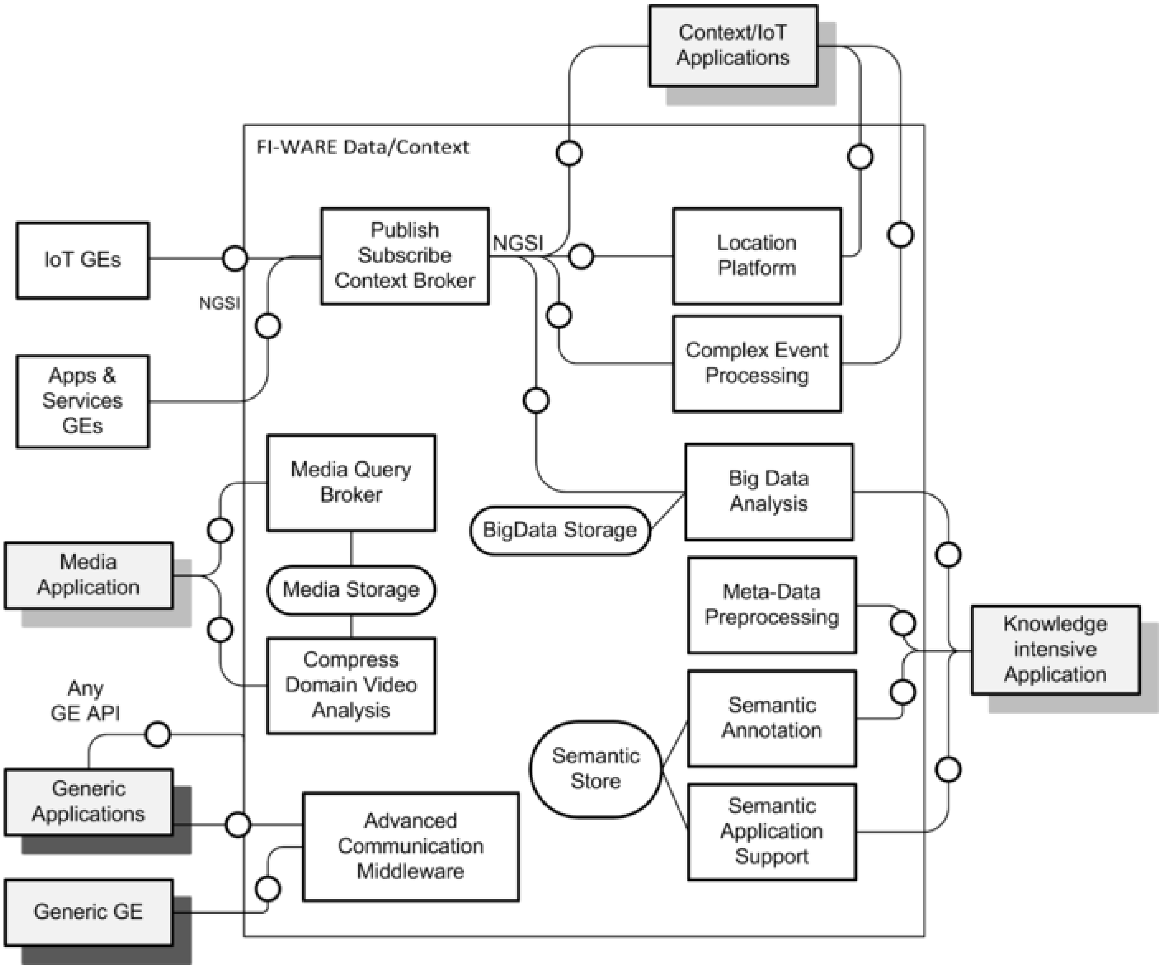


FIGURE 3. GENERIC ENBLERS OF FI-WARE DATA/CONTEXT CHAPTER.

2.1.2.2. *Internet of Things services enablement*

This chapter is dedicated to the integration of devices into information system. It is typically distributed across a large number of device, several gateways and the backend. This chapters defines GEs spread in two domains: (i) Gateway, providing inter-networking and protocol conversion functionalities between devices and the backend, and (ii) Backend, which provides management functionalities for the devices and IoT domain specific support for applications.

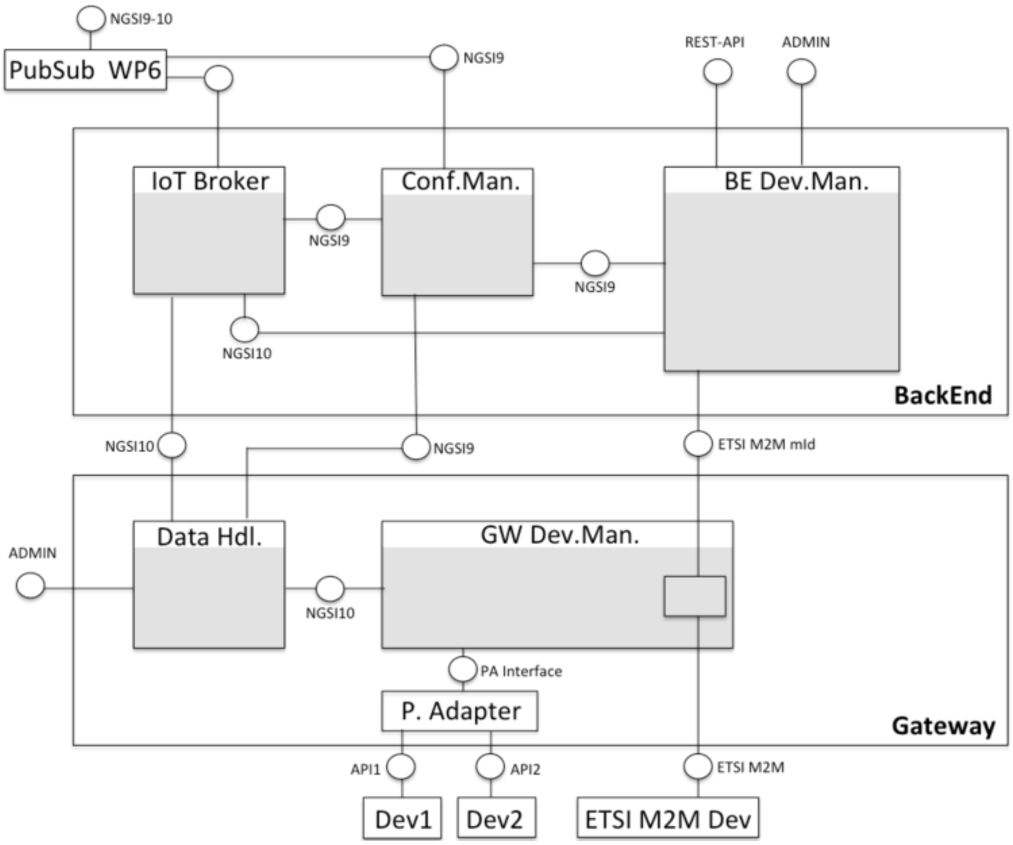


FIGURE 4. MAIN GENERIC ENABLERS OF FI-WARE IOT CHAPTERS.

Among those chapters, several Generic Enablers are particularly in relevant with the objectives of SITAC project.

- Backend Device Management [3]
- Orion Context Broker (Configuration Management) [4]
- BigData Analysis [5]
- Access Control (Administration & Enforcement of RESTful API Authorization Policy) [6]
- Data Handling [7]

Additional Generic Enablers may also be useful for SITAC, and will be analyzed with future SITAC requirements in mind. In addition, GEs are young and probably not already stable enough for external usage. Further experimentations with Generic Enablers will be done to select some of them as part of SITAC architecture.

2.1.3. Web of Objects (WoO) ITEA2 project

The Web Of Objects (WoO) project's goal is to simplify object and application deployment, maintenance and operation on IoT infrastructures. The project will therefore leverage service architecture concepts to propose a coherent architecture applicable to heterogeneous (wired/wireless, different protocols) and dynamic environments of objects embedded in smart environments. As the nature of the envisioned resources (real-world objects ranging from battery-powered, low-bandwidth wireless networked sensors to complex and powerful devices) makes it necessary to have a much less strict separation of layers in the whole approach compared to the current paradigm – WoO should be much more "resource/network aware" than its well-known counterpart. This means that mechanisms such as offering scalability over tens of thousands of points, providing event filtering and aggregation, or support for heterogeneous media including wireless networks with low bandwidth availability should be made visible to the WoO layer.

To reach this goal, the project mainly covers the following:

- **For Network & Devices:** This project proposes enhancements to a set of low-level networking technologies covering Low Power Wireless Technologies and protocols including IPv6 and propose enhanced network mechanisms potentially accessible from upper layers (routing, localization). The project also investigates the security mechanisms necessary to protect user's privacy at the device level.

- **For Elementary Services:** This project proposes a semantic modeling describing objects, their capabilities and provide mechanisms to expose and manage them with respect to existing regulations and adapt existing embedded services technology to the specific requirements of resource-constrained devices. The project also provides mechanisms allowing objects to be aware of and to react to their environment.

- **For Composition & Semantic Mechanisms:** This project specifies and develop mechanisms for creation, composition, deployment and management of objects and aggregated services usable in applications and propose a way to test existing empowered objects behaviour and composed services consistency via ad-hoc simulation. The project also provides a way to integrate legacy systems in the WoO.

And, this project showcases the technology through several demonstrators covering business scenarios in professional and home buildings.

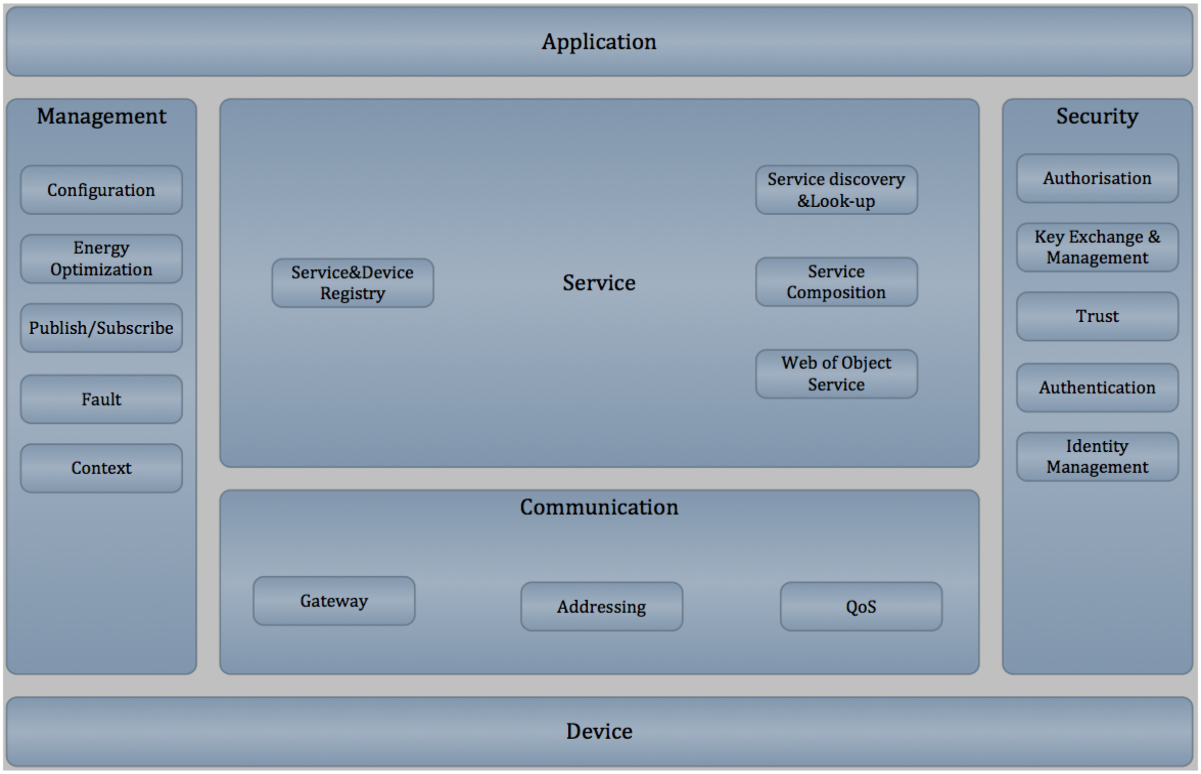


FIGURE 5. WOO FUNCTIONAL ARCHITECTURE.

Taken everything above into account and other ongoing works concerning IoT, Figure 5. Woo functional architecture. depicts a functional overview of the WoO reference architecture, explained in detail below.

- **Device Layer:** This layer involves all kinds of devices in charge of gathering or metering information from the environment, communicating with others devices, modifying the environment, etc. Each of them will provide different means and capabilities for interacting or communicating with other WoO architecture artifacts.

- **Communication Layer:** This layer considers every issue regarding the communication between devices and the rest of layers but security and management. The latters could need to access directly device resources.

- **Management Layer:** This layer combines all functionalities that are needed to govern the system.

- **Service Layer:** An open homogeneous distributed service infrastructure is introduced according to the functions and characteristics of the overall architecture. In addition, a context-aware service adaptation layer is formed targeting all the smart objects, which can collaborate together to accomplish assigned tasks. Within the service infrastructure, service & device registry, service discovery & look up, a semantic and adaptive service composition and service execution platform are introduced.

- **Security Layer:** This layer defines the security components for the system that provide a safe and reliable way to access the system, and ensure the security and privacy of the system. All the components can be divided into two parts. The first one is related to service security, and contains authorization; identify management, trust as well as authentication. The other one is about communication security in which key exchange and management is taken into consideration. It also defines security mechanisms that help protect the network from possible attacks that may occur.

- **Application Layer:** An Application (known as application or app) is a computer software designed to help the user to perform specific tasks. Depending on the activity it was designed for, an application can manipulate text, numbers, graphics, or a combination of these elements. Take a Web-based application for example, with desktop and smartphone interface that will allow users to interact with the system.

2.1.4. Standardized ETSI – TC – M2M architecture

The generic architecture model standardized by ETSI TC M2M is represented in Figure 6, which also shows the reference points for communication between elements. The blue boxes in particular represent the standardized M2M Service Capabilities Layer (SCL), which comprises a computing extension (e.g. in a Cloud) to a Wide Area telecommunication Network as well as computing components on Devices and Gateways directly connected to this WAN. These elements provide an Application Programming Interface to make the M2M functionalities available to M2M server applications on the Network side and M2M client applications on the Device/Gateway side. The difference between a standard M2M Device (D) and a Gateway (G) is that the later provides connectivity to so-called "D'" type devices, which support a compliant M2M application that will use the SCL of the Gateway to access the M2M functionalities.

Several related standardization efforts map well to this general architecture, such as the OMA Converged Personal Network Services (personal consumer networks, interconnecting M2M consumer devices around a telecommunication terminal) and the ETSI Customer Premises Network services standardized by ETSI TISPAN Industry verticals on the other hands had long ago started their independent standardization efforts resulting in very different directions. To a large extend they can still map to the logical architecture above, but the lack of incentive for existing working system to migrate to a new architecture has prevented full integration. For example while the OMA and BBF Device management architectures can be integrated into the ETSI M2M Service Capabilities Layer, interworking with particular technologies is generally provided by an "interworking Proxy" capability in the SCL, as developed for example in TR 102 966. ETSI is working with ESMIG to map the Smart Metering Architecture of the M/441 standardization mandate on its system, and discussions have also be initiated with ETSI TC ITS to map their Intelligent Transport System architecture on the M2M platform. Other verticals such as the Home Gateway initiative expressed willingness to converge toward the ETSI platform.

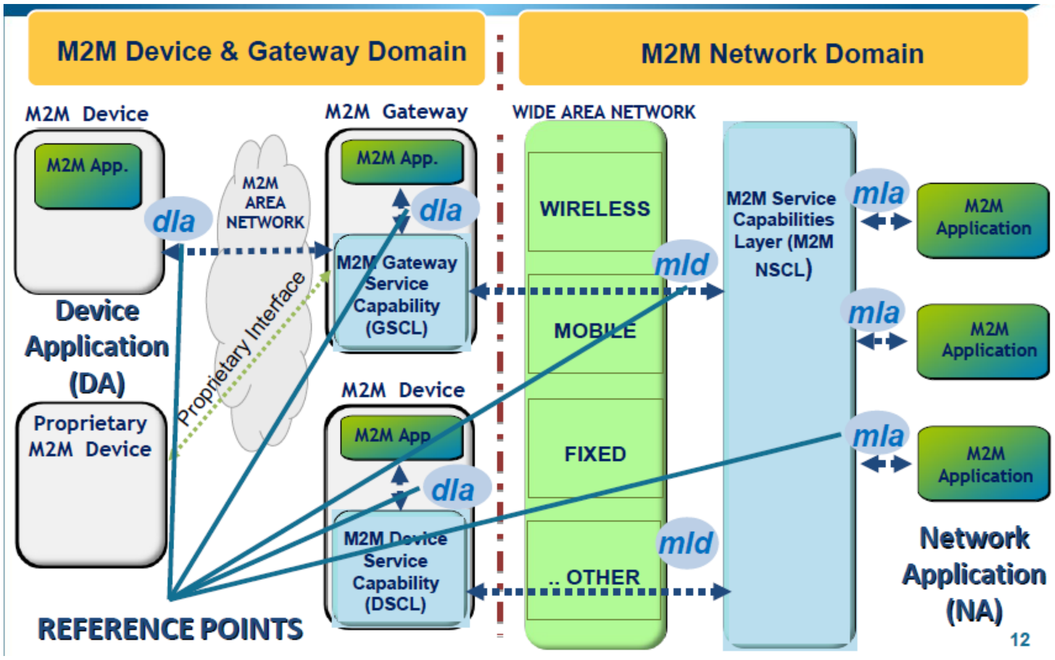


FIGURE 6. GENERIC ARCHITECTURE MODEL STANDARDIZED BY ETSI TC M2M.

However ETSI and the OneM2M partnership remain centered on the needs of telecommunication network operators: This leads to difficulties in working with certain verticals such as Energy utilities (for smart grid standards), and leaves a risk that other players from the Internet involved e.g. in social networking will be able to capture part of the market by promoting simpler approaches, especially in the consumer application domains.

2.1.4.1. *Communication aspects*

The high-level architecture developed within TC M2M is designed to be agnostic to the communication technology used to transport the data, though some awareness of the technology remains needed to benefit from their specificities. The general assumption is that an Internet Protocol connection can be established over the WAN and over the local network, but whether this is established using fixed or mobile lines or whatever network technology is not considered.

On the WAN side, fixed IP networks and converged networks such as defined by ETSI TISPAN, or mobile networks (GSM/3GPP/LTE or CDMA) are the main technologies. The differences between these technologies, especially in terms of security, explain the multiplicity of options proposed in the ETSI M2M specifications.

On the area network side, technologies such as Bluetooth, WiFi, wireless M-Bus or Zigbee are obvious candidates. The applications requirements in the various verticals may greatly vary, leading to predominance of given technologies in particular verticals.

Communication may be synchronous or asynchronous, and also unicast, multicast or broadcast, although the later modes have not been fully addressed yet.

Standard IETF protocols such as HTTP and CoAP are used to transport the data over the defined reference points.

2.1.4.2. *Data and context management*

ETSI M2M has adopted a stateless, RESTful (Representational State Transfer) based architecture style. In this model, all information is represented as resources which are structured hierarchically as a tree. The specifications standardize the resource structure that resides on the M2M Service Capability Layer (SCL, spread between Device/Gateway and Network). Each SCL keeps relevant information in a resource structure. M2M Applications and/or M2M SCLs exchange all information by means of these resources, using standardized procedures to handle them over the defined reference points. An access right mechanism is used to handle resource access. This basically enables cloud-based implementation of the M2M Service Capability layer.

2.1.4.3. *System management*

The system management capabilities provided by ETSI M2M rely on existing already deployed specifications from other committees, which are integrated in the M2M system:

- The TR069 specification from the BroadBand Forum (BBF) is used as the reference to provide M2M system management functionalities over wireline access networks
- The Device Management specifications from the Open Mobile Alliance are used to provide such capabilities over wireless networks.

2.1.4.4. *Service Layer*

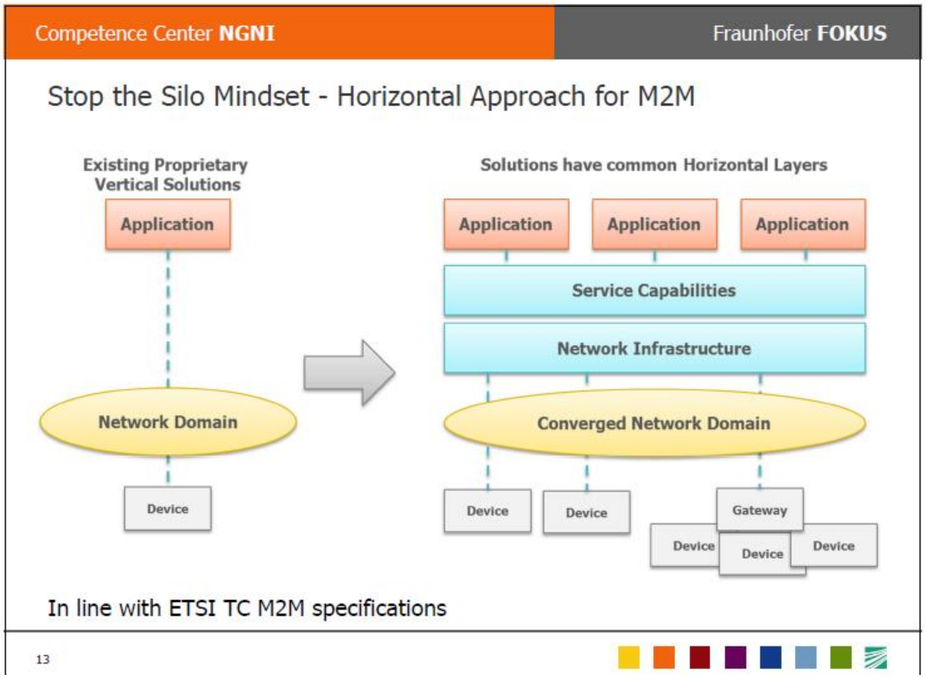
The M2M Service layer is based on standardized APIs used by local M2M applications to access the SCL services. In the end Release 1 provides mostly the following features:

- Identification of the M2M application and M2M device
- Mutual authentication between the Network SCL and the connected Device/Gateway SCL
- Secure channel for transporting data in confidentiality over the mId reference point
- Store and Forward mechanism based on policies for optimizing the communication: This is especially precious in the context of battery-powered devices (e.g. mobile devices, or sensors/meters with no access to main powered and desired long lifetime), which cannot afford to be always reachable online.
- Location information
- Communication management functionalities (see above)
- Device/System management functionalities (see above)

The ongoing work on release 2 may add several features such as end-to-end encryption (with credentials management), service discovery, charging functionalities, use of standardized access network interfaces, peer-to-peer communication across different service providers, Area network management and definition of data models and semantics functionalities.

ETSI M2M is designed for breaking the silo model, and separates the M2M application from the network (with their 3G, 4G, Wi-Fi…) and also from the device manufacturer.

Figure 7 is taken from a public presentation of Fraunhofer Fokus demonstrating the ETSI principles.



Competence Center **NGNI** — Fraunhofer **FOKUS**

Stop the Silo Mindset - Horizontal Approach for M2M

Existing Proprietary Vertical Solutions

Solutions have common Horizontal Layers

In line with ETSI TC M2M specifications

13

FIGURE 7. HORIZONTAL APPROACH IN LINE WITH ETSI TC M2M SPECIFICATIONS.

2.2. Social Networks

Social Networks since its proliferation has evolved rapidly changing the way people represent themselves and interact with each other on the Web. Social networks were basically introduced as a social forum bringing people in close communication with their circle of friends/acquaintances and encouraging them to build and expand a network centered on their own preferences and interests. These networks of people rely to a big extent on *user-generated content*, where users not only share resources of various textual and multimedia formats to their circle of interested friends, they can also contribute to the published content through rating, commenting, tagging, etc. hence they can endorse or denounce a content. All this contributed towards accumulating information to build rich *user profiles*, which became a cornerstone for studies utilizing social networks.

2.2.1. Definition of Social Networks

Recent years have witnessed an extensive and increasing participation of people over the web in various online activities centering on content publishing and evaluation. Such extensive online presence is not only initiated through individuals, communities also can participate in producing or rating content. This paradigm led to the production of a rich set of information including various resources and information content, it also includes relationships and interaction among individuals and communities. A tremendously growing phenomenon that has had a big influence on this online presence and supports the diversity of generated data is called Social Networks.

Social networks are a particular type of virtual community and social software. However, there is neither one generally accepted term nor one well-established definition for social networks. There rather exist numerous similar terms such as social networking service, social networking site, or social network site.

2.2.2. Growth of Social Networks

Since the launch of the first recognizable network, Six-Degrees in 1997 [9], multiple Social Networks such as Facebook, LinkedIn, or Google+ have become popular Internet platforms, where people around the world gather and get connected. The use of social networks has reached an enormous scale: the fraction of Internet users visiting OSNs at least once a month is expected to grow from 41% in 2008 to over 65% in 2014 [10].

This growing phenomenon has been applied in many fields ranging from social sciences, to distributed artificial intelligence and e-businesses. Social networks generally consist of nodes and edges. These nodes refer to any type of object or entity such as individuals and organizations, whereas the edges refer to relationships or associations between these nodes, such as the degree of relationship between two persons or the distance between two cities. Relationships in this sense could be directional, bidirectional, weighted, or a combination of all of this. Scientists in different academic fields have been studying social networks on all levels, from individuals, communities to nations. Such studies proves to play a crucial role in determining the way problems are being solved, predicting users' feedback about a certain product or content based on analyzing their social behavior, and to which extent are certain applications, products or content succeeding in meeting users goals and expectations [8].

2.2.3. Motives for Utilizing Social Networks

Existing literature intensively deals with the users' motives for using social networks. While the majority of studies focus on the most popular and well-known social network platform such as Facebook, it is important to keep in mind that a generalization of these findings for all other kinds of social networks is hardly possible due to their different nature.

Many research contributions in that field suggests that building and maintaining a personal profile to present oneself, is a major motive to use social networks [11]. In this regard Larsen [12] found that mainly the motives for using social networks are represented through the process of when user provide information on their own profile and when others puts more information about friends/acquaintances, through a message board.

In [13] moreover the major motive for using social networks centers around social motives which is represented in searching for personal contacts, and interests, i.e., interest in a certain type of contacts or activity. In this context, the management and maintenance of existing contacts appears as major motives for using social networks.

2.2.4. Research Fields Underlying the Use of Social Networks

To sum-up the research fields underlying the utilization and the investigation of social networks, next we highlight some of the important research fields.

In the field of distributed artificial intelligence, social networks can be used to aid the specification of coordination, cooperation, and negotiation mechanisms of software agents. According to Castelfranchi,“an agent can be helped or damaged, favored or threatened, it can compete or co-operate” [14].

In [15], the social networks to recommend individuals for possible collaboration based on their needed expertise are proposed. A similar process suggested in [16], which is a system that analyzes paper co-citation and co-authoring relationships.

The increasing importance of social networks in many aspects of everyday life also has an impact in collaborative workgroups and communities [17]. Internal social networks in enterprises and organizations offer an attractive means to create social structures and can serve as a channel for information transfer between individuals [18]. Research studies emphasized that internal social networks open up new possibilities for skill-based staffing of knowledge intensive projects [19] [20].

Whereas in [21] and [22] the concept of utilizing social networks as an infrastructure to enable the interaction between people and their physical world of devices and objects is surveyed, offering applications for the social web of things.

In [20, 23] a community detection scheme based on graph mining is proposed for an integrated Internet of things and social networks architecture is proposed. This proposal would help in detection and search operations undertaken by people or IoT nodes in such complex network of SIoT.

The emergence of social networks and increasing participation of people in activities in these sites along with the huge amount of various information like interactions, reviews, interests and different kinds of published contents that are logged by users have attracted researchers and other parties to have access to this information or to the results of analyzing it. This huge generated information raises indeed lots of benefits as well as challenges in studying and analyzing for various social, business and network communication benefits.

Conclusion

Today, the sectorial approach to machine-to-machine communication (based on industry-specific standards (such as for Industrial Control/SCADA, power substations or electric metering) remain the dominant model. This model prevents open data exchange between applications from different fields, which should be a fundament for the Internet of Things. New machine-to-machine deployments such as Smart Grids or Smart Cities already require a less siloed approach to M2M standardization. This need has been recognized by the telecommunication industry more than 5 years ago, and the ETSI TC M2M specifications represent the result of their efforts to standardize a horizontal M2M approach during this period.

Unfortunately most current M2M deployments are still driven by proprietary initiatives that have limited incentive to migrate to open communication infrastructures such as specified by the telecom industry. Therefore adoption of the ETSI horizontal model has remained limited to this day.

This limited audience was the reason for ETSI to consolidate their efforts with other accredited telecommunication standards organizations worldwide, by initiating the oneM2M partnership with TIA and ATIS (North America), TTA (Korea), ARIB and TTC (Japan) and CCSA (China). The oneM2M structure also facilitates involvement of sectorial industry actors in the standards development process. Unfortunately the oneM2M effort really started only about a year ago and is not expected to produce results before the end of 2014 at best.

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Also see:

http://pda.etsi.org/pda/AQuery.asp

http://docbox.etsi.org/SmartM2M/Open/Latest_Drafts/

ETSI TS 102 689, “M2M Service Requirements”

ETSI TS 102 690, ”M2M Functional Architecture”

ETSI TS 102 921, “mIa, dIa and mId interfaces”

ETSI TS 103 092, “OMA DM compatible management objects for ETSI M2M”

ETSI TS 103 093, “BBF TR-069 compatible management objects for ETSI M2M”

ETSI TR 103 167, “Threat analysis and Counter measures to M2M service layer”

ETSI TR 101 584, “Study of semantic support for M2M data”

ETSI TS 103 104, “Interoperability test specification for CoAP binding of ETSI M2M primitives”

3. Devices and Communications

This section presents a review of the different devices and communication paradigms that will be considered in the SITAC developments, representing an overview of the current technology related to IoT-based platforms.

3.1. Physical Objects

3.1.1. Gateways

A gateway is a device that provides inter-networking and protocol conversion functionalities between devices and IoT backend. It is usually located at proximity of the devices to be connected. An example of an IoT gateway is a home gateway that may represent an aggregation point for all the sensors/actuators inside a smart home. The IoT gateway will support all the IoT backend features, taking into consideration the local constraints of devices such as the available computing, power, storage and energy consumption.

One of the main roles of the Gateway is to work as a bridge with devices based on different technologies. The second main role is deployment of optimized smart services as closely as possible to the Things to enable smart applications development.

The level of functional split between the IoT backend and the IoT gateway will also depend on the available resources on the IoT gateway, the cost and quality of connectivity and the desired level for the distribution of intelligence and service abstraction.

It is becoming clearer that ‘smart things’ will need IoT Gateways for communicating with the Internet and various web services.

IoT Gateway should feature:

- Interfaces to networks like Bluetooth, RFID, ZigBee, XRF, etc.
- A way to forward communication from the device to the Internet and vice versa.
- Provide security, like proper authentication of the devices and the services, as well as data encryption.

It´s important to notice that the IoT Gateway will not always support all the IoT Backend features, taking into consideration the local constraints of gateway devices such as the available computing, power, storage and energy consumption. Gateways are connected northbound to the Backend via IP connectivity and southbound to:

- IoT compliant devices with or without IP connectivity.
- Legacy devices that needs protocol conversion.

3.1.2. Repeaters

In a Smart City (SC) environment, the target is to deploy millions of sensors in order to perform wide-scale monitoring. Obviously, there exist a wide variety of sensors, and we will therefore need to harvest a massive amount of heterogeneous data. The data sinks are IoT gateways in the SC architecture. The goal is to gather the heterogeneous sensed data provided by all of IoT nodes, comprising sensors, at the IoT gateways. In order to reach this goal, we need some forwarding nodes also known as repeaters. Repeaters receive the data from different types of IoT nodes and forward them to the gateways. Normally these components are high-raised in street lights, semaphores, information panels, and so on. The communication between IoT nodes and repeaters performs through IEEE 802.15.4 protocol. Last but not least, there are also some sensors embedded in the repeaters for sensing different kinds of parameters such as temperature, CO, noise, light, car presence, soil temperature, soil humidity. There are a few existing examples of SC testbeds, which are built based on this three tiered architecture (IoT nodes, repeaters, and gateways). From among we can refer to the SC of Santander in Spain [1].

3.1.3. Sensors

Sensors are devices that convert a physical parameter into a signal that can be measured electrically or read by an observer. Sensors are a bridge between the physical world and the Internet.

There are many types of sensors: chemical, magnetic, mechanical, position, pressure, temperature, CCD and CMOS image sensors, motion sensing, RFID etc. Each year hundreds of millions of sensors are manufactured. The application of nanotechnology to sensors should allow improvements in functionality. In particular, new biosensor technology combined with micro and nanofabrication technology can deliver a huge range of applications. They should also lead to much decreased size, enabling the integration of nanosensors into many other devices. Sensor/actuator combinations will deliver 'smart' and precise functions in products and processes. Many applications demand miniaturization to reduce power consumption for integration into portable devices. Affordable mass production is also a prerequisite for sensors for consumer products, and for disposable devices such as sensors pollution monitoring.

Sensors (wired and wireless) are ubiquitous and are in domestic appliances, medical equipment, industrial control systems, air-conditioning systems, aircraft, satellites, smoke detectors, robotics, missiles and toys. They are built into many consumer electronic devices, cars, medical devices, security and safety devices, and systems for monitoring pollution and environmental conditions. Sensors support applications across the economy - industrial processes, and those in construction, extractive industries, agriculture, health care and so on - and can be incorporated into new or existing products. In a city, ambient noise levels, CO2 levels, atmospheric temperature, humidity, wind speed, radiation levels etc. are monitored.

The following is a list of some application areas of wireless sensor networks:

- Asset and warehouse management
- Automotive
- Building monitoring and control
- Environmental monitoring

- Health care
- Industrial process control
- Security and surveillance

Sensors can produce large volumes of continuous data over a period of time. The data can be live data, existing data, low resolution, high resolution etc.

Sensors get physical parameter data which are used to make decisions, control systems etc. Once the physical parameter has been converted to an electrical equivalent it is easily input into a computer or microprocessor for manipulating, analyzing and displaying. Information from the data can then be used to make better decisions and smarter solutions leading to for example a smarter city which in turn results in better quality of life for the people.

One appropriate hardware platform for sensor-enabled Smart Cities (SCs), which recently has retained the attention of research community, is Libelium Waspmote. The hardware architecture, thanks to the different sleep modes, has been designed to be extremely low power consumption (0.07uA). Waspmote devices are able to perform wireless communication through eight different kinds of interfaces consist on long range (3G / GPRS), medium range (802.15.4, ZigBee, WiFi), and short range (Bluetooth, RFID, NFC). There are more than 60 sensors available to connect to Waspmote: CO, CO2, soil moisture, presence, humidity, temperature, vehicle detection, radiation, current, liquid, luminosity, etc. Yet another excellent privilege of Waspmotes is that they can be programmed over the air. Over the air programming (OTAP) enables firmware upgrades of the motes without the need of physical access. Firmware upgrades can be made within minutes and it is possible to choose between updating single nodes (unicast), multiple nodes (multicast) or an entire network (broadcast) [2]. Last but not least, there is a 6LoWPAN stack source code available on Waspmotes, and it is possible to program the nodes in Java and C#. So, interested users can simulate thousand of motes working in the same network [3].

3.1.4. Sensors enabled smartphones

In recent years, there is a tremendous growth in the number of mobile devices globally. These devices are typically equipped with various types of sensors such as; GPS, accelerometer, proximity and light sensors, gyroscope, microphone and built-in cameras.

The proximity and light sensors allow the phone to perform several types of context recognition associated with the user interface. The proximity sensor is used to detect the phone’s position such as in cases where the user holds the phone close to the ear in order to disable the touchscreen and keypad. Similarly, light sensors are used to adjust the screen brightness in accordance to the ambient light.

The positioning sensor (GPS) allows the phone to localize itself, thus enabling new location-based applications such as local search, mobile social networks, and navigation. The gyroscope represents an extension of location, providing the phone an increasing awareness of its position in relation to the physical world (e.g., its direction and orientation). The accelerometer detects the different states of the phone user (walking, sitting, etc.) [4].

The microphone and camera are the most powerful tools to identify the different user behavior. This can be achieved by analyzing the ambient level of noise and the picture samples respectively.

Thus, a mobile device can be considered as a multimedia sensor with higher computation, processing and storage capacity. Different health and environment related sensors can either communicate with the mobile phone or integrated within in order to provide additional sensing capabilities. Moreover, its constant connectivity to the communication networks such as Cellular, Wi-Fi and Bluetooth further enhances sensing on a massive scale.

3.1.5. Actuators

Wireless Sensor and Actuator Networks (WSANs) are composed of large numbers of minimal capacity sensing, computing, and communicating devices and various types of actuators.

Sensors gather information about the state of physical world and transmit the collected data to actuators through single-hop or multi-hop communications over the radio channel. Upon receipt of the required information, the actuators make the decision about how to react to this information and perform corresponding actions to change the behaviour of the physical environment. As such, a closed loop is formed integrating the cyber and physical worlds. In addition to sensor and actuator nodes, there is commonly a base station in the WSAN (see Figure 8), which is principally responsible for monitoring and managing the overall network through communicating with sensors and actuators [5].

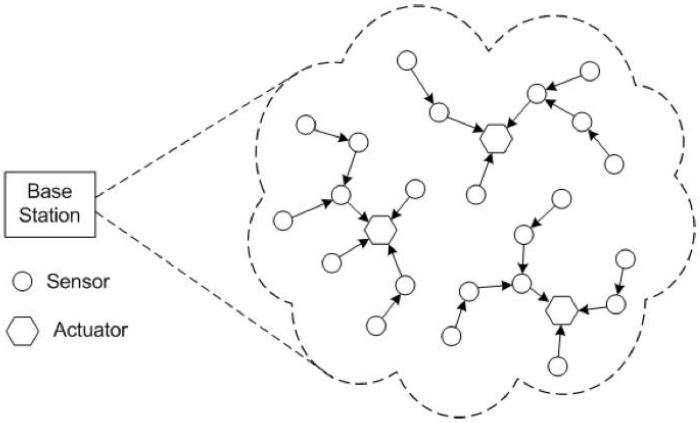


FIGURE 8. A WIRELESS SENSOR AND ACTUATOR NETWORK.

The primary functionality of WSNs is to sense and monitor the state of the physical world. In most cases, they are unable to affect the physical environment. In many applications, however, it is not sufficient to just observe the state of the physical system; it is also expected to respond to the sensed events/data by performing corresponding actions upon the physical system. For instance, in a fire handling system, it is necessary for the actuators to turn on the water sprinklers upon receipt of a report of fire. WSANs can satisfy such requirements by enabling the application systems to sense, interact, and change the physical world, e.g., to monitor and manipulate the lighting in a smart office or the speed of a mobile robot. Yet another example is an HVAC system. In an HVAC system, we might have a control loop designed around reading temperature and CO2 values that need to be processed in order to actuate the heaters, coolers and blowers in different parts of the building [6].

As mentioned previously, there are three essential components in a WSAN: sensors, actuators, and a base station. Depending on whether there are explicit controller entities within the network, two types of system architectures of WSANs for cyber-physical control can be distinguished. These architectures are called automated architecture and semi-automated architecture respectively [7].

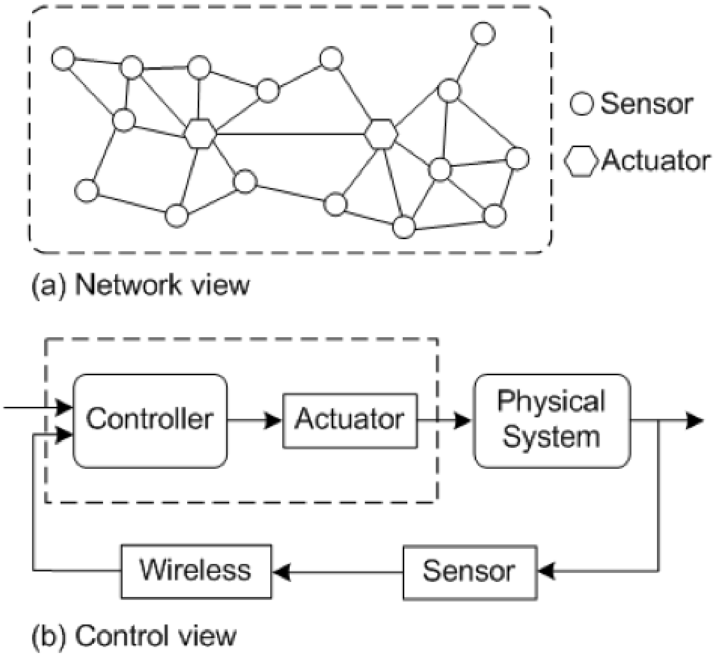


FIGURE 9. WSAN ARCHITECTURE WITHOUT EXPLICIT CONTROLLERS.

For example, an HVAC system might have a control loop designed around reading temperature and values in For making decisions on what actions should be performed upon the physical systems will be executed on the actuator nodes. The data gathered by sensors will be transmitted directly to the corresponding actuators via single-hop or multi-hop communications. The actuators then process all incoming data by executing pre-designed control algorithms and perform appropriate actions. From the control perspective, the actuator nodes serve as not only the actuators but also the controllers in control loops. From a high-level view, wireless communications over WSANs are involved only in transmitting the sensed data from sensors to actuators. Control commands do not need to experience any wireless transmission because the controllers and the actuators are integrated, as shown in Figure 9. In the following, we consider cyber-physical control systems with this architecture [7].

3.1.6. RFID

Radio-frequency identification (RFID) is the wireless non-contact use of radio-frequency electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. The tags contain electronically stored information. Some tags are powered by and read at short ranges (a few meters) via magnetic fields. Others use a local power source such as a battery, or else have no battery but collect energy from the interrogating EM field, and then act as a passive transponder to emit microwaves or UHF radio waves.

The term of RFID encompasses different kinds of technologies. They can be distinguished by their capability of reading distance and the induced applications. Realization of IoT paradigm depends on integration of RFID systems (tracing and addressing items non-contact and automatically).

RFID tags could be used for identification of objects with reading distance which can reach 7 to 8 meters. These tags can work with an important variety of frequency: 135 kHz, 13.56 MHz, 433 MHz, 860 to 950 MHz, 2.45 GHz and 5.8 GHz.

In an IoT scenario, there would be billions of devices that could be addressable and could be connected to IP-based networks. RFID identified as an important identification technology with communication capabilities. Because of its low power consumption in case of active tag and passive tag, large-scale deployment drives it to enable on IoT environments.

3.2. Network Technologies

This section describes the various networking approaches that provide communication capabilities to the different nodes detailed above.

3.2.1. ZigBee

ZigBee as a trademark of ZigBee Alliance is Network Layer (OSI layer 3) protocol facilitating energy efficient wireless mesh networking features on top of IEEE 802.15.4 which is a standard addressing OSI Layer 1 and 2 for devices with constrained resources such as energy and processing. ZigBee specifications which are created and maintained by ZigBee Alliance are as follows [8];

- ZigBee Specification is the basis for energy-efficient mesh networking but also provides a security layer and an application framework. ZigBee specification provides these features under two feature sets;
    - ZigBee PRO
    - ZigBee

While ZigBee PRO is the mostly used implementation among developers, both implementations are designed to interoperate with each other. The main difference between two specifications is the size of the network; ZigBee PRO is capable of supporting larger networks of thousands of devices whereas ZigBee supports smaller networks of hundred devices. For both ZigBee and ZigBee PRO feature sets, the compatibility tests and certification of devices are conducted by ZigBee Alliance.

- ZigBee IP Specification defines IPv6 for wireless sensor network on top of IEEE 802.154. It is an open standard-based specification aiming seamless internet connection of constrained devices via standard internet protocols such as TCP, UDP, 6LowPAN, PANA but without the need of intermediate gateways.
- ZigBee RF4CE Specification provides a simplified network stack with bi-directional device-to-device communication features. Just like the other two specification, RF4CE specification also defines a network layer on top of IEEE 802.15.4 but narrowing the target field of application to simple control applications where full-featured mesh networking is not

necessary. Therefore, RF4CE specification provides a less complex implementation yielding lower memory and cost requirements.

Beyond these three specifications ZigBee Alliance also defines application profiles so called ZigBee Standards which provide customized ZigBee stack for specific application domains which also helps device manufactures to focus more on business needs. The list of these standards and the specification that supports these standards is shown in Table 1 [9]:

TABLE 1. ZIGBEE SPECIFICATIONS AND STANDARDS.

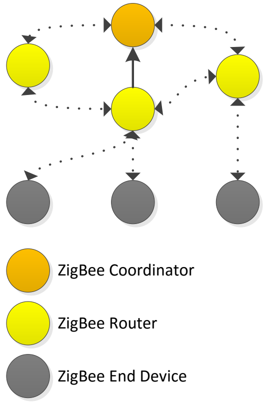
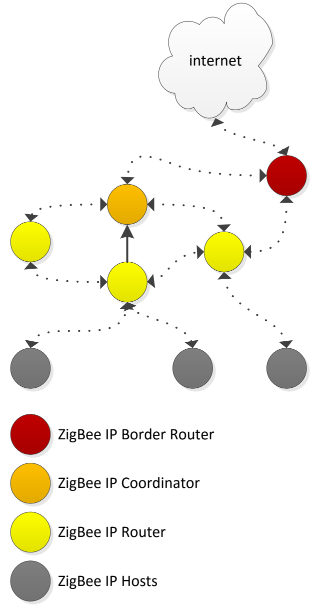
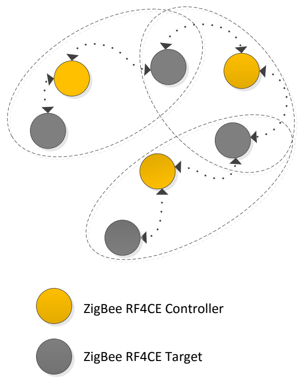
	ZigBee Specification	ZigBee IP Specification	ZigBee RF4CE Specification
Building Automation	✓		
Remote Control			✓
Smart Energy	✓		
Smart Energy v2		✓	
Health Care	✓		
Home Automation	✓		
Input Device			✓
Light Link	✓		
Retail Services	✓		
Telecom Services	✓		

As stated before, ZigBee provides the connectivity of ZigBee nodes by constituting a mesh network so that the output power requirement and the cost of ZigBee devices are lower than WiFi, Even though both WiFi and ZigBee operates on the same ISM band and for an home area network (HAN) the coexistence of these two technology is a common situation, channel variation and the CSMA-CA protocol defined within IEEE 802.15.4 provide robust network connectivity in the coexistence of WiFi devices and other ZigBee devices. On the other hand to satisfy the goal of being low power and low cost, most of the time not only the output power but also the processing and memory capacity of devices are constrained, which has to be taken into account depending on the application specific purposes. For example, in an home automation use case, using ZigBee for the control of battery powered and low cost devices such as thermostats and switches may be a better choice however for white appliances having AC power supplies, built-in control units and circuitry, it may not be the optimum solution.

From the technical specification's point of view the three ZigBee specifications have a lot in common; however there are also some differences which are summarized in the table below.

TABLE 2. ZIGBEE TECHNICAL SPECIFICATIONS.

	ZigBee Specification	**ZigBee IP Specification**	**ZigBee RF4CE Specification**
Physical Radio	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4
Operating Frequency	2.4 GHz plus 915MHz Americas, 868 MHz Europe	2.4 GHz plus 915MHz Americas, 868 MHz Europe and 920 MHz Japan	2.4 GHz plus 915MHz Americas, 868 MHz Europe
Number of Channels	16 channels @ 2.4GHz 10 channels @ 915MHz 1 channel @ 868MHz	16 channels @ 2.4GHz 10 channels @ 915MHz 1 channel @ 868MHz	3 channels @2.4GHz Channels: 15, 20, 25
Raw Data Throughput	250Kbp @ 2.4GHz 40Kbp @915MHz 20Kbs @868MHz	250Kbp @ 2.4GHz 40Kbp @915MHz 20Kbs @868MHz	250Kbp @ 2.4GHz
Transmission Range	10-100m (depends on power output and environmental characteristics)	50-200m (depends on power output and environmental characteristics)	10-100m (depends on power output and environmental characteristics)
Security	AES128 Encryption/ Authentication/ Trust Centers	AES-128-CCM @ link layer TLS v1.2 @ application layer PANA/EAP for authentication	128-bit AES-CCM 128-bit link keys

Topology	 	 internet ZigBee IP Border Router ZigBee IP Coordinator ZigBee IP Router ZigBee IP Hosts	
Scalability	64.000 nodes per network	No explicit limitation	

3.2.2. IPv6 over Low Power Wireless Personal Area Network (6LowPAN)

Since the concept of wireless sensor and actuator networks came into view, many protocols and standards have been defined regarding to machine to machine communication of constrained devices. However most of the focus of these studies is on the protocol efficiency within the network constituted by these constrained devices. Interfacing these devices to the outer world is the responsibility of gateway hardware and/or software. As the concept of internet of things comes up, the machine to machine communication turned into machine to cloud communication, and this brought the necessity of a more standard mechanism to interface these constrained devices to the internet. While the existing IPv6 infrastructure with its upper layer protocol support, existing know-how and tools is a good candidate to connect billions of things, it has never been designed by concerning constrained devices.

Having these requirements, IETF (Internet Engineering Task Force) which is an organization defining standards of the internet, proposed a set of standards; RFC4944 (2007), RFC6282 (2011), RFC6775 (2012) so called 6loWPAN to enable IPv6 routing over low power personal area networks and more specifically over 802.15.4 networks, typically having the following architecture (see Figure 10);

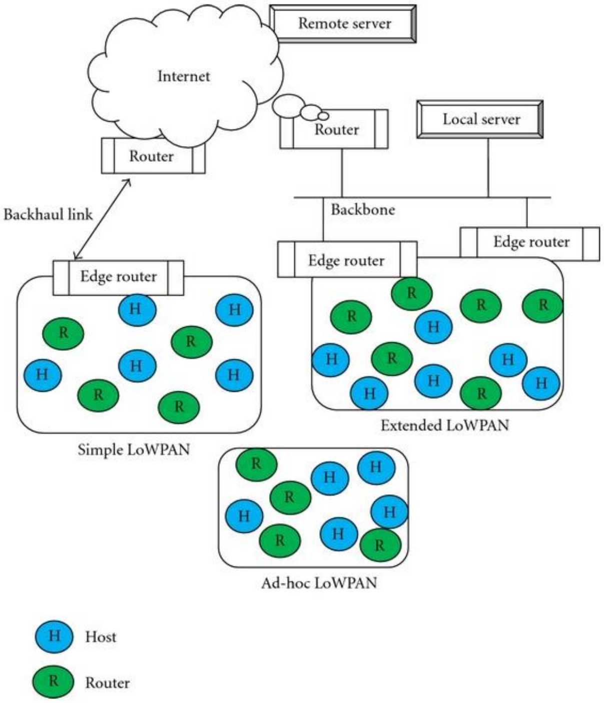


FIGURE 10. 6LOWPAN ARCHITECTURE

As depicted in Figure 11**Error! Reference source not found.**, the most important layer in the 6LoWPAN stack is the adaptation layer which is sitting on top of MAC layer. Among many others, the most significant functionalities addressed within this layer are;

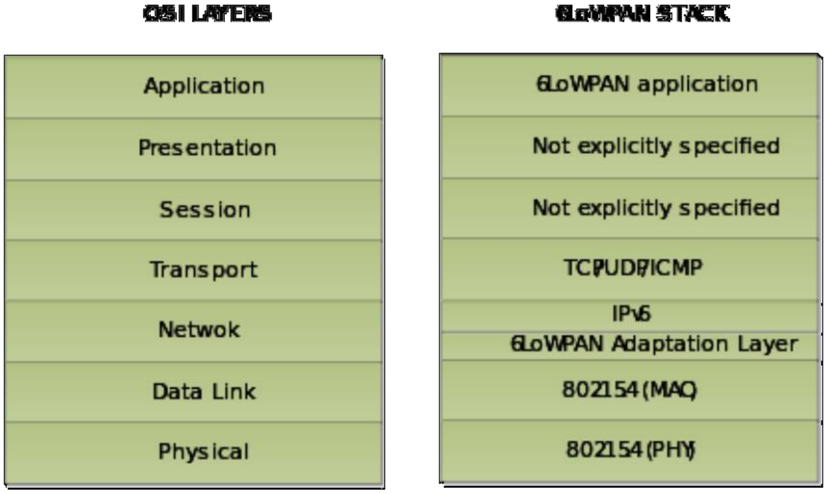
- Header Compression: The header overhead of IP and other upper layer protocols such as UDP, TCP is large. More specifically:

  25 bytes for 802.15.4 maximum frame overhead
  21 bytes for link layer security
  40 bytes for IP header
  8 bytes for UDP header
  Since 802.15.4 has a maximum transmission unit (MTU) of 127 bytes, only 33 bytes left for actual data and it gets even smaller if TCP is used (20 bytes for TCP header). To resolve this issue the adaptation layer facilitates a header compression mechanism which compresses the IP address and upper protocol headers.

- Packet fragmentation and reassembling: IPv6 packets with an MTU of 1280 bytes are too large to fit in 802.15.4 packets. The adaptation layer specifies a fragmentation and a flow control mechanism to overcome this issue.

- Routing: The routing mechanism of 6LoWPAN stack is defined under two cases;

- ○ Mesh Under: routing of packets in LoWPAN. Routing operations such as packet forwarding, path calculation takes place in adaptation layer. There are several routing protocols defined for mesh-under routing such as; Hi-Low, Extended Hi-Low, LOAD, MLOAD, DYMO-Low.
- ○ Route Over: routing of packets in between IPv6 domain and LoWPAN domain. Routing operations take place in IPv6 layer.



OSI LAYERS	6LoWPAN STACK
Application	6LoWPAN application
Presentation	Not explicitly specified
Session	Not explicitly specified
Transport	TCP/UDP/ICMP
Netwok	IPv6 6LoWPAN Adaptation Layer
Data Link	802.15.4 (MAC)
Physical	802.15.4 (PHY)

FIGURE 11. PROTOCOL STACK

As stated above, 6LoWPAN is designed to provide IP capability to constrained devices, therefore the following domains; Home & Building automation, physical security, environment monitoring are all good use cases for 6LoWPAN applications just like ZigBee. On the other hand 6LoWPAN does not specify application profiles unlike ZigBee. This was used to be evaluated as a down side; one can easily come across few years old journals and studies on which ZigBee and 6LoWPAN are considered competitors. However, today they are more like complement of each other and this becomes more obvious after the ZigBee Alliance announced the new ZigBee IP specification for smart energy profile (SEP2) based on the 6LoWPAN.

3.2.3. Bluetooth

Bluetooth is a set of specifications providing wireless connectivity for electronic devices and peripherals. It is mainly designed for low data rate, low cost, low energy consumption and short range communication. Bluetooth technology was first developed by Ericsson researchers in 1994. Today, maintained by Bluetooth Special Interest Group (SIG) which was founded by Ericsson, IBM, Intel, Nokia and Toshiba in 1998, since that time there are several specifications published [11]:

- Core version 2.0 + Enhanced Data Rate (EDR), 2004
- Core version 2.1 + EDR, 2007
- Core Specification Addendum (CAS) 1, 2008

- Core version 3.0 + HS, 2009
- Core version 4.0, 2010
- Core Specification Addendum (CAS) 2, 2011
- Core Specification Addendum (CAS) 3, 2012
- Core Specification Addendum (CAS) 4, 2013
- Core version 4.1, 2013

The technology was also standardized as IEEE 802.15.1 by IEEE 802.15 WPAN Task Group 1 in 2002 [12] and 2005 [13]. Among these specifications, version 4.0 has to be explained in more detail; this is because the specification introduced a new protocol stack which is called Bluetooth Low Energy (BLE) for low energy applications besides the classical Bluetooth (v1.0 to v3.0). One of the significant differences between BLE and the classic Bluetooth is that, BLE is not backward compatible with the previous specifications. However, specification allows implementing either or both of the protocols and the devices which implement both are capable of communicating with both the classical Bluetooth and Bluetooth Low Energy devices. These dual-mode devices are branded as Bluetooth SMART Ready and devices implementing only BLE stack are branded as Bluetooth SMART.

Classic Bluetooth device network is composed of at least 1 master device and 1 (up to 7) slave device(s) and it is called piconet. The communication is initiated by the master device but once the connection the roles may change as requested by slave(s). Slave devices do not communicate with each other directly but over the master device. So that each piconet needs and may have only one master device, on the other hand slave devices can be members of different piconets which form the topology called scatternets.

3.2.4. Near Field Communication

Near Field Communication (NFC) technology allows a simpler way to make payments, pair/connect devices or exchange content just with proximity contact. A standards-based connectivity technology, NFC harmonizes today's diverse contactless technologies, enabling solutions in areas such as: Access control, consumer electronics, Healthcare, Information collection and Exchange, Loyalty and coupons, Payments or Transport. NFC-Forum promotes the use of NFC short-range, was founded in 2004 by Nokia, Philips and Sony, and now has more than 160 members. The Forum also promotes NFC and certifies device compliance. NFC standards cover communications protocols and data exchange formats, and are based on existing radio-frequency identification (RFID) standards including ISO/IEC 14443 and FeliCa. Structurally, NFC Forum specifications are based on existing radio-frequency identification (RFID) and recognized standards like ISO/IEC 18092 and ISO/IEC 14443-2,3,4, as well as JIS X6319-4. NFC structure is shown in Figure 12.

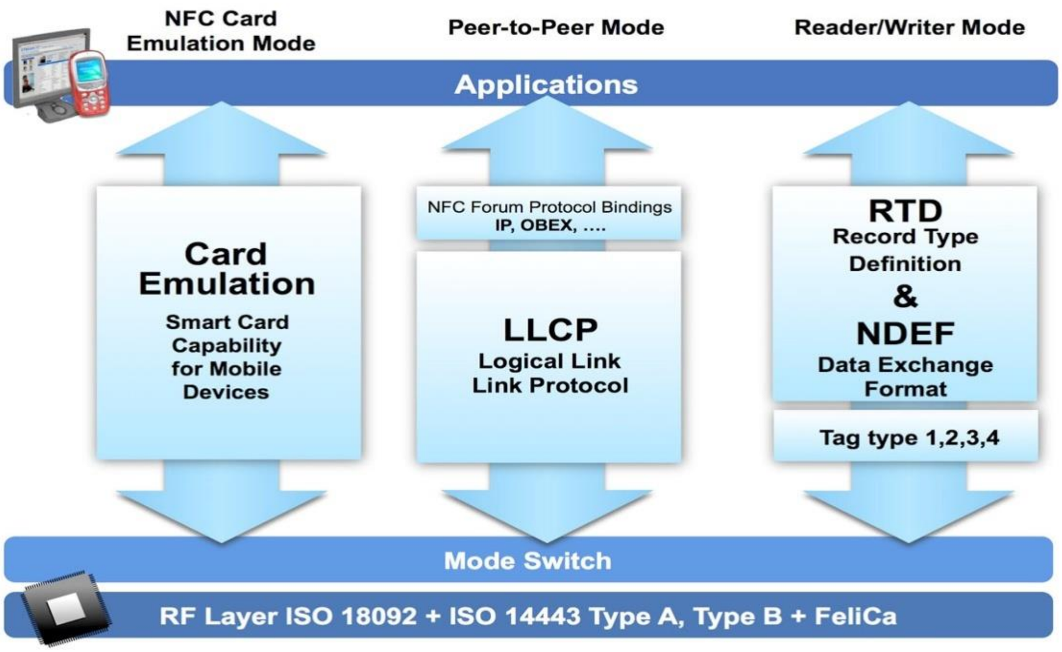


FIGURE 12. NFC STRUCTURE

NFC provides a range of benefits to consumers and businesses, such as:

- *Intuitive*: NFC interactions require no more than a simple touch
- *Versatile*: NFC is ideally suited to the broadest range of industries, environments, and uses
- *Open and standards-based*: The underlying layers of NFC technology follow universally implemented ISO, ECMA, and ETSI standards
- *Technology***-***enabling*: NFC facilitates fast and simple setup of wireless technologies, such as Bluetooth and Wi-Fi.
- *Inherently secure*: NFC transmissions are short range (from a touch to a few centimeters)
- *Interoperable*: NFC works with existing contactless card technologies
- *Security***-***ready*: NFC has built-in capabilities to support secure applications

3.2.5. Radio Frequency ID

RFID is a contactless system for wireless communication which uses frequency bands as shown in Table 5.2. This technology uses electromagnetic fields to transfer data between a passive component and a device or between enabled devices, for example mobile phones.

Passive tags require no battery, there are powered by the electromagnetic field used to read them. RFID tags can be attached to any kind of objects (e.g. cloths, wallets, cars) or devices (e.g. mobile phones, tablets.), enabling the possibility of reading personally linked information.

These are some examples of use cases: commerce, product tracking, telemetry, transportation payments, animal identification, access control or advertising. Main problems around the RFID technology are: data flooding, global standardization, privacy or XMPP temperature exposure.

TABLE 3.COMMON RFID FREQUENCY BANDS.

Band	**Regulations**	**Range**	**Data speed**	**Remarks**	**Approximate tag cost (USD) in volume (2006)**
120-150 kHz (LF)	Unregulated	10 cm	Low	Animal identification, factory data collection	$1
13.56 MHz (HF)	ISM band worldwide	1 m	Low to moderate	Smart cards	$0.50
433 MHz (UHF)	Short Range Devices	1-100 m	Moderate	Defense applications, with active tags	$5
868-870 MHz (Europe) **902-928 MHz (North America) UHF**	ISM band	1-2 m	Moderate to high	EAN, various standards	$0.15 (passive tags)
2450-5800 MHz (microwave)	ISM band	1-2 m	High	802.11 WLAN, Bluetooth standards	$25 (active tags)
3.1-10 GHz (microwave)	Ultra wide band	to 200 m	High	Requires semi-active or active tags	$5 projected

Standards that have been made regarding RFID technology include:

- ISO 14223 – Radiofrequency identification of animals – Advanced transponders
- ISO/IEC 14443: This standard is a popular HF (13.56 MHz) standard for HighFIDs, which is being used as the basis of RFID-enabled passports under ICAO 9303. The Near Field Communication

standard that let's mobile devices act as RFID readers/transponders is also based on ISO/IEC 14443.

- ISO/IEC 15693: This is also a popular HF (13.56 MHz) standard for HighFIDs widely used for non-contact smart payment and credit cards.
- ISO/IEC 18000: Information technology—Radio frequency identification for item management:
- Part 1: Reference architecture and definition of parameters to be standardized
- Part 2: Parameters for air interface communications below 135 kHz
- Part 3: Parameters for air interface communications at 13.56 MHz
- Part 4: Parameters for air interface communications at 2.45 GHz
- Part 6: Parameters for air interface communications at 860–960 MHz
- Part 7: Parameters for active air interface communications at 433 MHz
- ISO/IEC 18092 Information technology—Telecommunications and information exchange between systems—Near Field Communication—Interface and Protocol (NFCIP-1)
- ISO 18185: This is the industry standard for electronic seals or "e-seals" for tracking cargo containers using the 433 MHz and 2.4 GHz frequencies.
- ISO/IEC 21481 Information technology—Telecommunications and information exchange between systems—Near Field Communication Interface and Protocol -2 (NFCIP-2)
- ASTM D7434, Standard Test Method for Determining the Performance of Passive Radio Frequency Identification (RFID) Transponders on Palletized or Unitized Loads
- ASTM D7435, Standard Test Method for Determining the Performance of Passive Radio Frequency Identification (RFID) Transponders on Loaded Containers
- ASTM D7580 Standard Test Method for Rotary Stretch Wrapper Method for Determining the Readability of Passive RFID Transponders on Homogenous Palletized or Unitized Loads

In order to ensure global interoperability of products several organizations have setup additional standards for RFID testing. These standards include conformance, performance and interoperability tests.

Groups concerned with standardization are:

- DASH7 Alliance: international industry group formed in 2009 to promote standards and interoperability among extensions to ISO/IEC 18000-7 technologies

EPCglobal – this is the standardization framework that is most likely to undergo International Standardizations according to ISO rules as with all sound standards in the world, unless residing with limited scope, as customs regulations, air-traffic regulations and others. Currently the big distributors and governmental customers are pushing EPC heavily as a standard well accepted in their community, but not yet regarded as for salvation to the rest of the world.

3.2.6. LTE: Low cost-M2M and the proposed D2D architecture

3.2.6.1. *The LTE access technology*

LTE is a cellular wireless access technology developed for wideband data access, ubiquitous coverage and universal access. Enhancements have been provided and, unquestionably, enhanced LTE identified as LTE Advanced (LTE-A) will be the leading global 4G standard fulfilling the defined ITU-R requirements [18] on IMT-Advanced identified as the peak data rates beyond 1Gbps. While further enhancements to LTE-Advanced have just been completed in 3GPP Release 11, the new technology trends become visible to serve the continuously growing traffic demand.

There are new key technologies that the LTE Release 12 will address. These are: Small Cell Enhancements, a New Carrier Type, 3D-MIMO Beamforming, Machine-Type-Communication, LTE-WiFi Integration at radio level and Public Safety incl. Device-to-Device communication. The completion of Release 12 is expected for the mid of 2014 and deployments might be seen around the end of 2015 and later. This section will present in detail some of the key technologies addressed by the LTE R12 and what can be its evolution, R13 and R14/ R15. For this project, the Machine type communication is what is on our interest.

3.2.6.2. *The new LTE Releases*

Standardization work and release timing in 3GPP used to be splited into three stages. The Stage 1 for Requirements and Service Aspects, Stage 2 for Architecture and Technical Design and Stage 3 for Detailed Specifications. For the Release 12 the Stage-1 work started in 2011. Nevertheless in the radio groups little time was spent on it due to a 3 month delay of Release 11 completion. The following are the official completion dates of Release 12 as of today:

- Stage 1: March 2013 RAN
- Stage 2: December 2013 RAN
- Stage 3: June 2014 RAN
- ASN.1 freeze likely in September 2014

First products should not be expected sooner than 15 to 18 months after ASN.1 freeze. Therefore actual deployment could be expected end of 2015 and later.

At 3GPP RAN Plenary#58 in December 2012 in Barcelona [15] major decisions concerning the content of Release 12 where made where respective decisions were made respective to the Release 12. In this section we summarize the technology proposals and explained in relative detail, most taken from [16].

Surely the content and timing of Release 13 will depend on progress in Release 12.

It can be deduced there will be another release to further enhance LTE-A technology, a Release 13. Dates of Release 13 are still hypothetical and not official, yet. Planning are to Start on June 2014 for RAN and Completion for December 2015

The timing of Release 14/15 is likely to be influenced by the World Radio Conference (WRC) 2015 scheduled to take place in September 2015. Potential candidate bands allocated at WRC 2015 might include the bands 1427-1525 MHz, 3.4-3.6 GHz and 3800-4200 MHz

As consequence a completely new access technology might be defined in the Rel.14/15 time frame for commercial deployment at the end of this decade. Up to today most companies call this technology Beyond 4G.

3.2.6.3. *Low Cost Machine Type Communication*

A massive growth of Machine to Machine (M2M) communication, devices and traffic is expected to support smart grid, transport, logistics, e-health, energy, safety applications etc. Therefore the LTE radio interface shall be prepared to efficiently support the massive transfer of small, infrequent packets using very low cost, low complexity and low power devices. Quite some work on Machine Type Communication (MTC) was already standardized in Release 11. The work covers service requirements, architecture and security issues. Among others, a MTC Interworking Function and Service Capability Server [17] are defined in Release 11. Significant link budget enhancements are targeted in this work to improve indoor penetration. The use case is that some MTC UEs are installed in the basements of residential buildings or locations shielded by foil-backed insulation, metalized windows or traditional thick-walled building construction, and these UEs would experience significantly greater penetration losses on the radio interface than normal LTE devices. Most promising and simple techniques are around adding time diversity (e.g. TTI bundling), extensive use of HARQ repetition as well as power boosting.

3.2.6.4. *LTE Device to Device Communication architecture*

Device to device communication allows direct communication between UEs that are in proximity to each other. Besides its potential to save energy, reduce interference and extend coverage, the key driver for this work is to ensure that 3GPP LTE meets the needs of Public Safety. Until today different technologies are used for public cellular networks and for dedicated public safety networks. LTE is already globally promoted as future public safety system.

Once D2D is standardized the market might also see new proximity-based applications and services [18][18]. Focus is mostly given to network controlled D2D communication as shown in Figure 13. In this case, the control signaling (e.g. initial access, authentication, connection control) as well as resource reservation is handled by the network

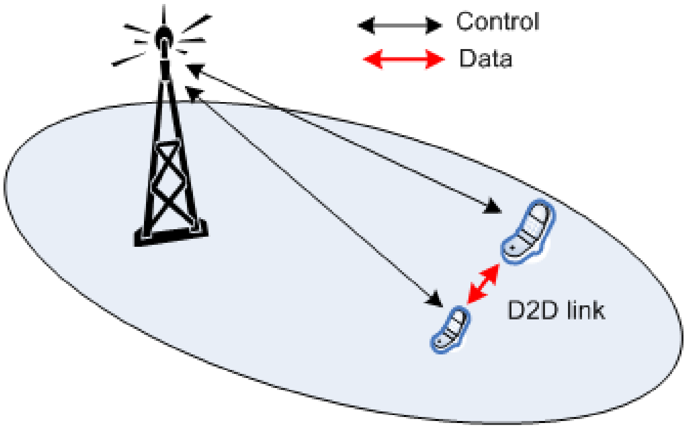


FIGURE 13. THE LTE NETWORK CONTROLLED DEVICE TO DEVICE COMMUNICATION.

This way Quality of Service can be guaranteed and the network operator still remains in control of the transmission. Although standardization did not start yet, it can be assumed that schemes that are transparent to the user equipment will be preferred. Although not shown in Figure 1, it is also likely that a radio bearer for potential data transmission to the network is being maintained all the time.

The Radio Resource Control System Information might require that a new specification also supports an autonomous control by the UEs or a hybrid approach with a distributed control between network and UEs.

3.3. Resource modeling

The use of different sensors in one system leads to architectural and language incompatibilities making them expensive and difficult to maintain and extend. This is because specific proprietary software is traditionally designed for each sensor. Therefore, the integration of a system is major concern which usually requires from developing complex and redundant software code, which in many cases turns to be inefficient.

Moreover, the data gathered from different sensors is liable to be in different formats hindering the management and processing of the information. Proper storage and access is also an important activity when needing to manage large volumes of information.

To alleviate or even eliminate those problems, several sensor system modeling techniques have been developed.

This section includes a review of the most relevant techniques to this matter that has been proposed in the last decades analyzing their characteristics according to SITAC project requirements.

Within SITAC concept, any resource: sensor, actuator, device, user or process is treated in the same way and as a part of a social network. According to that, a common standard for the definition and modeling of resources (either devices or users) is required, allowing an easy and full integration of any of them in the SITAC platform without special requirements to higher levels of abstraction due to their nature.

3.3.1. AMON

AMON [19] is a standard developed by AMEE UK Limited with the assistance of expert companies in the metering/monitoring device industry; it defines an appropriate data format to describe the exchange of measurement data and device monitoring. It is an open source, released under Creative Commons Attribution 2.0 UK: England & Wales License.

AMON's objectives are: to be appropriate for the description and exchange of measuring and monitoring device data; to be human readable and self-documenting, to be widely supported, bandwidth sensitive, simple, extensible and easily support new types of data.

AMON data format defines a number of commonly used data fields for devices (such as the device name, its location etc.), and a number of commonly used data fields for device readings. This ensures that the data format is suitable for the description and exchange of metering/monitoring device data and is simple to use. Moreover, it uses JSON encoding which ensures that the data format balances the need to be human readable and self-documenting against the need to be bandwidth sensitive. Additionally, as other languages that have library support for JSON encoding, AMON is widely supported. Finally, although the data format does define commonly used data fields for devices and device readings, it does not exclude the use of custom device data or reading data. These can be described and exchanged using the AMON data format without modification to the data format, ensuring that the format is extensible.

Therefore, AMON provides a quick and efficient data exchange from both device and their measurements. It can be complemented with Storage platform for metering/monitoring device and a RESTful. However, it lacks dictionaries to assist and facilitate the modeling and the introduction of processes to the system.

3.3.2. Device Kit

The Device Kit [20] is OSGi based technology that uses XML language and that enables the development of applications for devices when the information about the hardware is unknown. It uses the publication and subscription methods, thus, an application subscribes to a service and it is notified when an event is published.

3.3.3. EDDL

Electronic Device Description Language (EDDL) was originally developed by the University of Florida and currently standardized under the IEC 61804-3 [21]. It supports device integration, including sensors and actuators. EDDL assumes that devices have no networking capabilities and are connected to applications via sensor platform, thus, it is just focused on device to device connections.

3.3.4. ECHONET

ECHONET (the Energy Conservation and Home care Network) standard is a Japanese initiative that started in 1997 which specifies and open system architecture that enables the integration of a variety of home appliances and sensors [22]. It supports basically energy consumption monitoring and management and allows networked applications and services to access and control home appliances. It provides a definition of properties and access methods to devices, however, it requires vendors to create the same interface in their devices and it is not suitable for scalable systems.

3.3.5. IEEE 1451

The IEEE 1451 [23], [24], a family of Smart Transducer Interface Standards, describes a set of open common network-independent communication interfaces in TDL (template description language) for connecting transducers (sensors or actuators) to communication networks and processors. The key feature of these standards is the definition of a TEDS (Transducer Electronic Data Sheet). The TEDS is a memory device attached to the transducer, which stores transducer identification, calibration, correction data, and manufacture-related information. The goal of 1451 is to allow the access of transducer data through a common set of interfaces whether the transducers are connected to systems or networks via a wired or wireless means. The family of IEEE 1451 standards is sponsored by the IEEE Instrumentation and Measurement Society's Sensor Technology Technical Committee.

3.3.6. FlowTalk

FlowTalk [26] is an object-oriented programming language. It is designed to develop easily software for embedded wireless sensor devices. It adapts the models that usually come from using sensors with controlled disruption and light-weight continuation mechanism. The model converts asynchronous long-latency operations into synchronous and blocking method calls. In addition, Built for TinyOS, FlowTalk exchanges dynamism for a reduction in memory consumption.

3.3.7. Ptolemy

The Ptolemy Project [26] studies the modeling, simulation and design of embedded real-time concurrent systems. The basic objective is the assembly of concurrent components. Its principle is the use of well-defined models of computation. These models govern the interaction between components. The use of heterogeneous mixtures of models of computation is proposed.

A software system called Ptolemy II is being constructed in Java. The work is conducted in the Center for Hybrid and Embedded Software Systems (CHESS)_in the Department of Electrical Engineering and Computer Sciences of the University of California at Berkeley.

3.3.8. SensorML

Sensor Model Language (SensorML) [27], is a standard of the Open Geospatial Consortium (OGC) which provides standard formats and models in Extensible Markup Language (XML) to describe sensors and measurement processes. It can be used to describe a wide range of sensors including both static or dynamic platforms and both remote or in-situ sensors.

SensorML is defined and built on common data definitions that are used throughout the OCG Sensor Web Enablement (SWE) framework. Although it does not depend upon the presence of the other SWE components, it can be complemented by the use of other SWE techniques and tools, such as Observations and Measurements (O&M), Transducer Markup Language (TML), Sensor Observation Service (SOS), Sensor Planning Service (SPS), Sensor Alert Service (SAS), Web Notification Service (WNS) and TML which are described below.

Therefore, it provides a common framework for any process and process chain but it is particularly well-suited, but not exclusively intended, for the description of sensors, systems and the processing of sensor observations. Specifically, it provides the required information for sensor discovery, geolocation, programming, alert subscription and support for on-demand processing of the observations.

According to this standard, every device or component can be modeled as a “Process”. Processes are entities that take inputs and through the application of well-defined methods using specific parameters, results in outputs. Additionally, they provide relevant metadata.

These processes are classified according to their nature into two groups, physical and non-physical process. Among those considered as physical processes, we can found transducers, actuators and processors that are treated as “Process Components[1]” and sensors and platforms that are modeled as “Systems[2]”. Among those considered as non-physical processes, we have “Process Models[3]” that provide executable process description of processes and “Process Chains[4]”. In addition, “Process Methods” provide relevant pieces of information for validating and enabling the execution of individual atomic processes (either process components or process models).

Thanks to the SensorML definition, a quick and efficient data exchange from any type of device, component, entity or system is achieved. It also provides efficient management of device observations taking care of their sampling and processing. Thus, this standard is suitable for the definition of any kind of resource independently of its nature and includes predefined dictionaries to ease the addition of new “processes” to the system.

It is important to highlight that SensorML describe measurement processes but it does not encode the data coming from those measurements. Therefore, to achieve a complete model of the system, measurements need to be represented by other methods. The tandem SensorML/O&M is the most versatile and widely used.

3.3.8.1. O&M

Observations and Measurements (O&M) [28], ISO 19156 standard defines an XML implementation of the conceptual models for describing observations and sampling features.

An observation has a single and observable procedure and a single result. The description of the procedure provides important metadata to support the interpretation of the result. If it is a sensor, then it may be a “sensor package” measuring an “aggregate observable” and producing a resulting “aggregate value”. But when associated with an observation, the sensor, the observable and the result are single logical entities.

[1] Atomic physical process that transforms information from one form to another.

[2] Components physical model consisting of a group of physical process.

[3] Atomic non-physical blocks of processing.

[4] No-physical compound modeling blocks, composed of interconnected threads that can be both models and chain processes.

Thus, it is through its association with an observation feature that a value is bound to a feature of interest or a geospatial location, to a time instant or period and to the sensor instance responsible for that observation.

3.3.8.2. TML

Transducer Markup Language (TransducerML or TML) [29] is a standard developed by OGC. It defines a set of models describing the hardware response characteristics of a transducer and an efficient method for transporting sensor data and preparing it for fusion through spatial and temporal associations. It basically provides a conceptual approach and XML schema to support real-time transmission of data and sensor systems.

TML is capable of precise time-tagging of data, so that it is possible to know precisely when a physical phenomenon was measured at the individual measurement level, and also captures latency or delay information at a fine resolution. This enables the precise determination of when a data point was taken, as well as aiding in interpolation between data points and the reconstruction of events.

3.3.9. ThingML

ThingML [30] is a modeling language for embedded and distributed systems. It is proprietary language developed by the Networked Systems and Services department of SINTEF in Oslo, Norway. It is focused on models for embedded systems with limited resources such as sensors or microcontroller-based devices.

ThingML has been developed as a domain-specific modeling language. It includes concepts to describe software components and communication protocols. The formalism used is a combination of architecture models, state machines and language. Also, ThingML includes tools such as text editors to create and edit ThingML models and code generators to compile ThingML to C, Java and Scala.

TABLE 4. RESOURCE MODELING COMPARATIVE TABLE

	AMON	DEVICE KIT	EDDL	ECHONET
DESCRIPTION	Appropriate data format to describe the exchange of measurement data and device monitoring.	OSGi based technology for the description of devices	Description language for device integration	Open system architecture for the integration of devices
LANGUAGE USED	JSON	XML	------	------
APPLICATION	------	Development of applications for devices	Device to device connection	Home appliances and sensor integration
FEATURES	Quick and efficient data exchange	Description of devices when the HW is unknown	Service-oriented. Assumes no networking capabilities for devices	Definition of interface (properties and access methods). Requires vendors to include the interface in the device
TOOLS	Storage platform for metering/monitoring and a RESTful	Publication and subscription methods	------	------

	IEEE 1451	FLOWTALK	PTOLEMY	SENSORML	THINGML
DESCRIPTION	Set of open common network-independent communication interfaces	Software development language for embedded wireless sensors devices.	Software system for design of concurrent embedded real-time system.	Standard for modelling, observation and measurement of devices.	Language for modelling embedded and distributed system such as sensors and microcontrollers devices.
LANGUAGE USED	TDL	FlowTalk	Java	XML	ThingML
APPLICATION	Connection of devices to networks or processors	Built for TinyOS.	Still under development.	Description of any kind of resources (devices, entities, processes, etc)	Embedded systems with limited resources.
FEATURES	Inclusion of TEDs	Low memory consumption.	------	Quick and efficient data exchange. Importance of sampling and processing. Easy incorporation of new processes to the system.	Proprietary solution. Combined formalism of architecture models, state machines and language

TOOLS	TEDs	------	------	Additional techniques and tools: O&M, TML, etc. and predefined dictionaries.	Text editors and code generators to C, Java and Scala

Conclusion

The variety of devices that conforms the IoT, together with their different characteristics and capabilities, and the different communication mechanisms that make them interoperate are a key concept when designing services and applications for IoT. This, together with the addition of Social Networks, and the inclusion of different users in the loop, significantly augments the complexity of the final system.

This chapter depicts a review of the different technologies that are part of the IoT. First, a revision of the physical objects: sensors, actuators, and RFID, that can be fixed or mobile, even included in smartphones, as well as those components such as gateways and repeaters that are part of the communication infrastructure which is the bridge from the sensors and actuators to the rest of the system.

The current developments regarding networking technologies are also detailed. At present, there exist a number of communication technologies that enable the orchestration of the different devices to be able to efficiently gather their data. ZigBee and 6LowPAN represent the new wave in sensor communications, but other well-known technologies such as Bluetooth and LTE are also considered in order to augment the communication capabilities of the IoT.

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4. Services and Applications

Building an application that used many devices can be seen as been a service composition, while each device offers one or more services. It is then possible to create an application that calls or requests data, actions from/to these devices. This approach is similar to SOC (Services Oriented Computing) [1], in which devices are seen as services, in a so called “Object as a service” paradigm. To be achieved, SOC needs to have information about each service, and then to compose them.

4.1. Service Creation and Discovery

Service discovery protocols (SDP) [2] are protocols which allow automatic detection of devices and services offered by these devices on a computer network. Service discovery requires a common language to allow software agents to make use of one another's services without the need for continuous user intervention.

There are several SDP protocols such as:

4.1.1. Dynamic Host Configuration Protocol (DHCP)

DHCP [3] is a network protocol used to configure devices that are connected to a network so they can communicate using the Internet Protocol (IP). The protocol is implemented in a client-server model, in which DHCP clients request configuration data, such as an IP address, a default route, and one or more DNS server addresses from a DHCP server. This protocol is for host configuration only. It does not fit request for a service when the requester does not known the device he is looking for

DHCP uses UDP broadcasts, and configuration is done with a unicast answer.

4.1.2. Zeroconf, Bonjour, Avahi

Zeroconf [4] is an IETF standard protocol for host configuration and services requesting. It can resolve name to address without a central server. Zeroconf has the same role than DHCP and DNS without having a dedicated server. Based on multicast request, each node builds its own host lists, and answers requests if they are concerned by the query. Discovering a service is done by altering the request, changing the name by the service description. Each node offering a service that fits the request will respond.

Some other protocols are based on the same approach. Bonjour (made by Apple) uses a mDNS (multicast DNS) and a DNS-SD (DNS Service Discovery) to retrieve hosts and services.

Avahi is an implementation of Zeroconf under Linux and BSD, while Microsoft offers its own solution named SSDP.

4.1.3. UPnP

UPnP [5] is a set of protocols for the SoHo (Smart office, Home office) that provide the global configuration and discovery of devices and services inside a small network. Based on IP, it can work without a DHCP server, as it provides all the steps to auto configure each node, or to join an already set network. Once connected to the network and able to communicate with other nodes, a UPnP device will announce its services. This is done through a udp multicast message. This announcement will be received by all nodes of the multicast network. The description of the service is provided by the node itself, and can be accessed with an HTTP request.

SSDP, the Simple Service Discovery Protocol, uses these announcements to set a Control point inside the network, that will collect all announces made by nodes, or send a request on the multicast network to ask for it.

UPnP has good results, but is limited to small network (as it uses multicast) and is not secure enough to be use in other conditions.

4.1.4. Service Location Protocol (SLP)

The Service Location Protocol (SLP, srvloc) [6] is a service discovery protocol that allows computers and other devices to find services in a local area network without prior configuration. SLP has been designed to scale from small, unmanaged networks to large enterprise networks. It has been defined in RFC 2608 and RFC 3224 as Standards Track document.

SLP is used by devices to announce services on a local network. Each service must have a URL that is used to locate the service. Additionally it may have an unlimited number of name/value pairs, called attributes. Each device must always be in one or more scopes. Scopes are simple strings and are used to group services, comparable to the network neighborhood in other systems. A device cannot see services that are in different scopes.

SLP has three different roles for devices. A device can also have two or all three roles at the same time.

- **User Agents** (UA) are devices that search for services

- **Service Agents** (SA) are devices that announce one or more services
- **Directory Agents** (DA) are devices that cache services. They are used in larger networks to reduce the amount of traffic and allow SLP to scale

4.1.5. Web Services Dynamic Discovery (WS-Discovery)

WS-Discovery [7] is a technical specification that defines a multicast discovery protocol to locate services on a local network. As the name suggests, the actual communication between nodes is done using web services standards, notably SOAP-over-UDP.

The protocol was originally developed by BEA Systems, Canon, Intel, Microsoft, and WebMethods. On July 1st 2009 it was approved as a standard by OASIS.

A Service Provider can explicitly register a service with a Web Services Registry such as Universal Description Discovery and Integration (UDDI) or publish additional documents intended to facilitate discovery such as Web Services Inspection Language (WSIL) documents. The service users or consumers can search Web Services manually or automatically. The implementation of UDDI servers and WSIL engines should provide simple search APIs or web-based GUI to help find Web services.

4.1.6. Discovering Services in the Internet of Things

DHCP, ZeroConf or UpnP answer the need of discovering services inside a controlled network, where everything is under the control of an administrator, secured from external attack, and in a limited zone where the number of services and nodes is quite stable and limited. The choice made for these protocols is then coherent with the needs and the ability of each stakeholder.

But regarding the huge size of the Internet of things, with 50 billion devices offering and consuming services, involved in a great number of applications, dynamically requesting for services, using them and then moving to another place, the approach of devices announcing their services through multicasts messages is not scalable.

The solution of a central server storing all services offered everywhere, by every device, is also an issue: Who has the right to store services description? According to which model? How to request for a specific service, without being overwhelmed by multiple answers?

Service discovering in very large networks needs to be restricted to a limited part of the overall offer. This “Context aware” limitation can be based on the user, his devices and the public devices accessible from the place he is located at the moment.

The use of messaging protocol can solve this issue, because it is user-oriented, and it offers some mechanisms that can be used for the dynamicity of context change (presence information for example).

4.1.6.1. Extensible Messaging and Presence Protocol (XMPP)

XMPP [8] is a communication protocol for message-oriented middleware based on XML (Extensible Markup Language). The protocol was originally named **Jabber**, and was developed by the Jabber open-source community in 1999 for near real-time, instant messaging (IM), presence information, and contact list maintenance. Designed to be extensible, the protocol has also been used for publish-subscribe systems, signaling for VoIP, video, file transfer, gaming, **Internet of Things applications** such as the smart grid, and social networking services.

Unlike most instant messaging protocols, XMPP is defined in an open standard and uses an open systems approach of development and application, by which anyone may implement an XMPP service and interoperate with other organizations' implementations. Because XMPP is an open protocol, implementations can be developed using any software license; although many server, client, and library implementations are distributed as free and open-source software, numerous freeware and commercial software implementations also exist.

4.2. Service Composition

Service compositions [9] can be defined as the way a set of single services can be linked to produce as a result a new service. More technically, such compositions are defined as the process of coordinating an exchange of information through service interactions. However, depending on how this coordination is performed we refer to service orchestration (when the coordination is performed by a central entity, usually a workflow engine) or service choreography (when there is not a central entity managing such coordination). The main differences between these two types of compositions lie in their executability and control. For example, the existence of a central entity in service orchestrations ensures that every single task is been executed properly and it also avoids the exchange of multiple messages as it is required in service choreographies. In fact, service choreographies are defined by protocols which define legal peer-to-peer interactions, i.e., message exchanges between two partners. There are different languages to represent both, service orchestrations and choreographies.

Examples of orchestration languages are BPEL (Business Process Execution Language) and its extensions to consider humans in the orchestration (BPEL4People and WS-Human Task), BPMN 2.0 (Business process Model and Notation), Orc (academic language built at the University of Texas), YAWL (Yet Another Workflow Language, a language inspired in Petri-Nets), EPC (Event-driven Process Chain, a language based on graphs).

On the other hand, examples of choreography languages are the W3C specifications WS-CDL (Web Service Choreography Description Language) and WSCI (Web Service Choreography Interface (WSCI), academic initiatives such as BPEL4Chor (a BPEL extension to support service choreographies) or Let’s Dance (a generic description of requirements for languages to support service interactions) and BPMN 2.0, a specification from the OMG which includes diagrams to represent service choreographies.

In addition to these two ways of creating service compositions, a more light way of composing services are mashups. Mashups allow connecting open APIs and data sources to produce enriched results that were not necessarily the original reason for producing the raw source data. Examples of tools allowing the construction of mashups are Pipes by Yahoo or Deri Pipes.

All these languages can be used to compose any service that is exposed in the Internet to produce as a result a new service with an added value.

4.3. Services & Applications

During last years, the adoption of Web2.0 and IoT related technologies, lead to an explosion of public applications and services available. Some of these services are designed to help developers to develop its own composed services or applications easily, providing components such as frameworks, APIs or standard communication protocols.

Some of these derived services and applications are described below:

4.3.1. Apple Find My Friends

With Find My Friends [10], users can follow people and track where they are at a certain moment. Users can also share their location with the people they choose. Location is determined using GPS in the iOS device when Location Services are turned on. Notifications appear when a user requests another user to see where they are. The feature can be turned on and off at any time. Like many iOS application that use Location Services, parental controls are available, and the application synchronizes with other applications with locations, such as Maps and Contacts.

4.3.2. Google Now

Google Now [11] is implemented as an aspect of the Google Search application. It recognizes repeated actions that a user performs on the device (common locations, repeated calendar appointments, search queries, etc.) to display more relevant information to the user. The system leverages Google's Knowledge Graph project, a system used to assemble more detailed search results by analyzing their meaning and connections. Some examples of information shown to the user are: Events, Mail, Places, Weather, News, etc.

4.3.3. Waze

Waze [12] is a GPS-based geographical navigation application program for smartphones with GPS support and display screens which provides turn-by-turn information and user-submitted travel times and route details, downloading location-dependent information over the mobile telephone network. Waze differs from traditional GPS navigation software as it is a community-driven application which gathers some complementary map data and other traffic information from users. Like other GPS software it learns from users' driving times to provide routing and real-time traffic updates. People can report accidents, traffic jams, speed and police traps, and can update roads, landmarks, house numbers, etc. Waze also identifies the cheapest fuel station near a user or along their route.

4.3.4. Amazon Cloud Services

Amazon Web Services (abbreviated AWS) [13] is a collection of remote computing services (also called web services) that together make up a cloud computing platform, offered over the Internet by Amazon. Amazon cloud offers different services database or remote storage management, to computation and network cloud services.

4.3.5. Uber

Uber [14] uses your phone's GPS to detect your location and connects you with the nearest available driver. The concept behind Uber is: ‘Get picked up anywhere - even if you don't know the exact address’.

4.3.6. Gimbal

By creating fully customizable digital boundaries around physical spaces, Gimbal Geofence [15] links with your customer’s mobile device to create a streamlined, battery optimized system of geographical awareness, so you can deliver your message when and where it matters most.

With Gimbal Geofence, it is possible to set up the places that matter most to your app and interact with customers at those locations. Once an individual enters into a geofence you set, you can choose to send content to their mobile device or simply use that data to further refine offers based on their personal preferences. When enabled by the end-user, Geofence works in the background even when the app is closed.

4.3.7. Locale

With Locale [16], you create situations specifying conditions under which your phone's settings should change. For example, your "At School" situation notices when your Location condition is "77 Massachusetts Ave." and changes your volume setting to vibrate.

Conclusion

One of the main innovation points of the SITAC project is related to the creation of a platform enabling a diverse group of users to collaboratively create its own services and applications. In order to achieve this goal, two main areas must be explored: service and application discovery and service composition technologies. Regarding service discovery, scalability is the key point taking into account the huge number of potential and heterogeneous services and devices. The utilization of messaging protocols, like XMPP, will be explored.

Service composition and creation could greatly benefit from existing APIs and services aimed to help developers with the task of composing and orchestrating applications and services. SITAC will further explore the technologies listed and will use both those services and ideas derived from them for the creation of its own service and application platform.

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5. Data Management

Nowadays everything is a data. Data is the common denominator for all of the activities in our lives. But what is really crucial is to have the right and accurate data when is need it. That is the focus of the "Data Management" systems.

There could be four different phases or steps before you get the data you need in a "Data Management" system:

- **Data collection** – basically means to transfer data from an external source to the "Data Management" system.
- **Data Storage** – storage of the information in the appropriate hardware and software, allowing it to be stored and retrieved.
- **Data Aggregation** – data aggregation is the process of gathering information and showing it in a summary form for different purposes, as for example statistical analysis. Data aggregation also has the goal of putting together information about particular groups based on specific criteria.
- **Data Analysis** - Analysis of data is a process of inspecting, cleaning, transforming, and modeling data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making.

5.1. Data Collection

Data Collection means to transfer data from an external source to the "Data Management" system.

There could be different methods (formats) to collect data from the data sources, some of them are typically used by all "Data Management" system and applications and others are proprietary.

The most common formats used by every "data management" system are the followings:

- **Text-Delimited** – the method most commonly used for data loading. Most of the applications and data management systems are able to open files containing data structured as "Text-Delimited".
  Every value of a field or column ends with a delimiter, and each set of these values of rows of records has and end-of-record delimiter, typically a new line character.
  Column headers are sometimes included as the first line, and each subsequent line is a row of data.
- **Fixed-Length** – A fixed record length file is one where each record takes up the same amount of space, regardless of how many characters are in each field. Each field is also a fixed length. This format allows increasing the kinds of data formats and the layouts that can be loaded.

Data gathering can be categorized to data collection and data aggregation. Data aggregation works with the aggregated values such as minimum, maximum, and average values of the entire data. However data collection harvests all the data without any aggregation. Some seminal works prefer to categorize the data collection to Snapshot Data Collection (SDC) and Continuous Data Collection (CDC). Snapshot refers to the union of all sensed data at some particular time instance, and collecting one snapshot is called SDC. On the other hand, the act of collecting multiple snapshots is CDC. The performance of data collection can be measured by data collection capacity, which is the data reception rate at the sink. Some works propose different set of algorithms for maximizing the capacity of SDC and CDC for large-scale WSNs. From among, we can refer to Cell-based Path Scheduling (CBPS) and Segment-based Pipeline Scheduling (SBPS), which are proposed for SDC and CDC respectively. CBPS is based on network partitioning, and SBPS is a combination of Compressive Data Gathering (CDG) technology and pipeline technology [5].

Some works propose the fastest ways of SDC/CDC data collection. Among different types of traffics, they concentrate on convergecast traffic, which is the most common type of traffic in tree-based sensor networks. They consider aggregated convergecast in case of CDC, and raw-data convergecast in case of SDC. For the MAC layer, they take into account contention free protocols (e.g. TDMA), which are better fit for fast data collection. Interference in the wireless medium, half-duplex transceivers of sensors, and the topology of the network are the factors that limit fast data collection. In order to decrease the interference, a number of clues exist in the literature. First, nodes have to transmit not with maximum transmission power but only with enough transmission power. Second, using multi-frequency scheduling can almost eliminate most of the interference (For moderate scales, up to 100 nodes, it almost eliminates all of the interference). The last factor, which affects the scheduling performance, is the topology of routing trees. Therefore, after proposing clues for alleviating interference, they propose algorithms such as BFS-TIMESLOTASSIGNMENT and LOCAL-TIMESLOTASSIGNMENT to construct spanning degree-constrained trees as well as capacitated minimal spanning trees, in order to boost the scheduling performance [6].

The IoT envisions to connect 20 billions of heterogeneous devices to the Internet till 2020. Undoubtedly, one of the major targets is to perform wide-scale monitoring. Large-scale WSNs as an indispensible part of IoT nodes, are supposed to monitor the environment of Smart Cities (SCs). Even if there have been lots of good papers on data harvesting form WSNs up to now, effective collection is crucial for classes of smart city services that require a timely delivery of urgent data such as environmental monitoring, homeland security, and city surveillance. An original solution is to integrate and opportunistically exploit MANET overlays, impromptu, and collaboratively formed over WSNs, to boost urban data harvesting in IoT. Indeed, it should be mentioned that MANET-WSN integration could be dynamically activated only for specific classes of WSN traffic, for example data labeled by source nodes as urgent. More precisely, the monitoring application should trigger an alert to be delivered faster than other normal sensor readings to WSN data collection points, when one critical event is detected. The idea is to reduce the delivery time of only most relevant urgent data without sacrificing battery. To glue together WSNs and MANETs, MANET nodes exploit their WSN interfaces to participate to urgent data routing by dynamically discovering WSN nodes during their roaming and by advertising their presence to them.

To overcome mobility and scalability issues typical of large and dense MANET deployments, novel solutions and standards to organize MANET nodes in small local clusters is required. Roots are sensor nodes that advertise themselves as collection tree roots, typically acting as gateways to the Internet. All other sensor nodes build routing trees to forward collected data toward roots at the WSN layer. A WSN exit point is any WSN node in visibility of at least one MANET node and able to jump urgent data over the MANET, while a WSN entry point is the WSN node with the lowest gradient cost that the MANET cluster can reach. Finally, MANET entry/exit points are MANET nodes that can respectively receive/forward data from/to the WSN. Our solution is general enough to work with most tree- based sensor data collection standards and related research- oriented protocols, such as IETF RPL and CTP. IETF RPL is a very promising standard specification in the field, but at the current stage there are still a very few examples of its deployment and it suffers from limited testing in realistic in-the-field scenarios. Therefore, in our current prototype of the proposal, we have decided to be fully compliant with CTP because of its thoroughly assessed robustness and its strong developers community working on it. In this scenario the value of the gradient of a sensor node is defined as the sum of the expected transmission hops to route a packet from that node to the root [7].

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About MANET-WSN integration, two facilities can enable a MANET to play the role of WSN backbone: discovery, to let MANET nodes explore the WSN topology and select the WSN node with the best gradient, i.e., WSN entry point, and advertising, to inform the WSN of the presence of MANET entry points.

In fact, regardless of WSN traffic, keeping the MANET-WSN integration support always active would impose an additional traffic load on the WSN thus worsening node power consumption. Hence, the solution avoids packet exchanges between MANET and WSN nodes in normal situations, by keeping MANET nodes usually idle. MANET only passively snoop CTP traffic to obtain information about the underlying WSN tree topology and, only upon sniffing an urgent packet, MANET nodes start coordinating and communicating with WSN ones to self-organize as relays for urgent WSN packets

Thus, upon snooping an urgent WSN packet, MANET nodes should organize themselves in local independent clusters, each one with its own MANET entry and exit points. Note that, due to diversity in wireless coverage ranges between IEEE 802.15.4 and IEEE 802.11, even small clusters can significantly improve data collection performance, by making it possible to jump several WSN hops by traversing fewer MANET ones. In addition, small clusters are intrinsically more tolerant with regard to node mobility if compared with fully connected mobile networks because they have to keep a limited number of routing paths. The MANET-WSN integration exploits MANET clusters formed opportunistically in localized areas that need urgent data transmission. Elaborating on the cluster formation protocol is indeed out of the scope of this deliverable, but we refer the interested reader to [8].

5.1.1. Data Collection via Mobile phones: Crowdsensing

Crowdsensing is defined in [6] as individuals with sensing and computing devices collectively sharing information to measure and map phenomena of common interest.

Initially, crowdsensed inputs were analyzed offline for different mapping applications such as traffic and transportation monitoring. However, in more recent crowdsensing applications, the collected inputs are processed in real time such as collaborative searching or public safety.

For collecting data from sensor enabled mobile devices, we can proceed in two different ways: participatory sensing and opportunistic sensing. The participatory sensing requires active involvement of the individuals while collecting data (e.g., taking a picture, recording voices, activating GPS). Consequently, people involved in such data collection usually ask for “rewards”. In recent works, there are different proposals and solutions to provide incentives to the respective participants.

On the other hand, the opportunistic sensing is more autonomous where minimal user involvement is required (e.g., continuous location sampling without any explicit action from the user). However, the user should interfere at least once to allow the data collection via its device for privacy issues.

The obtained data can be in different formats such as videos, images, texts etc. This data can also be of different quality depending on the sampling rate, accuracy and the network or the device performance.

5.2. Data Storage

Big data refers to a massive amount of data, too large to be managed, analyzed or stored with traditional infrastructures. Thus, every day, we create 2.5 quintillion bytes of data. So much that 90% of the data in the world today has been created in the last two years alone. Big Data is not a single technology but a combination of old and new technology. It is the capability to manage a huge volume of disparate data, at the right speed and within the right time frame to allow real time analysis and reaction. The main characteristics of big data are:

1. **Velocity**
2. **Variety**
3. **Volume**

The challenge is to have the most useful information through those data. One of the most important issues of big data management is the data storage. The different possibilities of big data storage will be developed in the following parts.

5.2.1. SQL Scalable Technologies

- MySQL Cluster: It replaces InnoDB engine from MySQL with a distributed NDB layer. It is open source, although there is a proprietary version with more management functionalities.
- VoltDB: System designed for high performance in each node and high scalability. Tables are partitioned in multiple servers. Allows table replication across the servers, and provides replication for failovers.
- Clustrix: Similar to VoltDB and MySQLCluster, but nodes are defined as devices mounted on racks. Provides sharding, replication and failover recovery. It supports ACID transactions, and its distribution and load balancing is transparent to users. MySQL compatible.

- ScaleDB: Derived from MySQL, it replaces the InnoDB engine, and uses multiple server clustering to obtain scalability. It needs shared discs between the nodes. It allows adding new servers at any time, and has automatic fail recovery.

- ScaleBase: Obtains horizontal scalability by defining a layer over MySQL, instead of modifying it. It includes a partial SQL parser and a optimization to provide sharding over the MySQL tables. It introduces the problem of no spanning of transactions across the different MySQL databases.

- NimbusDB: It uses MVCC and object-based distributed storage. It uses SQL for the queries and provides a transaction optimizer and AVL tree based indexes. It offers transaction isolation without blocking and a massive parallel processing. It is now called NuoDB.

- DBMS-X: SQL based parallel database system. It stores data in a row based system. It does not compress data by default, but allows the compression of tables using a Dictionary based scheme. It has replication functionalities.

- Vertica: Another parallel database system, designed of huge data warehouses. The main difference with other systems is that data is stored in columns instead of rows. It uses an engine specifically designed to operate over a column storage based layer. It compresses data by default, and it is possible to operate with compressed tables.

5.2.2. NoSQL Databases

A new alternative to RDBM is the NoSQL database. A NoSQL database provides a mechanism for storage and retrieval of data that uses looser consistency models rather than traditional relational databases. Motivations for this approach include simplicity of design, horizontal scaling and finer control over availability [7]. There are different kinds of NoSQL databases:

- **Key-Value Pair Database**
- **Columnar Databases**
- **Documents Database**
- **Graph Database**

5.2.2.1. Key-value pair database

It is the simplest NoSQL database: It stores key-value pairs in memory. Each key-value pair (KVP) identifies a Binary Large Object (Blob), which stands for data. KVPs do not require a schema and offers a great scalability and flexibility. As well, KVP databases do not respect ACID and are not typed. So, data are often stored as strings.

Examples: DynamoDB, Riak, Redis.

5.2.2.2. Columnar Databases

In this kind of database, the data is stored across rows. It is very easy to add columns and it offers high flexibility, performance and scalability. It has very high throughout for big data and has a strong partitioning support and a great read write access.

Example: Google BigTable, HBase from Apache, Cassandra, HyperTable, Vertica.

5.2.2.3. Documents Databases

There are two types of document databases. The first one is a repository for full document style content and the second one is a database for storing document components for a permanent storage as a static entity or for dynamic assembly of the parts of a document

Examples: MongoDB, CouchDB, Terrastore, RavenDB, SimpleDB, RaptorDB.

5.2.2.4. Graph databases

It is a kind of database based on node relationship. It is very useful to deal with highly interconnected data. Nodes and relationships support properties, a key value pair where the data is stored. Graph databases are very helpful in social networking, classification of biological or medical domains and for creating dynamic communities of practice and interest.

Examples: hypergraphDB, Neo4j, FlocKdb.

5.2.3. Strengths and Weaknesses of NoSQL Databases

The different types of NoSQL databases are designed for different needs. So, it is important to compare them in order to know their strength and weaknesses, and to choose the most efficient for the project.

Table 5 presents an overview of NoSQL databases strengths, weaknesses, uses cases and implementations.

TABLE 5. STRENGTHS AND WEAKNESSES OF NOSQL DATABASES.

NOSQL DATABASES	KEY VALUE PAIR	COLUMNAR	DOCUMENTS	GRAPH
STRENGTH	Parallel processing Links and link walking Speed search Do not need feature set after add/delete query Very simple	High consistency Sharding High availability Management of semi structured data High scalability (use MapReduce for the scalability) Response in real time	High availability and replication services for scaling across local and wide area networks Sharding services Querying service with ad hoc queries, distributed queries, and full text search Do not need maintenance after add/delete query	Node relationship Key Value Pair when the data is stored Navigation following the relationships Trustworthy and scalable
WEAKENESSES	Too simple Just CRUD for Queries	Not useful for linked data Need feature set after add/delete query	Slowness with MapReduce algorithm Not adapted for interconnected data Can use only key and indexes for querying	Complex
USING	Sensor´s data Log´s data Consumer's data High volume, Media-rich data gathering	EBay for the optimization of the search Data processing for Business Intelligence (BI) Television channels to get information about their audience, and for	Web analysis Real time analysis Social networking Archiving	Business Intelligence Web semantic Social computing Geospatial data Linked and hierarchic

	and storage Caching layers for connecting RDMBS and NoSQL Databases Mobile applications requiring flexibility and dependability	viewers voting		data Scientific data Web of things
EXAMPLES	Riak, Redis, Voldemort, DynamoDB	HBase, Cassandra, SimpleDB, BigTable	CouchDB, MongoDB,	Neo4j OrientDB

5.2.4. Comparison of some NoSQL technologies

There are many implementations of each type of NoSQL databases. For this part, we have chosen to introduce one of the most popular of each type, and then, to compare them.

5.2.4.1. Cassandra

Apache Cassandra is an open source distributed database management system. It is an Apache Software Foundation top-level project designed to handle very large amounts of data spread out across many commodity servers while providing a highly available service with no single point of failure. It is under Apache License 2.0 [8]. Apache Cassandra is the technology of choice for such data-driven organizations as Netflix, eBay, Constant Contact, Adobe, Comcast, Barracuda Networks and scores of others [9].

5.2.4.2. CouchBase

CouchBase Server, originally known as Membase, is an open source, distributed NoSQL document-oriented database that is optimized for interactive applications. CouchBase is licensed under the Apache 2.0 License [10].

5.2.4.3. CouchDB

Like MongoDB, CouchDB is open source. It is maintained by the Apache Software Foundation and is made available under the Apache License v2.0. Unlike MongoDB, CouchDB was designed to mimic the web in all respects [11].

5.2.4.4. HBase

HBase is a columnar database project in the Apache Software Foundation distributed under the Apache Software License v2.0. HBase uses the Hadoop file system and MapReduce engine for its core data storage needs.

5.2.4.5. MongoDB

MongoDB (from "humongous") is an open-source document database, and the leading NoSQL database [12]. It is maintained by a company called 10gen as open source and is freely available under the GNU AGPL v3.0 license. Commercial licenses with full support are available from 10gen.

5.2.4.6. Neo4j

One of the most widely used graph databases is Neo4J. A supported, commercial version is provided by Neo Technology under the GNU AGPL v3.0 and commercial licensing [13]. Due to its graph data model, Neo4j is highly agile and blazing fast. For connected data operations, Neo4j runs a thousand times faster than relational databases [14].

5.2.4.7. Redis

Redis is an open-source, networked, in-memory, key-value data store with optional durability. It is written in ANSI C. The development of Redis is sponsored by VMware. It is available on BSD Licenses [15].

5.2.4.8. Tokyo Cabinet/Tokyo Tyrant

Tokyo Cabinet is a key value pair library of routines for managing a database. The database is a simple data file containing records. It is free, and licensed under the GNU Lesser General Public License.

5.2.4.9. SimpleDB

Amazon SimpleDB is a highly available and flexible non-relational data store that offloads the work of database administration. Developers simply store and query data items via web services requests and Amazon SimpleDB does the rest [16]. Amazon SimpleDB is licensed by Amazon Web Services, Inc.

5.2.4.10. Scalaris

Scalaris is a scalable, transactional, distributed key-value store. It was the first NoSQL database, which supported the ACID properties for multi-key transactions. It can be used for building scalable Web 2.0 services [17].

5.2.4.11. Riak

One widely used open source key-value pair database is called Riak. It is developed and supported by a company called Basho Technologies and is made available under the Apache Software License v2.0. Riak is a very fast and scalable implementation of a key-value database. It supports a high-volume environment with fast-changing data because it is lightweight [18].

5.2.4.12. Terrastore

Terrastore is a distributed, scalable and consistent document store supporting single-cluster and multi-cluster deployments. It provides advanced scalability support and elasticity feature without loosening the consistency at data level [19]. Terrastore is a very young Apache Licensed document.

5.2.4.13. Voldemort

Voldemort is a distributed data store that is designed as a key-value store used by LinkedIn for high-scalability storage. The source code is available under the Apache 2.0 license [20].

5.2.4.14. Hypertable

Hypertable is a high performance, open source, massively scalable database modelled after BigTable, Google's proprietary, massively scalable database [21]. It is available under the GNU General Public License 2.0.

Table 6 and Table 7 depict different characteristics of those NoSQL databases. They present these technologies following some characteristics:

- Data model: specifies the type of NoSQL database
- Consistency concept: the politic adopted for data consistency
- Storage model: defines how the NoSQL database manage the data storage
- Horizontal scalability: evaluate how the database can add nodes to the system

- Query possibilities: the query language used to manage data
- Data access and API: different possibilities to access to the data
- Adapted tasks (optimized for): the most performing task with this kind of database
- Replication: how the data is stored on multiples devices
- Graphical monitoring/Admin console
- Implementation language
- Programming language

TABLE 6. COMPARISON OF HBASE, CASSANDRA, MONGODB, COUCHDB, SIMPLEDB, REDIS AND NEO4J

EVALUATION CRITERIA	HBASE	CASSANDRA	REDIS	MONGODB	NEO4J	COUCHDB	SIMPLEDB
DATA MODEL	Columnar	Columnar	Key Value	Document store	Graph	Document store	Key Value
CONSISTENCY CONCEPT	Immediate consistency	Eventual consistency Immediate consistency (can be individually decided for each write operation)	Optimistic locking	Eventual consistency mediate consistency (can be individually decided for each write operation)	ACID compliant Eventual consistency	ACID compliant Eventual consistency	Eventual consistency Immediate consistency (can be specified for read operation)
STORAGE MODEL	HDFS	Data is distributed across the cluster and every node of the cluster has the same role	Dictionary of key value pairs stored in memory	BSON documents with GridFS	Nodes relationship and properties	JSON Document In pair based distributed database	Hosted on Amazon Cloud

HORIZONTAL SCALA **BILITY**	Scale linearly and automatically with a new node	Read and write throughput both increase linearly as new machines are added, with no downtime or interruption to applications.	The scalability will be as good as running on a single partition	MongoDB scales horizontally using sharding	Neo4j is designed to run in one machine but has massive scalability	Can scale with Read requests, Writes requests and Data	SimpleDB also enables scalability by allowing you to partition your workload across multiple domains
QUERY	Using of Hive	Cassandra Query Language (insert, get, delete)	Redis Query language	CRUD requests	Cypher Query Language	JavaScript	Amazon SimpleDB Query Language
DATA ACCESS AND API	JAVA API RESTFULL HTTP API Thrift	Thrift API CLI	Proprietary protocol	Mongo Wire Protocol	Java API RESTFUL HTTP API	RESTFUL HTTP API JSON API	SOAP and Web services
OPTIMIZED FOR	Random, real-time read/write data access	Writes	Sorted sets	CRUD (Create, read, update and delete) operations	Complex and linked data	Web	High availability and flexibility, with little data
REPLICATION	Selectable replication	Replication strategies are	Master-slave	Master-slave	Master-slave replication (only	Master-master replication	Writes are automatically

	factor	configurable In default mode, data is automatically replicated to multiple nodes for fault-tolerance	replication	replication	available on the Enterprise Edition)	Master-slave replication	replicated across availability zones within a region
GRAPHICAL MONITORING/ADMIN CONSOLE	HBase GUI Manager	Datastax Ops center Cassandra Cluster Admn	Redis Admin UI RedisLive	MongoDB Monitoring Service (MMS) Server Density	Neoclipse and Graph visualization	Futon is the graphical interface Curl	T-437 is graphical user interface AWS Toolkit for Eclipse
IMPLEMENTATION LANGUAGE	Java	Java	C	C++	Java	Erlang	Erlang

SUPPORTED PROGRAMMING LANGUAGES	C, C#, C++, Groovy, Java, PHP, Python	C, C++, Clojure, Erlang, Go, Haskell, Java, JavaScript, Perl, PHP, Python, Ruby, Scala	C, C++, C#, Clojure, Dart, Erlang, Go, Haskell, Java, JavaScript, Lisp, Lua ,Objective-C, Perl, PHP, Python, Ruby, Scala, SmallTalk, Tcl	ActionScript, C, C++, C#, Clojure, ColdFusion, D, Dart, Delphi, Erlang, Go, Groovy, Haskell, Java, JavaScript, Lisp, Lua , Matlab, Perl, PHP, PowerShell, Prolog, Python, R, Ruby, Scala, SmallTalk	. Net, Clojure, Go, Groovy, Java, JavaScript, Perl, PHP, Python, Ruby, Scala	C, C# , ColdFusion, Erlang, Haskell, Java, JavaScript , Lisp, Objective-C, OCaml, Perl, PHP, PL/SQL, Python, Ruby, Smalltalk	.Net, C, C++, C#, Erlang, Java, PHP, Python, Ruby, Scala

TABLE 7. COMPARISON OF SCALARIS, RIAK, TERRASTORE, VOLDEMORT, TOKYO CABINET/TOKYO TYRANT, COUCHBASE AND HYPERTABLE.

EVALUATION CRITERIA	**VOLDEMORT**	**RIAK**	**SCALARIS**	**TOKYO CABINET/TOKYO TYRANT**	**COUCHBASE (previous membase)**	**TERRASTORE**	**HYPERTABLE**
DATA MODEL	key value	key value	Key value	Key value	Document store	Document store	Columnar
CONSISTENCY CONCEPT	Optimistic locking. It updates replicas asynchronously, so it does not guarantee consistent data.	Eventual consistency	Transaction processing with strong consistency over replicas	While a writer is connected to a database, neither readers nor writers can be connected. While a reader is connected to a database, other readers can be connected, but writers cannot. According to this mechanism, data consistency is guaranteed with	Couchbase Server includes a built-in object-level cache, based on memcached, proven data caching technology. This provide consistency and high performance	Terrastore provides per-document consistency features: you're guaranteed to always get the latest value of a single document, with *read committed* isolation for concurrent modifications. More complex consistency/transactional requirements, such as multi-document consistency, are not supported in order	Consistency is achieved through a distributed consensus protocol.

				simultaneous connections in multitasking environment.		to guarantee scalability.	
STORAGE MODEL	It can store data in RAM, but it also permits plugging in a storage engine. It supports a Berkeley DB and Random Access File storage engine.	Riak objects can be fetched and stored in JSON format. Objects can be grouped into buckets, like the Collections supported by document stores. Does not support indices on any fields except the primary key.	Scalaris uses a structured overlay with a non-blocking Paxos commit protocol	The database is a simple data file containing records, each is a pair of a key and a value. Table database does not express simple key/value structure but expresses a structure like a table of relational database. Each record is identified by the primary key and has a set of multiple columns named with arbitrary strings.	Couchbase Server persists all data to disk asynchronously and lets you store datasets larger than the physical RAM size. Couchbase automatically moves data between RAM and disk and keeps the working set in the object-level cache. The storage model is	Terrastore is a distributed document store supporting single-cluster and multi-cluster deployments. It is elastic: you can add and remove nodes dynamically to/from your running cluster(s) with no downtime and no changes at all to your configuration.	It uses column families that can have any number of column “qualifiers”. It uses timestamps on data with MVCC. It requires an underlying distributed file system such as Hadoop, and a distributed lock manager.

					based in JSON documents and Memcache.		
HORIZONTAL SCALABILITY	Supports automatic sharding of data. Consistent hashing is used to distribute data around a ring of nodes.	Data is distributed across nodes using consistent hashing. Consistent hashing ensures data is evenly distributed around the cluster and new nodes can be added automatically, with minimal reshuffling. Supports sharding by hashing on the primary key	In distributing data over nodes, it allows key ranges to be assigned to nodes, rather than simply hashing to nodes. A query on a range of values does not need to go to every node, and it also may allow better load balancing, depending on key distribution.	Scalability of Tokyo Cabinet is great. The database size can be up to 8EB (9.22e18 bytes).	Auto-sharding distributes data uniformly across servers, enabling direct routing of requests to the appropriate server without any application changes. Adding (or removing) a server initiates data rebalancing across the cluster with continuous	Documents are partitioned and distributed among your nodes, with automatic and transparent re-balancing when nodes join and leave. Query and update operations are distributed to the nodes which actually holds the queried/updated data, minimizing network traffic and spreading computational load.	Hypertable will break tables into ranges and distribute them to what are known as ***RangeServer*** processes. Th ese processes manage ranges of table data and run on all slave server machines in the cluster.

					data availability.		
QUERY	Voldemort queries (get,put,delete)	MapReduce, Riak Search, Secondary Indexes	Insert, delete, and lookup	Get/set/update operations. Table database supports query functions with not only the primary key but also with conditions about arbitrary columns.	Incremental map reduce Javascript queries	Map/Reduce querying and processing.	HQL
DATA ACCESS AND API		REST-ful HTTP API protocol buffers interface	Java API, Python API, Ruby API	Perl API, Ruby API, Java API, Lua API	Couchbase Server Management REST API	HTTP API, Java API	Trhift API, C++ API
OPTIMIZED FOR	High performance and availability	Availability, fault-tolerance, operational simplicity and scalability	ACID transactions	Space and time-efficiency, parallelism, usability and robustness	Consistency and partition of data.	Scalability and elasticity	Scalability

REPLICATION	Data is automatically replicated over multiple servers. Data is automatically partitioned so each server contains only a subset of the total data	Riak automatically replicates data in the cluster (default three replicas per object). You can lose access to many nodes in the cluster due to failure conditions and still maintain read and write Availability	It does replication synchronously (copies must be updated before the operation is complete) so data is guaranteed to be consistent	Supports asynchronous replication with dual master or master/slave	Couchbase Server easily replicates data from one cluster to another. Cross datacenter replication (XDCR) and replication within a cluster occur simultaneously.	Terrastore automatically partitions data over server nodes, and can automatically redistribute data when servers are added or removed.	Tables are replicated and partitioned over servers by key ranges.
GRAPHICAL MONITORING/ADMIN CONSOLE	Voldemort Admin Tool				Couchbase Server has advanced monitoring and a rich administration web interface.		Hypertable Monitoring UI
IMPLEMENTATION	Java	Erlang	Erlang	C		Java	C++.

LANGUAGE							
SUPPORTED PROGRAMMING LANGUAGES		Java, Python, Perl, Erlang, Ruby, PHP, .NET, etc.	Java, Python, Ruby	Perl, Ruby, Java, Lua	Java, C#, PHP, C, Python and Ruby.	Java	C++. Java, PHP, Python, Perl, Ruby.

The first point we can retain is the fact that considered NoSQL databases provides huge possibilities of Data access with APIs. The most of them provide high scalability and replication possibilities. As well, they support, for the most of them, different programming languages. Java is the most common supported language.

5.3. Data Aggregation

5.3.1. Hadoop Framework

Hadoop is an Apache-managed software framework derived from MapReduce [22]. Hadoop allows applications based on MapReduce to run a large cluster of commodity hardware. It is designed to parallelize data processing across computing nodes to computation and hide latency. It is based on a distributed file system called HDFS (Hadoop Distributed File System) [23]. HDFS is a clustered approach based on two components:

- NameNode: the NameNode manage the arborescence of the file system. The location of the data blocks is centralized on the NameNode. It also assigns tasks for each DataNode. In order to do it, the namenode uses a daemon, the JobTracker. There is one NameNode in a cluster

- DataNode: the DataNode store and returns data to the namenode when it is asked. It also uses a TaskTracker to execute his tasks and to give information back to the NameNode

Hadoop is based on MapReduce algorithm. MapReduce is a processing model designed by Google as a way of efficiently executing a set of functions against a large amount of data with a parallel and distributed algorithm on a cluster. MapReduce comprises two processing programs: Map and Reduce.

The Map step consists to split up and to process data in a form of Key Value Pairs (KVP). The Reduce step is a merging of KVP in a final result.
NoSQL databases use Hadoop to complete their tasks. Indeed, for example, queries and searching operations are converted to MapReduce tasks.

Hadoop is a very powerful technology to deal with big data. However, to tackle big data challenges it is also important to have some tools.

The most useful tools of Hadoop ecosystem are: Hive, Apache Pig, Sqoop, and Zookeeper. There are also packages that bring statistical analysis and big data algorithm capabilities to Hadoop. One known package is Apache Mahout.

5.3.1.1. Hive

Hive is a batch-oriented, data warehousing layer built on the core elements of Hadoop. It gives a SQL lite interface to users. Hive is used for data mining and deeper analytics that do not require real time behaviors. Hive uses three mechanisms for data organization for tables, partitions and buckets.

5.3.1.2. Apache Pig

Apache Pig is a platform for analyzing large data sets that consists of a high-level language for expressing data analysis programs, coupled with infrastructure for evaluating these programs [24]. It is designed to make Hadoop more approachable and usable by non-developers. Pig is very interactive and support a language used to express data flows: Ping Latin. This language is very rich and allows doing some operations like:

- Loading and storing of data
- Streaming data
- Filtering data
- Grouping and joining data
- Sorting data
- Combining and splitting data

5.3.1.3. Sqoop

Sqoop (SQL-to-Hadoop) is a tool designed for efficiently transferring bulk data between Hadoop and structured data stores such as relational databases. So, it offers the capability to extract data from non-Hadoop data stores, transform the data into a form usable by Hadoop and then, load the data into HDFS. It is the ETL process (Extract, Transform, and Load). Its allows to do some tasks like

- Import and map SQL directly into Hive
- Generate Java classes

5.3.1.4. Zookeeper

Zookeeper is a centralized service for maintaining configuration information, naming, providing distributed synchronization, and providing group services [25]. Zookeeper is very powerful and has the capability to do:

- Process synchronization
- Configuration management
- Self-election reliable messaging

5.3.1.5. Apache Mahout

The Apache Mahout machine learning library's goal is to build scalable machine learning libraries. The Apache Mahout team defines its goal as following (from Mahout Project wiki):

Our core algorithms for clustering, classification and batch based collaborative filtering are implemented on top of Apache Hadoop using the map/reduce paradigm. However we do not restrict contributions to Hadoop based implementations: Contributions that run on a single node or on a non-Hadoop cluster are welcome as well. The core libraries are highly optimized to allow for good performance also for non-distributed algorithms

Mahout can be used for clustering of objects into categories, and identify M2M devices in a cellular network, for example.

5.4. Data Analysis

5.4.1. Machine Learning: Techniques and Algorithm for Data Analysis

Machine learning can be defined as the set of techniques and methods that can be used to automatically learn programs from data. It can be seen as an intersection of Computer Science and Statistics. While Computer Science focuses on how to write programs and Statistics on how to infer conclusions from data, Machine Learning focuses on how to get computers to program themselves in order to analyze those data efficiently and effectively. Machine learning is actively used in a wide amount of disciplines like Web search, spam filters, recommender systems, ad placement, credit scoring, fraud detection, stock trading, drug design and many other applications [26]. It has been pointed out that machine learning will be one of the key technologies of the next big wave of innovation [27].

According to the desired outcome of the algorithm, we can divide machine-learning algorithms into the following types:

- Supervised learning
- Unsupervised learning
- Semi-Supervised learning

5.4.1.1. Supervised Learning

The main goal of supervised learning algorithms is to learn a classification system that has been created in advance.

Supervised learning is the most common technique used to train neural networks and decision trees. In both cases, we want to be able to classify input data into one of the pre-determined classifications. These techniques make use of supervision in the sense of these pre-existing categories that will be used for classification. For neural networks, the supervision allow to minimize the error of the classification produced by the network and for decision trees, the supervision is intended to choose the attributes that provide the most power to discriminate categories.

Every supervised learning technique starts with the collection of the dataset. Although it is not compulsory, it is recommended to take into account expert recommendations about which fields or features to collect. If this is not feasible, as much information as possible should be collected hoping for further discrimination of the proper features. Nevertheless, in most cases this proves to be inadequate to perform induction, as it tends to contain noise and missing feature values, which force to perform intensive pre-processing [28].

As we have just seen, depending on the data collection method, it may be necessary to perform additional procedures in the dataset, for instance, to handle missing data or to perform noise detection. Instance selection is also used when dealing with very large datasets for keeping the mining quality while reducing the sample size.

It is critical also to be able to identify the subset of feature that is really relevant for the classification. The existence of dependencies among features influenced negatively the accuracy of the supervised classifiers. The discovery of meaningful features greatly contributes to a better understanding of the classifier. Supervised models try to minimize the classification error on given inputs. This is how they are built. These given inputs are the training set. There is an inherent risk associated to the use of this training method, which is memorizing the training set rather than generalizing to learn a classification technique. This risk is called over-fitting and can appear too if the training set has classification errors. The design challenge for supervised learning is to construct algorithms powerful enough to learn complex functions while robust enough to be able to generalize results.

As we have seen, supervised learning is closely related to classification. Next, we are going to present the most typical types of supervised learning algorithms used for classification:

- Decision Trees
- Rule-based Classifiers
- Linear Classifiers
- Artificial Neural Networks
- Bayesian Networks
- Instance-based Classifiers

5.4.1.1.1. Decision Trees

Decision trees are a special case of trees that classify data points based on feature values. In these trees, there is direct correspondence between each node in the tree and a feature in an instance to be classified, and between each branch and a certain value of that feature. Classification for an instance is performed starting at the root node and depending on their feature values.

Although there is plenty of methods for finding the feature that best divides the training data, according to the studies found in the state of the art, it seems that there is no single best method [29]. Decision trees are usually univariate although there are a few methods that construct multivariate trees like [30,31].

The most common and well-known algorithm for building decision trees is the C4.5 algorithm. C4.5 shows a good compromise between error rate and speed. Its main drawback is that the training data must fit in memory, although some authors [32,33] have proposed modifications to overcome these limitations.

5.4.1.1.2. Rule-based Classifiers

Rule-based classifiers can be defined from decision trees just by creating a separate rule for each path from the root to the leaf in the tree. Nevertheless, it is also usual to derive them directly from training data. The goal is to construct the smallest rule-set consistent with that training set.

A rule induction system has to generate decision rules both with high predictability or reliability. These two properties are typically measured by the rule quality.

There are many rule-based algorithms. The two main paradigms for rule generation are creating rules from decision trees and the separate-and-conquer rule-learning technique. Genetic algorithms have also been used for rule learning. In these cases, the fitness function scores the classification accuracy of the rule over a set of training instances. There is an iterative process that takes the population at each iteration and generates a new population such that the overall fitness is increased.

Rule-based classifiers are better suited than decision trees for learning binary problems because they are more comprehensible. On the contrary, if we deal with multiple class definitions, the learner has to be run independently for each class. This is prone to rule inconsistency, something that simply does not happen with decision trees. For this kind of problems, the divide and conquer approach used by decision trees is more suitable than the separate and conquer approach used by rule-based algorithms. Separate and conquer algorithms focus on one class at a time and create rules for identifying that class. This is, as we have seen, independent from the rules created for the other classes. Because of this, for small datasets it may be better to opt for the divide and conquer approach, which focus on the entire dataset, not in specific classes.

Finally, notice that, as it happened with decision trees, the most remarkable feature of rule-based algorithms is its comprehensibility.

5.4.1.1.3. Linear Classifiers

A linear classifier uses a linear combination of the features to be able to perform the classification. The input feature to the classifier is a vector where each of its components corresponds with a particular feature. To compute the output, a dot product with a weight vector is performed and a certain function *f* is applied to the result. The weight vector is learned from a set of labelled training examples. Because of its simplicity, linear classifiers are used when speed of classification is an issue.

Support Vector Machines (SVM) [34] perform classification by constructing a N-dimensional hyperplane that divides the data into two categories. SVM are closely related to classical neural networks. In the SVM context, predictor variables are known as attributes. For the hyperplane definition, attributes are transformed into features. By feature selection, we mean the process of choosing the most appropriate representation for the features. A set of features, which is nothing but a row of predictor values, is known as vector. According to this definition, we could reformulate the goal of SVM as to find the optimal hyperplane that separates cluster of vectors so that cases with different categories of the target variable are at different sides of the hyperplane. The set of vector that are closest to the hyperplane are the support vectors.

Depending on the complexity of the data set, it may be necessary to employ more than two predictor variables or using non-linear curves for the separation of categories. Also there are situations where the categories cannot be completely separated or where more than two categories have to be used.

5.4.1.1.4. Artificial Neural Networks

Artificial Neural networks (ANN) can be viewed as weighted directed graphs in which artificial neurons are nodes and directed edges (with weights) are connections between neuron outputs and neuron inputs [35]. The most popular architecture for ANN is multilayer perceptrons. In this architecture, the units perform a biased weighted sum of their inputs. This sum itself will be the input to its transfer function to compute the neuron output. Under this scheme, the units are arranged in a layered feed forward topology. The network complexity will depend on the number of layers and the number of inputs in each layer. While the number of inputs and output units is usually defined by the problem, the number of hidden units to use is not that straightforward and to be defined carefully.

Once we have defined the structure of the network, weights and thresholds have to be defined to minimize the error made by the network. To evaluate this error, we use a training algorithm. The error of a particular configuration of the network is evaluated by processing all the available cases in the training data set and comparing the obtained output with the expected output. The network error is defined as a combination of the target outputs. While in traditional linear model, it is possible to determine the configuration that minimizes the error, because of the non-linearity of ANN we cannot be sure whether the error is at its minimum or it can still be lowered.

To model the network error, the concept of error surface is introduced. For any possible configurations of the N weights assigned, the error can be plotted as a function of the weights in the N+1 dimension as an error surface. Our goal would be to find the minimum, if any, in that surface. Because of the complexity of neural networks, it is not possible to analytically determine the global minimum. Alternative techniques must have to be taken into account, typically gradient-based techniques, which try to find and then improve local minima.

One desirable property would be the ability to generalize to new cases. There are no guarantees about the error we will obtain when dealing with new data. Associated to this situation, it is the problem of over-fitting. The more weights an ANN has, the more prone to over-fitting that it is. To deal with this, the concept of selection set is introduced. The selection set is a portion of the training dataset that is reserved and actually not used for training. As training progresses, training error naturally decreases and selection error (that is, the error obtained when evaluating versus the selection set) decreases too. If the training error stops dropping, it is god indicator that over-fitting is starting to occur, and training should stop because the network is powerful enough to model the underlying function. Finally, a third set is reserved, the test set, to ensure that the results of the selection and training are real and not something artificially created from the training process. Notice that for this approach to be effective the test set must only be used once, otherwise it becomes training data.

ANN has been applied to plenty of real-world problems. Their main drawback is their lack of ability to reason about their output in a way that allows effective communication. Many researchers have tried to improve the comprehensibility of ANN, for instance, by extracting symbolic rules from trained neural networks [36].

5.4.1.1.5. Bayesian Networks

Bayesian Networks (BN) can be defined as a graphical model of the probability relationships existing among a set of variables. It can be seen as a directed acyclic graph (DAG) where there is a one to one relationship among nodes and features. Each node is random variable in the Bayesian sense. When there exists an influence between features, there will be an arc joining them, while the absence of arcs means conditional independence.

Bayesian networks can be used for learning. In order to accomplish that, two conditions must be fulfilled. First, the structure of the DAG network has to be determined. Second, the parameters of the network have to be found. There is a table for each of the variables (nodes) where it is reflected the local conditional distribution of the variable with respect to its parents. From these relationships, the joint distribution can be constructed just by multiplying the tables.

The dominant approach for learning Bayesian networks from data is based on the use of a scoring metric, that evaluates the fitness of any given candidate network to the data, and a search procedure, that explores the space of possible solutions. Most existing learning tools apply standard heuristic search techniques. It has been shown that the selection of a single good hypothesis using scoring and greedy search often leads to accurate predictions [37,38]

There are proposals [39] that focus on reducing the search space thus improving efficiency. Ant Colony Optimization has also been proposed for finding the optimal structure of Bayesian networks [40].

Naïve Bayesian networks (NB) are a specific case of Bayesian networks where the DAG only has one parent and several children and with a strong assumption of independence among child nodes in the context of their parent. This assumption is wrong in most cases and this is why NB is less accurate than other methods. The main advantage of NB classifiers is the short computational time for training.

To summarize, we would like to stress that BN are specially interesting, compared to decision trees or neural networks, when there is prior information that can be taken into account about a certain problem, e.g. some expertise or domain knowledge. On the other hand, BN are not suitable for datasets with many features because of the complexity of the network construction.

5.4.1.1.6. Instance-based Classifiers

Instance-based learning algorithms store the training samples and instead of first generalizing and later classifying, they just store the training samples and try to compute the generalization only when classification is needed. They are examples of lazy-learning algorithms. This kind of algorithms requires less computation time during the training phase but, on the contrary, more computational time during the classification process.

k-Nearest Neighbor (kNN) is based on the fact that instances in a dataset will tend to be closer to other instances that have similar features. Taking this into account, a particular instance could be classified by observing the class of its nearest neighbors. kNN uses the k-nearest neighbors and identify the most frequent class label. Weighting schemes can be used to model the influence of each instance. Also, attributes can be weighted.

kNN has large storage requirements and is very sensitive to the similarity function used to compare instances and to the choice of k. It has been shown that the performance of kNN is not sensitive to the choice of k when k is large, which will be the case in high dimensionality cases.

5.4.1.2. Unsupervised Learning

While supervised learning starts from labeled data and tries to generalize from the already classified examples, unsupervised learning tries to find any structure underlying unlabeled data. Among the approaches used for unsupervised learning, we can find clustering techniques (like k-Means or mixture models) and blind signal separation using feature extraction techniques for dimensionality reduction.

K-means [42] tries to classify data point into a set a certain number of clusters. The goal is to minimize the distance from the data points to the center of the cluster where it has been classified. K-means is an iterative procedure. First, taking into account the a priori clusters, we have to set the *k* initial centroids, one for each cluster. Second, we associate every data point to its nearest centroid. Finally, we recomputed the centroids. Taking into account these new centroids, we start over. We iterate over this process until there is no change in centroids’ positions.

The k-means method is widely used because of its simplicity but has some drawbacks, though. There is no guarantee that an optimal solution will be found and it is quite sensitive to the initial location of the centroids. Also it is not robust to outlying data. Another shortcoming of k-means based methods is that they only can process isotropic clusters such as circles, spheres, etc.

Fuzzy clustering algorithms or Soft K-Means (as opposed hard K-means), e.g. C-means [43], allow a data point to belong to more than one cluster and associated to every data point there is a set of membership levels, which measure the strength of the association of the data point to each particular cluster.

Unsupervised learning can also be applied to topology learning. This family of algorithms tries to infer the representation of the topology structure of a high-dimension data distribution. Most of the proposals require a predetermination of the network size [44], the network structure or both [45].

5.4.1.3. Semi-supervised learning

Semi-supervised learning is the kind of learning algorithms where we a have a small subset of labeled data and a big amount of unlabeled data. Under suitable assumptions, it uses unlabeled data to help supervised learning task. The cost associated to labeling the data may deem impossible to label the whole data set, while acquisition of labeled data may be easy and cheap. In such situations, semi-supervised learning can be of great value. A good review of semi-supervised learning techniques can be found in [46].

5.4.2. Distributed and Parallel Architectures for Machine Learning

In the context of the SITAC project, the amount of data that is expected to be collected stored and processed is huge. The first part of this document is devoted to how to efficiently store and process those heterogeneous data sets. One of the strongest points in the project is to be able to classify, infer and extract valuable information from data. While traditional machine learning approaches have proven valuable for those tasks, if we have to deal with data sets too large not to be handled on a single machine or that require statistical inference to be fast or in near real-time, those approaches just fail. The best algorithm for a given problem may change dramatically as more data becomes available [47]. This new situation has led to an increasing interest in distributed algorithms for machine learning, taking advantage of the increasing availability of multi-core architectures and the commoditization of grid computing.

There are scenarios where it can be found appropriate to move from single-machine processing to parallel and distributed architectures. According to [48], these scenarios are characterized by:

- Large number of data instances: the number of potential training examples is big enough to make not feasible to process that in one single machine.

- High input dimensionality: in some cases, data instances are represented by a high number of features. Machine learning algorithms may partition computation across the set of features, which allow for dealing with very complex scenarios.

- Model and algorithm complexity: there are machine learning algorithms that are based either on complex or on computationally expensive routines to provide high-accuracy results. Distributing the computation across multiple processing units could help to deal with learning on very large datasets.

- Inference time constraints: tight constraints on inference time may only be met if we opt for parallelized versions of algorithms.

- Prediction cascades: Sequential, interdependent predictions may be associated with highly complex joint output states that could take advantage of parallelization.

- Model selection and parameter sweeps: Tuning parameters of algorithms that require multiple executions of learning and inference are naturally suited for concurrent execution.

If we have a deeper look into the problem of scaling up machine learning algorithms, it can be seen that the problem must be tackled from different approaches. First, there is a need for programming frameworks adapted for parallelizing learning algorithms. MapReduce can be employed for parallelizing the training of decision trees ensembles, a class of algorithms that includes methods such as boosting and bagging. PLANET [49] is able to distribute the tree construction across multiple processing units expanding multiples nodes in each tree, leveraging the data partitioning which is implicit in the tree and using both parallel and local execution when convenient. A two-orders-of-magnitude on a 200-node MapReduce cluster on datasets large enough not be processed on a single node can be achieved using PLANET. DryadLINQ [50] is a declarative data-parallel programming language that compiles programs down to reliable distributed computations, which are executed by the Dryad execution engine. The Dryad execution engine is able to scale up computations across large clusters of machines. It main advantages are the ease of programming and its strong performance across multi-gigabyte datasets. IBM Parallel Machine Learning Toolbox (PML) eases down the implementation of parallel versions of machine learning algorithms. PML represents algorithms as a sequence of operators subject to algebraic rules of commutability and associability. Such operators correspond with algorithm steps during which training instances can be exchanged and partitioned in different ways, which helps it parallelization. Other interesting project is Apache mahout. Apache Mahout provides a library of machine learning algorithms developed for Hadoop.

On the other hand, we can also deal directly with the construction of parallelized versions of machine learning algorithms. Several authors have shown how to parallelize the training of Support Vector Machines (SVM) [51,52]. LambdaMART is a boosted decision tree algorithm for learning to rank. There are different distributed versions of LambdaMART [53] that improve the algorithm performance up to one order of magnitude by partitioning the features across nodes (citation needed). Statistical latent variable model, such as topic models, can also be distributed. This allows to scale up to large datasets by distributing data instances and exchange statistics across nodes. The underlying idea is to distribute the distributed collapse Gibbs sampling, a Markov Chain Monte Carlo technique, for algorithms such as Latent Dirichlet Allocation and Hierarchical Dirichlet Processes as well as Bayesian networks in general. Clustering methods can be parallelized using different techniques. Parallel spectral clustering techniques [54] are one of them. They are composed of three stages: sparsification of the affinity matrix, subsequent eigende composition and obtaining final clusters via k-means using projected instances. Sparsification can be distributed using MapReduce and the other two steps using MPI.

Apart from traditional supervised and unsupervised learning schemes, there are other interesting proposals. In online learning algorithms, training instances arrive in a stream and learning is performed on one example at a time. Features are partitioned (“sharded”) across cores and nodes achieving a speedup factor of 6 on a cluster of nine machines [55]. For graph-based semi-supervised classification, heuristics have been proposed to reorder graph nodes for the optimization of message passing, both for multicore and distributed settings, which are able to scale up to a 85% efficiency on a 1000 core distributed computer for a dataset of 120 million graph instances, in the context of speech recognition. Several other proposals for transfer learning and distributed learning selection can also be found. P2P networks have also been studied for distributed data mining [56].

Conclusion

Big data management induces issues like data collection, storage, aggregation and analysis. For the data storage, data have to be stored with in an efficient, scalable and powerful database. The database also has to deal with real time stream information. In view of those needs, a first approach should be to test some NoSQL databases in order to choose the most adaptable for the project. Thus, it will be interesting to test:

- CouchDB due to his web oriented approach
- Neo4j because it offers a great possibilities of query and is based on Graph model. This model is very adapted to manage linked data
- Hbase: it allows an efficient random access in real time for read and writes. In addition, its HDFS data storage model enables an easy integration with Hadoop
- MongoDB: it is the most common NoSQL databases.
- DynamoDB, as a good representative of key-value pair NoSQL databases.

Finally, regarding data analysis, it is necessary to take into account the requirements imposed by the type and volume of data, which will be collected in this project. While traditional machine learning approaches have proven valuable for those tasks, if we have to deal with data sets too large not to be handled on a single machine or that require statistical inference to be fast or in near real-time, those approaches just fail. There is a need for either parallelized implementations of existing machine learning algorithms or for developing parallel versions of existing machine learning techniques. Both approaches will be considered during this project.

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6. Crowd-based Technologies

This chapter aims to identify what is Crowd-based Technologies for the future. This foresight will help expose future research themes with high innovation and business potential, based on a timeframe roughly 15 years ahead at least. The purpose of crowd-based technologies is to establish a strong community across multi-technology fusion from partner organizations.

Trends

- Emergence of a new model of computation named crowdsourcing, which exploits human computation - "wisdom of the crowd".
- Crowdsourcing or crowd-based services, the trend is toward "everyone as a service" [1].
- Emergence of distributed sensing, using mobile phones, where the sophisticated sensing, processing, and communication capabilities of millions of smartphone users can be used towards a common sensing goal [2]. Moreover, the distributed sensing data collection from mobile phones and other devices will produce an essential part of the big data trend.
- The rise of social media platforms has shown that people want to create and share their content with others [3]. In the future, this will be included in the future Internet of Things (IoT) as part of social media.
- Public organizations will provide open data for the creation of new services. As part of the open data, public authorities also allow the generation from crowd behavior in people's daily lives. This also enables rethinking of data as learning human behavior, with history and future planning.
- Big data, including IoT, and open data trends will enable digital service fuse together with crowd-based data. This kind of fusion also make the data appear in new forms, while gluing these together can be used to create new service business models.

6.1. Crowd-based Services

Crowd-based services must be revisited and redefined when big data opportunities become clearer. The interplay between things and people based on various sensor-embedded devices makes massive data gathering possible. In the future, we will have to revise our conceptualization of how we look at the world, due to these new sources of data and big data. So a service system can be broadly understood to consist of people and ICT (Information and Communication Technology) systems for providing smart service (it can be named as: ecology ICT system, where the Ecology is the scientific study of interactions among organisms and their environment, that is, the interactions which organisms have with each other and with their abiotic environment). What is the essence of smartness? It is the idea that the services have some goals as systems that bring benefits to themselves, e.g., better user experience based on ICT system and big data mining. In summary, not only recognize, link and manage the things (IoT), and even mine the essence and laws inside the "things" (include people).

Which aspects will be included for crowd-based services? As described above, our "crowd-based" is based on big data mining. Crowdsourcing, and further mobile crowdsourcing, open data, and Internet of things all are steps that elaborate the link between the crowd and big data.

- Crowdsourcing. In its broadest sense, crowdsourcing could be viewed as synonymous with collective intelligence. But in the information service domain, this conception is used more frequently: everyone has ideas about how to improve the products or services which they use, how to simplify processes, or how to reduce costs. Crowdsourcing is based on the "crowd" process. The crowd can bring interesting, nontrivial, and non-overlapping information, insights, or skills, which, when are used through appropriate aggregation and selection mechanisms, can add the quality of solutions [4].

- Mobile crowdsourcing. A remarkable trend in crowdsourcing is the use of mobile devices: it breaks the time and space barriers between people and enables them to share information and knowledge [5]. Mobile crowdsourcing has the potential to help to tackle an array of new problems that involve real-time data collection from a large number of participants.

- Open data. In recent years, open data initiatives have emerged, and are now available in several countries [6]. Such initiatives consist of opening and sharing the public data of a country/city. The data can be reused to develop added-value services and applications or improve the quality of existing services and applications.

- Internet of Things (IoT). IoT is a computing concept that describes a future where everyday physical objects will be connected to the Internet and will be able to identify themselves to other devices. Based on the daily data from the IoT, the big-data-based research will spring up.

6.2. Crowd-based Applications

Currently research trend is shifted towards developing rich set of social networking, environmental and infrastructure mobile applications. In particular, with the proliferation of smartphones and their apps stores, mobile crowdsensing is used in a plethora of different applications of which we enumerate a few here.

CenceMe [9], a social networking application developed by Darmouth College, classifies citizen activities (walking, driving, exercising…) by sensing the level of noise or the mobile direction and then subsequently share these activities via social networks.

For the environmental MCS (Mobile CrowdSensing), the mobile user is involved to measure some natural phenomenon. In PEIR [10], authors measured the urban pollution level based on collected data samples through the individual's mobile microphones. Impact of Citizens on their respective environment is studied (ex: carbon emission) based on the sensed activities and locations. Another example is the IBM project, CreekWatch, where users report the water level and its quality in creeks by sending captured pictures or even simple text messages.

Researchers are also working on several transportation and traffic monitoring applications. MIT VTrack project [11] provides fine-grained traffic information on a large scale using mobile phones that facilitate services such as accurate travel time estimation for improving commute planning. Similarly, Nericell project [12] utilizes individuals mobile phones to not only determine average speed or traffic delays, but also detect honking levels and potholes on roads .

Mobile crowdsensing is an emerging field of research requiring further attention from researchers and developers in order to overcome several challenges concerning the heterogeneity of mobile hardware and OS, the energy efficiency and the network bandwidth reuse.

In recent years, in the crowdsourcing domain, mobile crowdsourcing is an increasingly popular mechanism to realize crowd-based applications which use a large volume of real-time data to improve daily life. Twitter is a breakthrough for mobile-crowdsourcing-based applications. Yan et al. [2] demonstrated "mCrowd", an iPhone-based mobile crowdsourcing platform, which enables mobile users to fully utilize the rich sensors with which the iPhones are equipped to participate and accomplish crowdsourcing tasks.

Väätäjä et al. [3] conducted two user studies to support the development of future mobile crowdsourcing processes and mobile tools for news reporting. Moreover, the findings of literature [3] revealed that SMS messages were experienced as an easy and handy means for news assignments.

A mobile application called "txteagle" [7] is a system that enables people to earn small amounts of money by completing simple tasks (such as translation, transcription, and surveys) on their mobile phone.

Mobile crowdsourcing can also be used to design smart parking. Chen et al. [5] studied the properties of crowdsourcing in the context of smart parking, and also investigated the use of information collected through crowdsourcing for parking guidance, which is integrated into a road navigation system (as a design alternative to lower the cost to install and maintain a dedicated infrastructure). The basic idea of the parking guidance system is: each participant driver helps with data acquisition, and in return, either the system provides the aggregate parking availability map and users make uncoordinated decisions, or the system provides customized recommendations of parking locations and navigation to the participants and thus attempts to coordinate their behavior.

Ubiquitous crowdsourcing is another popular mechanism to realize crowd-based applications [8]. With the adoption of mobile, digital and social media the crowd is increasingly reporting and acting upon events in smart environments; and sharing their data and experiences. The design goal of ubiquitous-crowdsourcing-related applications: engage crowd members as sensors, controllers and actuators to make the environments around us smart.

Conclusion

Using the "wisdom of the crowd" is main idea for crowd-based technologies. Moreover, in current days, along with the construction of digital (or smart) cities, big data era is coming. The big-data-based "crowd" will be different from the traditional one. Therein, the mobile and ubiquitous "crowd", are two promising aspects. In the future, the concept of service needs to be revisited based on the "smart city" frame - what is the essence of smartness? The "crowd" will be an attractive mechanism for processing data from the massive data, and for improving the quality of service (make the environment around us smart).

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7. Security, trust, and privacy

Privacy and security is one of the major aspects for enabling the M2M market. It is what is said in literature. Anyway, in reality, the many solutions do not provide security because of the cost for deploying security credentials in a secure way. The market is also reluctant to integrate security because user may think the security of the data is not important. For all these reasons, the M2M security and privacy concerns are often not handled properly. This state of the art describes the legacy architecture of M2M solutions and describes the techniques and protocols that can be used to support security and privacy.

7.1. Legacy M2M architecture

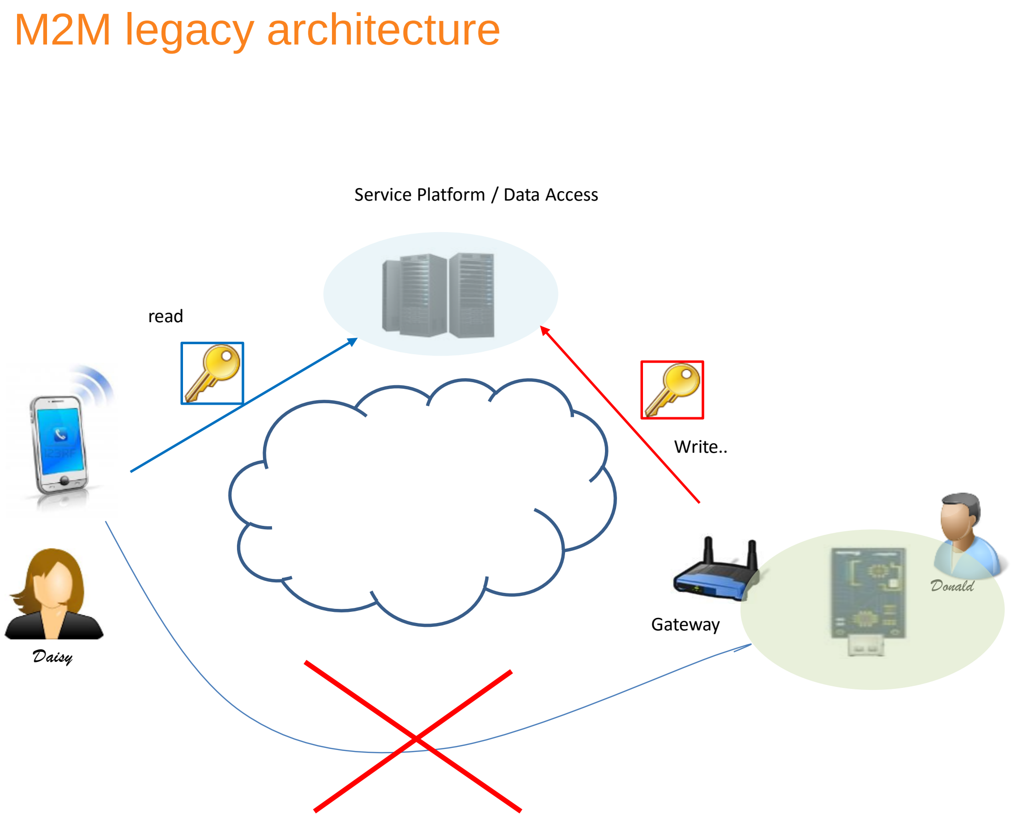

FIGURE 14. LEGACY M2M ARCHITECTURE.

In legacy M2M architecture, the device pushes data to Service Platform and the application reads such data from the Service Platform. In many security implementations, the TWO links are secure point-to-point but there is no end-to-end security between the consuming application and the device. This architecture poses a problem of privacy because the data is kept in clear at Service Platform and may be used in fraudulent way. This architecture is the typical architecture specified in ETSI M2M Standard. Anyway ETSI specifies also some security mechanisms like GBA to support end-to-end security.

In OneM2M standard which is worldwide in progress M2M standard, a huge effort is provided to support authorization mechanism and end-to-end security. Nevertheless, the underlying problems for end-to-end security are the deployment of the security credentials and the notion of user and owner of devices and objects and related data.

See first proposed SITAC Trust Model in SITAC Architecture document for an overview of the SITAC vision of t M2M Trust Model.

Anyway, even in legacy architecture, they are security issues at alllevel of the communication links.

7.2. Security concepts

The security concepts are the following:

- Confidentiality: the data shall be available/disclosure to legitimate entities.
- Authentication: the way to insure that a peer entity is legitimate
- Integrity: the data shall not be modified during data transfer.
- Non-repudiation: the receiving entity cannot claim that it has not received a message.
- Availability: the resilience of the communication network against attacks.

In M2M communication level, the security techniques rely on authentication, digital signature and encryption protocols. Anyway, all these techniques use initial bootstrap credentials to setup security session keys. The object themselves can be located in unsecure environment and are therefore subject to physical attacks.

7.2.1. End to end security

End-to-end security is a concepts allowing secure exchange of data between source of data and entity consuming the data. All technical components used to transfer the data shall not be able to have access to clear data. The machinism allowing such paradigm shall securely setup keys available only by the source and the destination and cannot be retrieved by any entities in the communication stack.

The mechanisms allowing such concept can be classified in two categories.

1. The mechanisms relying on public key infrastructure that do not use external third party for setting up the session keys. Diffie-Hellman mechanism is a well-known example. Anyway, such mechanism does not allow one-to-many paradigm where the device sends ciphered data (the one) to several applications (the many). This is quite important to reduce the required bandwidth for transferring data and the energy consumption at device which can is typically a constrained both according the CPU and memory and the according consumption of energy.

2. Mechanism using a third party for secret key distribution. This party is called a Trust Provider which - by design - is not involved in data transfer.

For this case, the both consumer entities and source entity shall trust the Trust Provider to retrieve the keys used for end-to-end secure data transfer. Typically, a Trust Provider can be an Authorization Server managing the right for an application to access a device. The distribution of the key to each party shall be done in a secure way for instance using above mechanism.

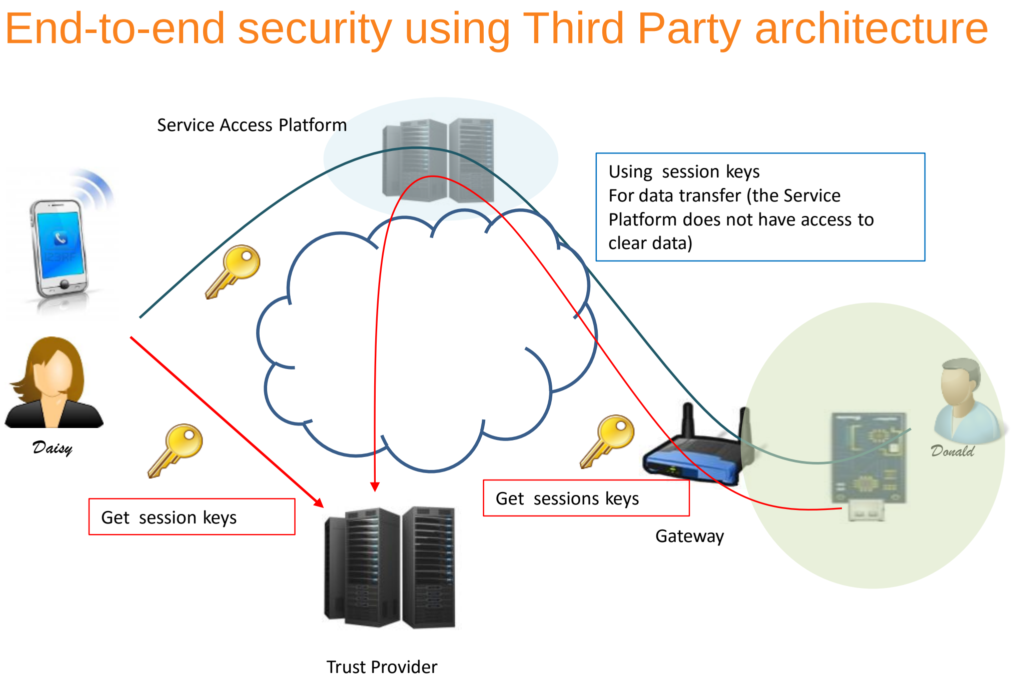
End-to-end security using Third Party architecture

FIGURE 15. TO END SECURITY USING THIRD PARTY.

The scenario is the following. The destination entity (Daisy Application in the above example) and the source entity (Donald Device in the above example) separately connect to the Trust Provider for receiving session keys. Using the session keys the two entities can securely exchange data and, if necessary, derive new session keys using the received session keys and shared algorithm between the two entities. These derived keys are not known by the Trust Provider.

7.2.2. Security of Communication

The communication layers are represented by the ISO Model view **Error! Reference source not found.** or, for now, using the Internet Model view. Some concepts are almost equivalent. Application layer is Internet Model encompasses all above the Transport layer. Each layer may implement security mechanisms – the choice of the layer depend on the deployment of the security credential.

7.2.2.1. *Security at Network Layer*

On the network layers, the source and destination hosts can be located on different network. In consequence, this layer shall support addressing and routing mechanisms. The well known protocol is the Internet Protocol. This layer relies on Data Link layer for transmitting data on each network. The studied network stacks is based on EAP which is the most used stack in M2M environment. IPSEC **Error! Reference source not found.** is mainly used to setup Virtual Private Network for Corporate Environment.

7.2.2.1.1. EAP

EAP stands for "Encapsulated Authentication Protocol". Typically EAP runs over Data Link Layer – .e.g. PPP - and does not require by itself Internet Protocol. It is designed for use in network access authentication. EAP has been designed to support many authentication methods by delegating authentication to back-end authentication server. In this case, authenticator runs as a pass-through authenticator – this is the typical architecture.

The EAP typical architecture is the following: a specific EAP method is carried over EAP which is itself carried over Lower Link Layer

EAP method	**EAP method**	**EAP method**	**EAP method**
EAP	**EAP**	**EAP**	**EAP**
PP Lower Layer	**PP Lower Layer**	**AAA Lower Layer**	**AAA Lower Layer**
Peer	Pass-through Authenticator		Auth Server

PP for Peer to Pass-through Authenticator link: example PPP, PANA **Error! Reference source not found.**

AAA for Authenticator to Auth Server link: example Radius , Diameter

The generic EAP Protocol is the following:

1) The authenticator sends a Get- Identity request to the peer.

2) The peer responses with the peer identity.

3) The authenticator forwards the identity to the authentication server

4) The authentication server deducts from the identity the authentication method to apply.

5) Thru the Authenticator, the peer and authentication server exchange authentication messages according the selected authentication method (see details descriptions of EAP-XXX methods).

6) On successful completion of the authentication, the Authenticator receives Master Session Key (MSK) from the Authentication Server and allows access to the peer. The MSK is computed by the EAP-XXX method and shall be - at least - 64 bytes long. The protocol to transport MSK from authentication server to authenticator is out-of-scope EAP specifications.

7) Peer to authenticator messages are exchanged using a Transient Session Key derived from MSK. The derivation mechanism depends on Peer To Authenticator protocol and shall be independent of EAP-Method (separation of authentication and data protection) and is handled by the lower layer protocol – IEEE 802.1X-2004, PPP, IKEv2, IEEE 802.11, PANA….

The 3 main methods are EAP-SIM, EAP-AKA and EAP-TLS.

EAP-SIM Error! Reference source not found. is an authentication method that uses the authentication engine of a SIM card (A3/A8 algorithm, IMSI/Ki) and the authentication infrastructure of a telecom operator (HLR) to prove user's identity. With EAP-SIM, the supplicant's functionalities are split between the user's device and the SIM card, the authentication server is a Radius server delegating authentication to the HLR.

EAP-SIM implements mutual authentication and replay protection above the 2G authentication algorithm.

EAP-AKAError! Reference source not found. is based on the same principle than EAP-SIM except that it uses 3G authentication algorithm (Authentication and Key Agreement, usually called "*milenage*") instead of 2G one (A3/A8). In this case mutual authentication and replay protection are "natively" supported by the authentication algorithm. Similar to EAP-SIM, EAP-AKA specifies an EAP-based mechanism for mutual authentication and session key agreement using the Authentication and Key Agreement (AKA) mechanism used in the Third Generation (3G) mobile networks (UMTS and CDMA2000). AKA is based on symmetric keys and runs on any type of smart cards, e.g. USIM card.

EAP-Transport Layer Security (EAP-TLS) **Error! Reference source not found.** is an IETF open standard. The security of the TLS protocol is strong, as long as the user understands potential warnings about false credentials. It uses PKI to secure communication to the RADIUS authentication server or another type of authentication server.

EAP-TLS is the original standard wireless LAN EAP authentication protocol. The highest security available is when the client-side keys are housed in smartcards. This is because there is no way to steal a certificate's corresponding private key from a smartcard without stealing the smartcard itself. It is significantly more likely that the physical theft of a smartcard would be noticed (and the smartcard immediately revoked) than a (typical) password theft would be noticed.

Security Summary

The Key Agreement depends on the method. Mutual Authentication between peer and Authentication Server is optional and depends on the implemented EAP-method.

In case the Authenticator is separate from the backend authentication server, the security analysis is more complicated as the peer authenticates the authentication server but not the authenticator. Case by case security analysis shall be provided – it is out-of-scope EAP specification.

7.2.2.2. Security at Transport Layer

The Transport Layer implements reliability of data transmission over the network link. TCP and UDP – even not fully consistent with L4 - ISO specification – are the most well-know protocols used at this level. The Transport Layer may support security of the data transmission.

We describe here SSL/TLS which is the most used implementation of Security at Transport Layer over TCP and DTLS over UDP.

7.2.2.2.1. SSL/TLS

Transport Layer Security **Error! Reference source not found.** is a major protocol securing communications on the Internet. The earlier version of the protocol was called Secure Sockets Layer (SSL). TLS is currently supported by the IETF and is described in **Error! Reference source not found.** (TLSv1.2) published in 2008. Basically, TLS builds a secure tunnel through the network between two hosts. Data packets are encrypted so that only the specified receiver can access the content to prevent eavesdropping, tampering, or message forgery.

TLS is based on several principles that led to his popularity and current massive usage to secure Internet communications for client/server applications: the server is authenticated, the integrity and confidentiality of data are proven thanks to the encrypted session, application data are transparently transferred (application independent), and client authentication is possible if needed.

To provide privacy and data integrity, TLS is based on two protocols: TLS Record and TLS Handshake protocol. TLS Record provides connection security and the TLS Handshake performs the authentication.

First, the TLS Handshake Protocol allows the client and the server to authenticate each other and to negotiate the secret that will be used to generate the symmetric keys used to specifically secure the communication. Server authentication is done through public key cryptography and relies mostly on the usage of a certification authority (CA).

The **TLS Handshake Protocol** process includes two phases:

- **Server Authentication** in which the client requests the server’s certificate. In response, the server returns its digital certificate and signature to the client. The server certificate provides the server’s public key. The signature proves that the server currently has the private key corresponding to the certificate.

- **Client Authentication** (optional) in which the server requests the client’s certificate. In response, the client sends the digital certificate and signature to the server.

The secret is securely negotiated so that a man in the middle attack (eavesdropping) cannot obtain it; neither modifies the negotiation without being detected. The two parties also negotiate the encryption algorithm to be used as presented in Figure 8 – step 1 and 2. Once set, symmetric cryptographic keys are generated (step 7) based on the shared secret and further communications are private.

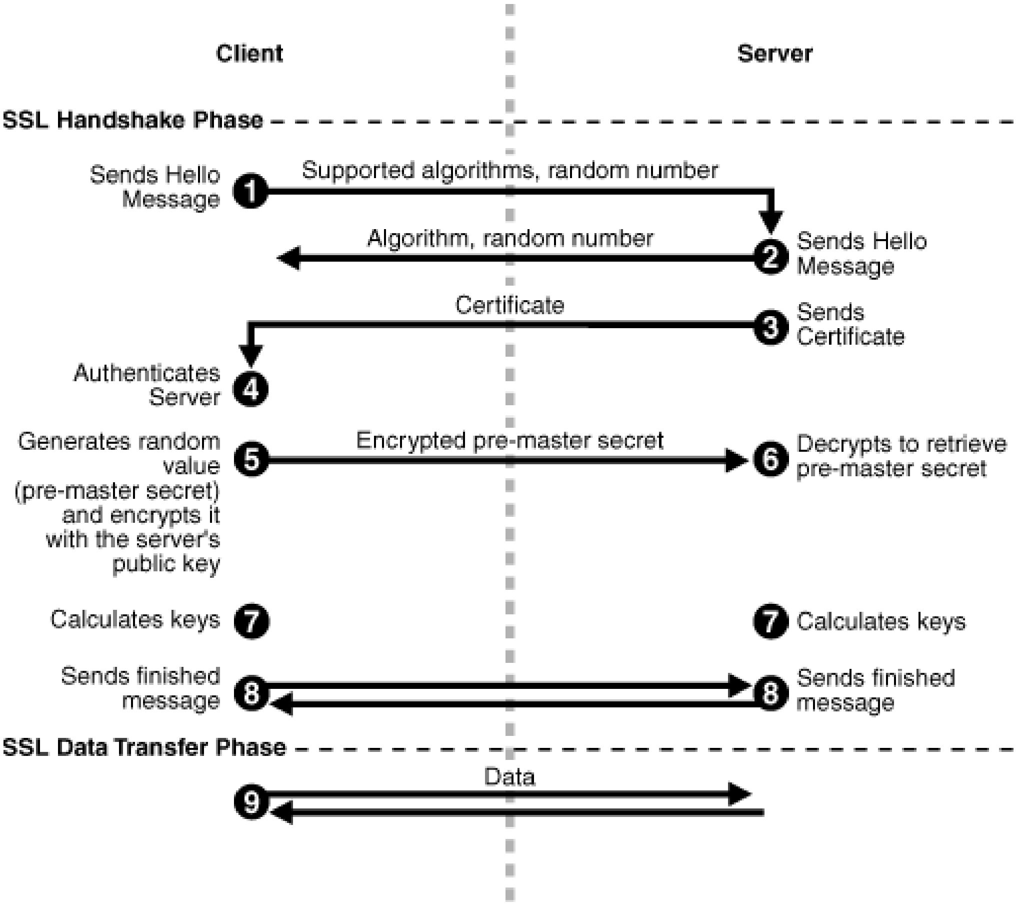

FIGURE 16. SSL HANDSHAKE FROM ORACLE® FUSION MIDDLEWARE ADMINISTRATOR'S GUIDE.

We can see that TLS protocol uses a combination of public-key (step 5) and symmetric key encryption (step 9). In fact, symmetric key encryption is much faster than public-key encryption, but public-key encryption is needed to provide authentication techniques. The handshake allows the server to authenticate it to the client using public-key techniques, and then allows the client and the server to cooperate in the creation of symmetric keys used for rapid encryption, decryption, and tamper detection during the session that follows. Optionally, the handshake also allows the client to authenticate itself to the server.

Then, the **TLS Record Protocol** encapsulates the application data and securely transports it. It relies on symmetric cryptography using previously generated keys for data encryption and is totally application independent. Message integrity can be checked by adding a keyed MAC which is generated by a hash function.

TLS provides the following security functions:

- **Data Encryption** to ensure data security and privacy. Both public key and secret key encryption are used to achieve maximum security. All traffic between a TLS server and TLS client is encrypted using both public key and secret key algorithms. Encryption thwarts the capture and decryption of TCP/IP sessions.

- **Data Integrity** to ensure that TLS session data is not manipulated en route. TLS uses hash functions to provide the integrity service.

- **Mutual Authentication** to verify the identities of the server and, on server request, may require client authentication. Identities are digital certificates. The entity presenting the certificate must digitally sign the data to prove ownership of the certificate. The combination of the certificate and signature authenticates the entity.

Security Summary

- TLS secures the link from eavesdroppers but if the host is directly compromised, TLS cannot secure the communication

- Some older version of SSL/TLS can still use cryptographic algorithms that are proven breakable

Using TLS in constrained objects.

- If the client needs to be authenticated to the server, the technology requires complex and huge deployment process of client certificates and therefore it is not well suited for M2M. The CA must be trustworthy and is a single point of failure in the system. It is not suited to secure pervasive and peer-to-peer M2M communications. Moreover, the required bandwidth and resource consumption have not been optimized for M2M communications with strict constraints (generally, the client authentication is based on RSA technology which is time and CPU consuming).

- However, message encryption and integrity is performed using symmetric cryptography (for example: AES) which is well suited for IoT objects.

7.2.2.2.2. DTLS

The DTLS **Error! Reference source not found.** protocol provides communications privacy for datagram based networks. It is almost similar to TLS, with important modifications to be compliant with datagram transport.

The TLS cannot be applied directly in datagram environments, reason that packets may be lost or reordered during transmissions. During handshake of TLS, all messages are follows defined order for transmitting and receiving whereas in DTLS it is not. TLS has no built in facilities to handle this kind of unreliability, and therefore TLS implementations are not suitable for datagram transport directly. DTLS uses a simple retransmission timer to handle packet loss. Some design requirements were mentioned from **Error! Reference source not found.**, which are summarized as follows,

1. Datagram Transport

DTLS must be capable of handling complete key negotiation and data transfer over a single datagram channel.

2. Reliable Session Establishment

As DTLS runs entirely over unreliable datagram transport, a reliable key establishing and secure negotiation should be performed. It must implement a retransmission mechanism for ensuring that handshake messages are reliably delivered.

3. Security Services

DTLS must maintain confidentiality and integrity for the data transmitted over it.

DTLS Handshake Protocol

The DTLS handshake is almost similar to TLS with minor adaptations. Because the DTLS handshake operated over datagram transport, it is vulnerable to two denials of service attacks that TLS is not. The first attack is the standard resource consumption attack. The second attack is an amplification attack where the attacker sends a Client Hello message apparently sourced by the victim. The server then sends a Certificate Message - which is much larger to the victim. To mitigate such attacks, DTLS added following changes in its handshake protocol as compared to TLS Handshake,

1. Stateless cookie exchange to prevent denial of service.

2. Reliability maintained by means of modifying the handshake header to handle message loss, reordering, and fragmentation.

3. Retransmission timers to handle message loss.

In DTLS, during transmissions messages may get lost, re ordered or modified. Clearly, this is incompatible with TLS handshake. Messages may larger than any given datagram, thus creating the problem of fragmentation. DTLS provides following fixes for these problems.

Packet Loss

DTLS uses a simple retransmission timer to handle packet loss.

Reordering

In DTLS, a specific sequence number assigned to each handshake message within that handshake. When a peer receives a handshake message, it can quickly determine whether that message is the next message it expects. If it is, then it processes it. If not, it queues it up for future handling once all previous messages have been received.

Fragmentation

Each DTLS handshake message may be fragmented over several DTLS records. Each DTLS handshake message contains both a fragment offset and a fragment length. Thus, a recipient in possession of all bytes of a handshake message can reassemble the original un fragmented message.

DTLS Record Layer

The DTLS record layer is very close TLS 1.1. The only change is the inclusion of an explicit sequence number and Epoch number in the record. This sequence number allows the recipient to correctly verify the DTLS MAC. Epoch numbers are also used by endpoints to determine which cipher state has been used to protect the record payload.

Security Summary

- DTLS includes a cookie exchange designed to protect against denial of service.
- Reliable transmissions are achieved by implementing suitable packet loss handling mechanisms, re ordering techniques.

Using DTLS in constrained objects.

Message encryption and integrity is often performed using symmetric cryptography (for example: AES) which is well suited for IoT objects that does not have huge deployment issue. DTLS is designed to IoT object because it is based on UDP protocol. It is often used to transport COAP protocol.

7.2.2.3. Security at Application Layer

In case the lower layer security is not sufficient and/or cannot be exploited at application level, it could be necessary to implement security at application level. It is particularly the case when, application provider cannot rely on single security environment but has to integrate security implemented by other security providers. The rational can be the cost of the deployment of the security credential, the ease of uses the partner technologies and solutions particularly when the required technology is provided by bug actors of the market (FaceBook, Google,).

7.2.2.3.1. SAML 2.0

SAML **Error! Reference source not found.Error! Reference source not found.** stands for Security Assertion Markup Language and is issued by the OASIS standard in 2005. This is a XML-based framework for federated identity management. SAML is used by many systems like Liberty/Kantara Framework **Error! Reference source not found.** and Microsoft Cardspace **Error! Reference source not found.**.

SAML specification allows token specification as well as exchange protocol. Different usages are specified – each binding correspond to a SAML Profile. The most famous on is the “SAML Web Browser SSO Profile”.

SAML Web Brower SSO Profile. In this Profile, the SAML assertion encompasses the Identity data.

Other profile may expose only an *artifact* that shall be used to retrieve the Identity at the Identity Provider.

SP: the service provider

IdP: the identity provider

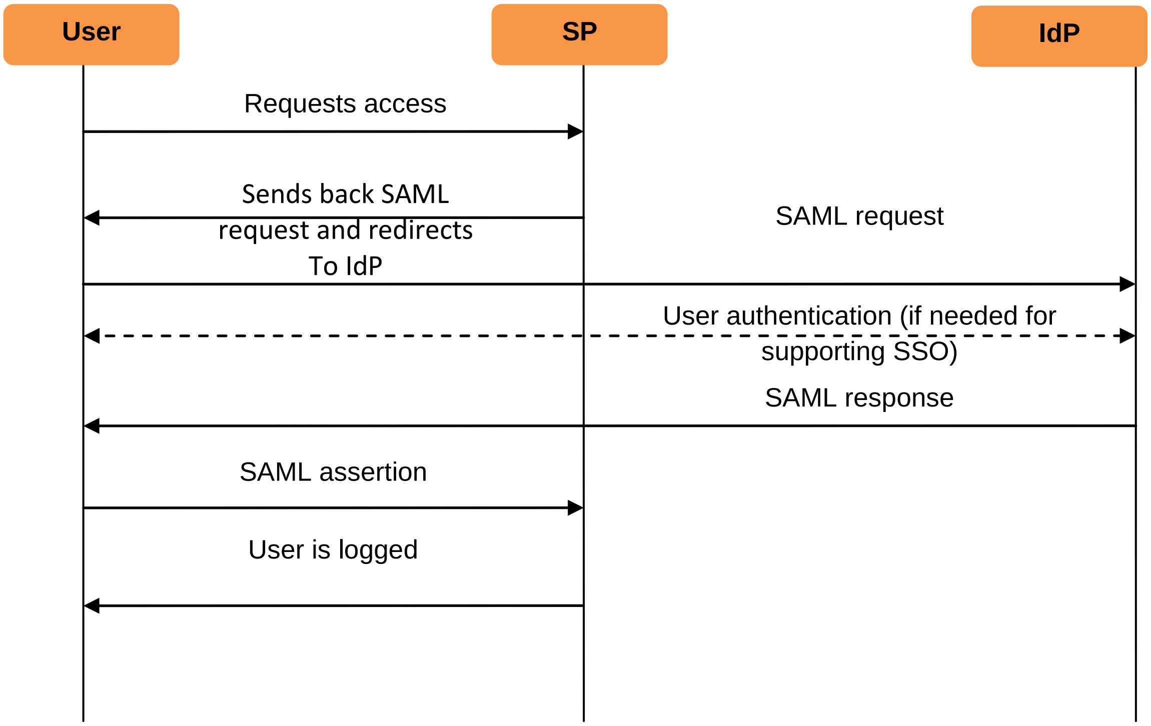
User
SP
IdP
Requests access
Sends back SAML request and redirects To IdP
SAML request
User authentication (if needed for supporting SSO)
SAML response
SAML assertion
User is logged

FIGURE 17. SAML TRANSACTION.

The SAML 2.0 standard is able to support either “identity federation” paradigm or “claim based identity” paradigm. The SAML assertion shall be signed with the private key of the IdP. It contains information about the user according the schema on which it is applied.

Security Summary

Based on standard security schemes :

- **SOAP message security model (security tokens combined with digital signatures)**
- **XML Encryption**
- **XML Signature**

Very often, the “XML Encryption” is not used during the exchanges of information – implementation relies on Secure Transport like SSL/TLS. Nevertheless, if XML Encryption is not used, system shall take care about the security at the user site - the SAML messages will be clear in at the client site, so it could be retrieved by attackers. If Encryption is not used, it is recommended to support at least Signature of the messages.

7.2.2.3.2. OpenID

OpenID **Error! Reference source not found.** is an open standard for distributed authentication. It allows single sign on. Users can select their identity provider of choice and may create accounts in several ones. It allows also secure exchange of user's attributes between OpenID providers. OpenID is a "Token Based Framework" using persistent token.

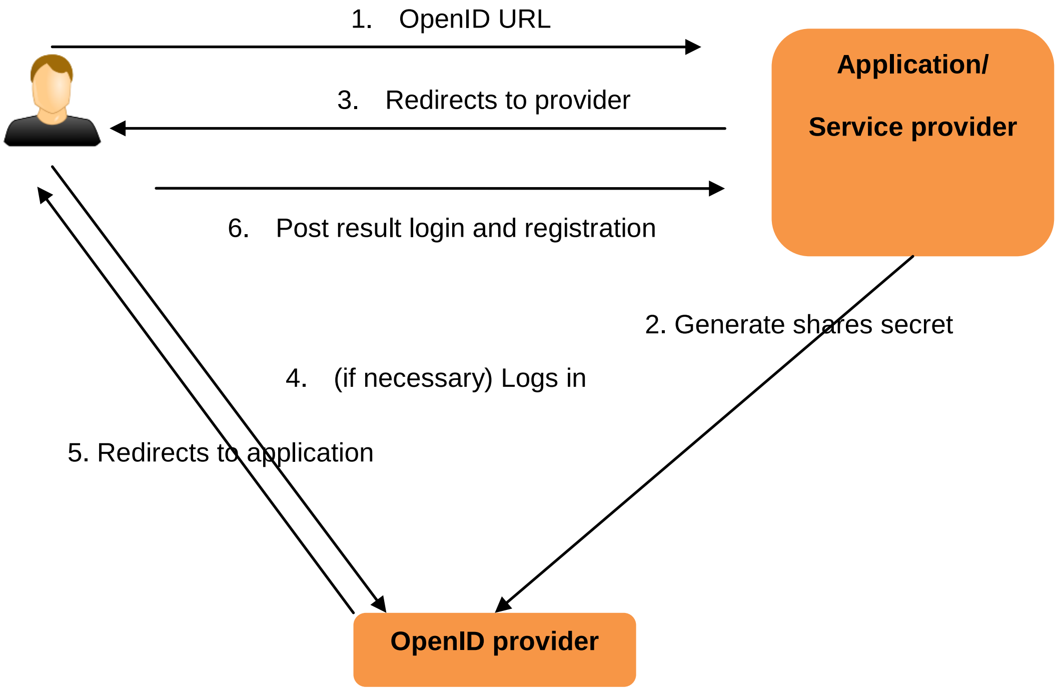
1. OpenID URL
3. Redirects to provider
Application/
Service provider
6. Post result login and registration
2. Generate shares secret
4. (if necessary) Logs in
5. Redirects to application
OpenID provider

FIGURE 18. OPENID OVERVIEW.

The messages are HTTP messages with plain-text keys associated to plain-text values. The message 6. Is signed with the shared secret between the OpenID provider and the application provider (HMAC-SHA1 or HMAC-SHA256).

Security Summary

There several known security issues (phishing, man in the middle, session swapping, replay attacks). Because of its centralized nature the OpenID provider is a very valuable target for the hackers: hacking once allows access to several sites.

7.2.2.3.3. OpenAuth (akaOAuth)

OpenAuth is an open protocol that allows an application to access protected resources from a Resource Provider. It is not really an identity management protocol but used as if by some systems like Google or FaceBook. In this case, the Resource Owner plays the role of Identity Provider.

RO: resource owner, resource server and authorization server (may be 3 separated entities)

APP: application

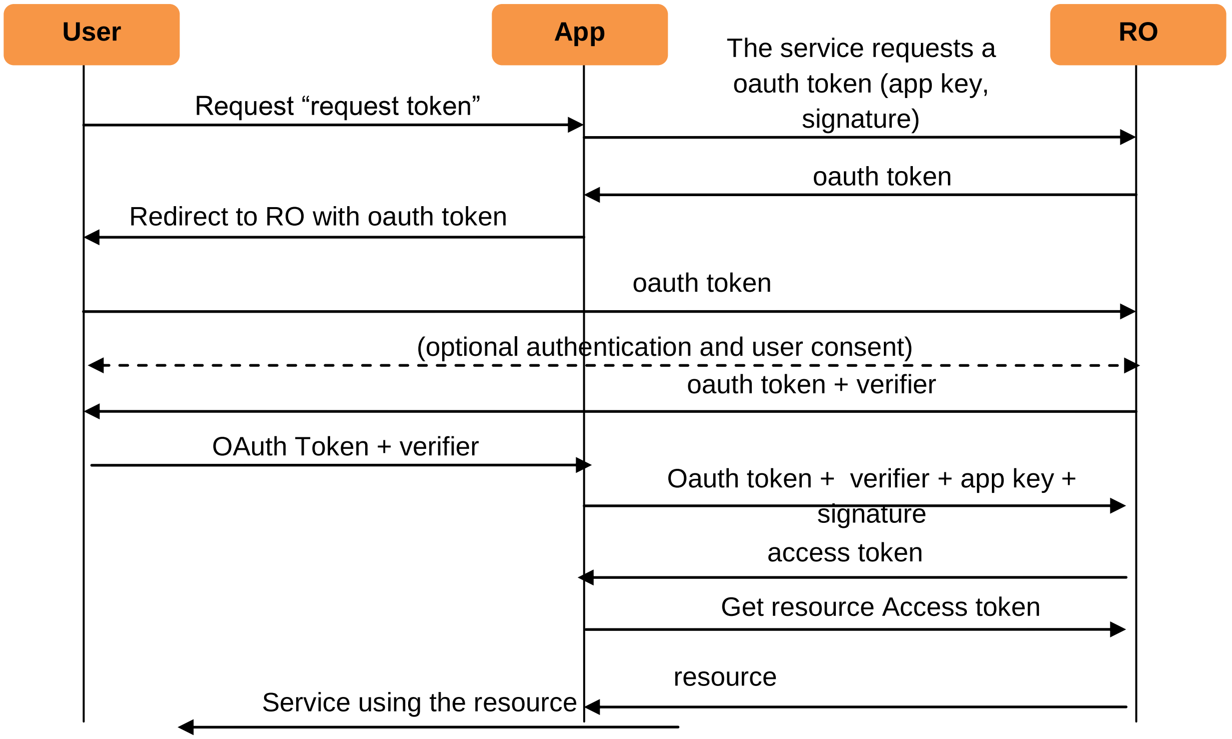
User
App
RO
Request "request token"
The service requests a oauth token (app key, signature)
oauth token
Redirect to RO with oauth token
oauth token
(optional authentication and user consent)
oauth token + verifier
OAuth Token + verifier
Oauth token + verifier + app key + signature
access token
Get resource Access token
resource
Service using the resource

FIGURE 19. OAUTH OVERVIEW.

Security Summary

Used as an identification protocol, the security of this protocol is very weak because one can reuse an access token obtained for a given application to log into another one. Security relies completely on the HTTPS protocol. Nevertheless, OAuth is vulnerable to several known attacks :

- Network eavesdropping
- Cross-site scripting
- Impersonation and session swapping
- Cross-site request forgery

Even OAuth does not strictly specify the format the "access token", it is often related to the resource itself and is not linked to the application that requested the token.

7.2.2.3.4. Generic Bootstrapping Architecture - GBA

GBA **Error! Reference source not found.** standard provides an application free mechanism able to build a shared secret between a user agent (generally running on a mobile phone) and a server. This shared secret enables client-server authentication. GBA relies on 3GPP AKA **Error! Reference source not found.** (Authentication and Key Agreement) used in 3G networks (USIM application), and also used in IMS infrastructure. GBA may also rely on 2G network infrastructure via ISIM application.

The GBA components are the following:

- UE (User Equipment). It is generally the user mobile phone and its SIM card.
- NAF (Network Access Function): the service provider the user would like to reach.
- BSF (Bootstrapping Server Function) : the MNO server is able to build the GBA shared secret between the User Agent and the NAF. The BSF relies to HSS (Home Subscriber System) : MNO server. The server describes the user’s subscription in its home network. It enables to specify, User identities, Registration data and Access parameter

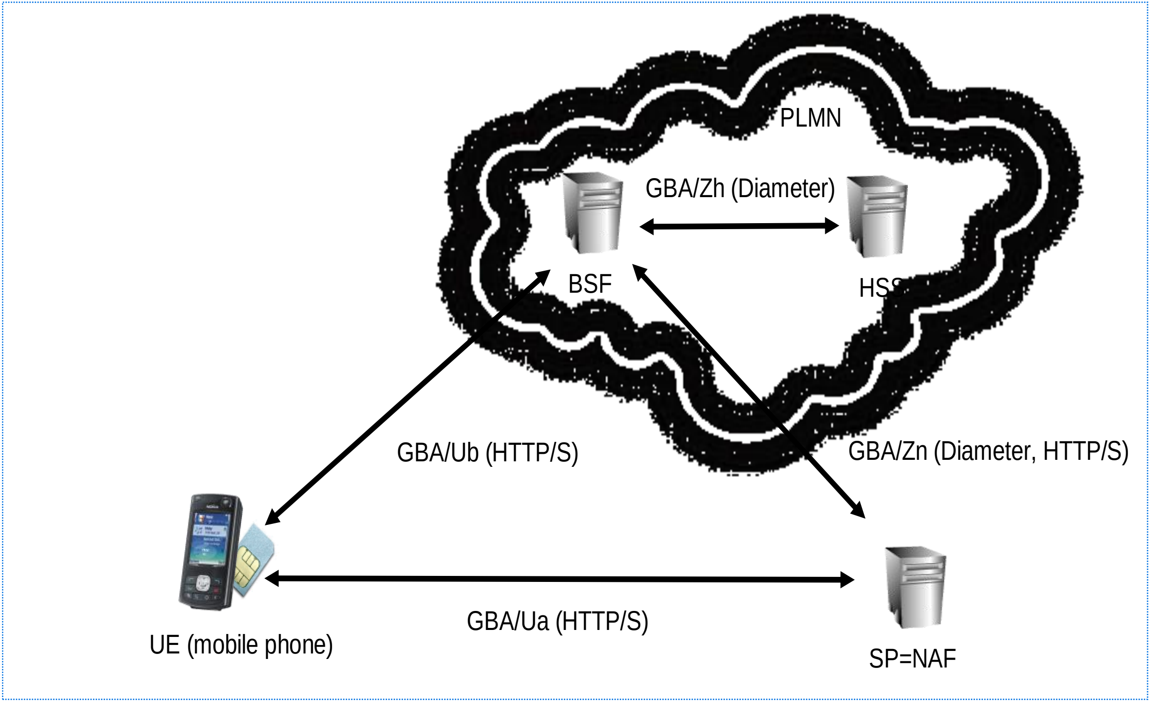

FIGURE 20. GBA ARCHITECTURE.

The User Equipment authenticated to the BSF using AKA protocol. BSF relies on HSS to perform the SIM card authentication. On completion, UE and BSF derive a session key. When the UE wants to reach a NAF, UE via the SIM application derives a new key (computed using NAF identifiers). The NAF requests the UE-NAF key to the BSF and the NAF is now able:

1) to check the UE is a valid one

2) to establish a secure communication with the UE.

Security Summary

Mutual Authentication of Card and BSF

Mutual Authentication of BSF and NAF.

The Card does not authenticates the NAF, but the NAF is able to check the UE is a valid one

NAF-UE Confidentiality: Link Layer can use GBA generated encryption key

NAF-UE Integrity : Link Layer can use GBA generated MAC key

Conclusions

The security and privacy state-of-the-art highlights many difficulties to support security in M2M solutions. The issues concern the deployment of the security credentials on M2M device; the constraints according the CPU and memory required for algorithm implementation and the security of the storage of the credentials at low cost. The easy-of-use of the security protocols for consuming application and according the implementation at the device is one the major problem for enabling security in real deployment of M2M solutions.

SITAC will explore such issues and will propose some solutions.

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