CONTEXT-AWARENESS SYSTEM FOR SMART SERVICES BASED ON SEMANTIC WEB WITHIN IOT

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Abstract - Recently, the number of sensors and actuators embedded in smart objects is increasing rapidly, covering different fields such as smart home, health care, environmental surveillance, etc. Therefore, different devices and protocols are integrated in heterogeneous implementations to provide automatically users by appropriate services, depending on their specific needs or environment ones. The heterogeneity and interoperability problems results by this new generation of platforms encourages researchers to propose new middleware models and solutions to overcome these issues. However, most of these models are not covering most functional requirement and are designed to a specific system layer. In this paper, wehave elaborated a state of art of middleware within the Internet of Things todiscuss our proposed model based on semantic web and context awareness. In this work, we tried to deal the issues cited belowwith the end be applied to any application level. Then we conclude with future work following the same research directions.

Keywords - Internet of things, Middleware, Semantic Web, Ontology, Context-awareness.

I. INTRODUCTION

Internet of Things (Iot) covers all sorts of things connected to the internet such as smart phones, smart alarm clocks, smart thermostat, etc. these things are equipped with sensors and actuators that permit to collect data and share it with different domain application such as smart home, smart building, healthcare, etc. so everything will act in harmony to make everyday life easier. According to Cisco, the number of connected devices will exceed 50 billion by 2020, this will give birth to huge quantity of data that should to be treated and managed to take advantage of it. Consequently, the need of developing a software layer called middleware to fill the gap between the physical and the application layer.

In the recent years, many middlewares have been proposed to overcome the issues cited previously. Each middleware solution focuses on specific domains in Iot such as smart home, healthcare, …. Even though, some solutions address multiple domains, an ideal middleware solution that addresses all domains in the Iot is yet to be designed.

To increase the semantic interoperability within Iotsystem, semantic webtechnologies are integrating in Iot system in recent years. Designing an ontology [1]is getting more and more popular to ease the interoperability among applications, services and platforms and for describing the domain knowledge. The main benefits of using ontologies are[1]: (1) exchanging data among systems, (2) providing interoperability among systems, (3) designing knowledge, (4) sharing knowledge, and (5) simplifying operations.

To design a system that provide a smart services and adapt themselves to rapidly changing situations, we need to use the context-awareness that permit the services to adapt themselves to rapidly changing situations. By context, we refer to any physical or conceptual information about the execution environment of a service.

The remainder of this paper is organized as follows. Section 2 mainly discusses the basics concept used in this article. Section 3 describes the related work. Section 4 we present the components of our proposed model. Finally, in section 5 we give a conclusion and future work.

II. BACKGROUND

A. What is Internet of things?

1) Evolution of the Internet

To understand the important role of the internet of things we must take a look in the history of internet of things in the evolution of the internet. This evolution can be resumed in five phases [2] as presented in figure 1:

- Network: In 1960s, communication between two computers was made possible through a computer network.
- Internet: In 1980s the TCP/IP stack was introduced. Then, commercial use of the Internet started in the late 1980s. Later, the World Wide Web (WWW) became

available in 1991 which made the Internet more popular and stimulate the rapid growth.

- Mobile Internet: Later, mobile devices connected to the Internet and formed the Mobile-Internet.
- Mobile – People - Internet: With the emergence of social networking, users started to become connected together over the Internet.
- Internet of Things: The next step in the IoT is where objects around us will be able to connect to each other (e.g. machine to machine) and communicate via the Internet.

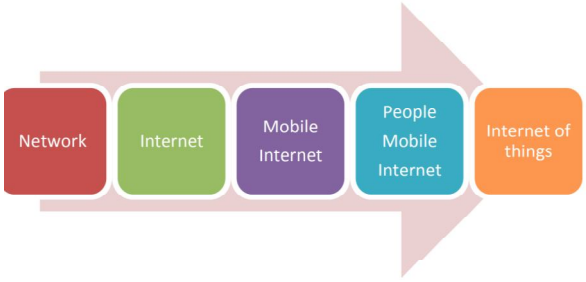


Figure 1: Evolution of the internet

2) What is internet of things?

There isn't a standard definition of the internet of things. Perera[2] in his study has accepted this definition"The Internet of Things allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service.", this last definition is depicted in figure 2.

In May 2015, IEEE published a document that provided an overview of current definitions and concepts used in the domain of Iot. The definition adopted depended on the size of the environment [3] :

For small environment: "a network that connects uniquely identifiable 'Things' to the Internet. The 'Things' have sensing/actuation and potential programmability capabilities. Through the exploitation of unique identification and sensing, information about the 'Thing' can be collected and the state of the 'Thing' can be changed from anywhere, anytime, by anything."

For large environment: "a self-configuring, adaptive, complex network that interconnects 'things' to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The representation contains information including the thing's identity, status, location or any other business, social or privately relevant information. The things offer services, with or without human intervention, through the exploitation of unique identification, data capture and communication, and actuation capability. The service is exploited through the use of intelligent interfaces and is made available anywhere, anytime and for anything taking security into consideration"

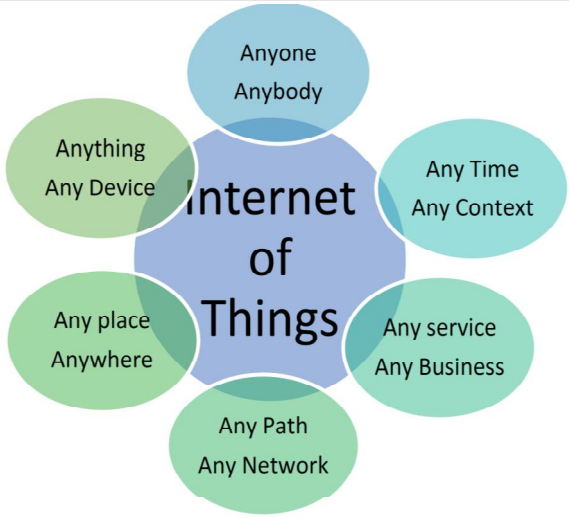


Figure 2: Definition of the Internet of things

3) What is a Middleware

Middleware, as depicted in figure 3, is a software layer that stands between the networked operating system and the application and provides well known reusable solutions to frequently encountered problems like heterogeneity, interoperability, security, dependability [4].

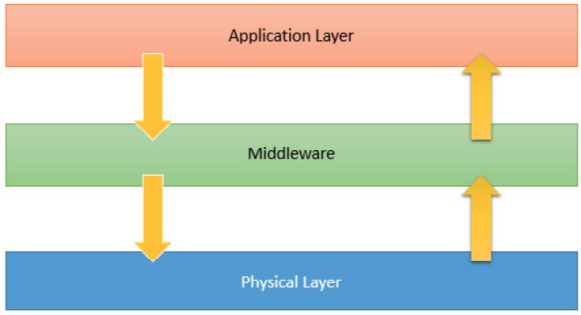


Figure 3: Middleware structure

The internet of things is made up with a huge number of smart things, solutions and services, so the Iot middleware is facing multiple challenge such as Managing limited battery power and resources, Scalability, mobility and dynamic network topology, Heterogeneity,Real world integration, Data Aggregation, Application knowledge, Quality of Service (QoS), Security, Fault tolerance. This challenges are detailed in[5].

There are different architecture designs in middlewares. [6]have specified a list of types of architecture's middleware, the most used of them are :

- Component-based:This type ofarchitecture is based on independent component that are semantically are working together to execute tasks.
- Distributed:Consists of different networked software and hardware components that coordinate their operation to execute tasks.
- Service-based:The components of this architecture offer services to each other a communication protocol.

• Centralized:In this architecture, all services are gathered in a specific location. Application or devices makes requests to use the resource and services.

B. Semantic web and Internet of things

1) Why semantic web?

The goal of the Semantic Web is to give a new form of content that is meaningful and processable by both humans and computers, and things[3].

The use of semantic web technologies [7] in the internet of things increased exponentiallyfrom2010to2015.The most cited and relevant areas are interoperability, data storage, data integration, data abstraction and access, semantic reasoning and interpretation, resource/service search, discovery and scalability.

The two main areas of an Iot system that benefit the most from the integration of semantic technologies are[3]:

• The representation and description of the Thing, its capabilities and environment.

• Semantic annotation of the data that the Thing produces.

2) Semantic ontology

Ontology is defined in[8]: "An ontology is a formal, explicit specification of a shared conceptualization. A conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon." Integrating ontology in middleware ensures the expressiveness, the flexibility and extensibility.

There are four main components that compose an ontology: Classes, relations, attributes and individuals. Classes are the main concepts to describe. Each class can have one or several children, known as subclasses, used to define more specific concepts. Classes and subclasses have attributes that represent their properties and characteristics. Individuals are instances of classes or their properties. Finally, relations are the edges that connect all the presented components[9].

There are already several projects that index ontologies and vocabularies on the Web. One of the most used schemas on the Web is provided by Schema.org and is defined as [3]"a collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet, on Web pages, in email messages, and beyond".

Linked Open Vocabularies(LOV) is an online catalogue provided by Open Knowledge Foundation, LOV facilitates of any kind of vocabularies used for data description on the Web[3].

C. Context Awareness

1) What is Context Awareness system?

The most appropriate definition for context and context awareness system is [10] :

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves

A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.

2) Life Cycle of context

As depicted in figure 3, the context life cycle consists of four steps:

• Context Acquisition: is the first step in a context awareness system it consists of gathering the context from the environment and users. [8]

• Context Modelling: also referred as context representation, is defined as the context representation that provides assistance in the understanding of properties, relationship, and details of context [12].

• Context Reasoning: Context reasoning can be described as the extraction of new knowledge from the available context and extraction of context sets from high level context for better understanding[12].

• Context Dissemination: Context distribution delivers context to consumers[12].

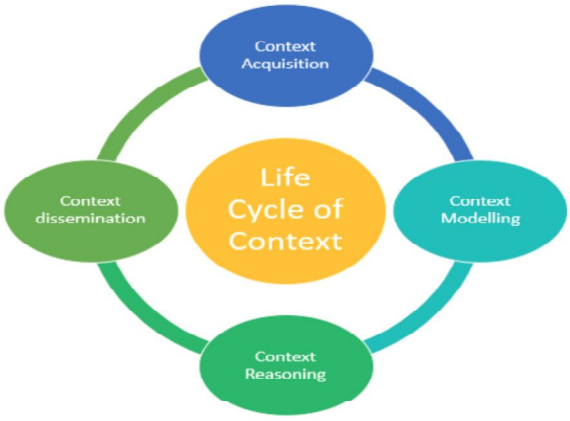


Figure 4: Life cycle of context

III. RELATED WORK

A. Middlewares of the IOT

There are many middleware that have been proposed by researchers within the Iot, Table 1 categorized a list of the well-known middleware's based on their application domains[6], for each middleware we have listed some references for more details.

B. Semantic middlewares

In recent years, the use of semantic web in the design of middleware have increased to overcome some issues within Iot like interoperability. some existing IoT middleware based on semantic web solutions are surveyed for the following.

UbiROAD[13]: is designed for smart traffic environments. This middleware uses semantic web technologies to enable autonomous co-ordination capabilities amongst the devices installed in as smart

traffic infrastructure e.g. discovery, adaptability, and negotiation.
OpenIOT[16] : OpenIoT uses W3C Semantic Sensor Networks (SSN), The OpenIoT middleware issues addressed are data management, service discovery, semantic interoperability.
Ubiware[14]: UBIWARE id designed to deal with distributed resources and heterogeneous services.
Hydra[15]: Hydra is designed for network embedded systems that allow to build ambient intelligence applications based on heterogeneous devices.

There are several ontologies that are developed for internet of things and can be used to build new ontologies and design semantic middlewares. Table 2 describe some existing ontologies regarding the presence of key concepts[16]. The key concepts used in this table are:
Device: constitute the two basic components of an IoT system, composed of both physical and virtual elements.
Sensor: are devices acquiring data system.
Actuator: are the devices that enable the system to act on the physical world.
Energy: In the paradigm of pervasive computing, many distributed Things perform computations. Most of these Things being physical devices, a complete modelling of the system will include a description of their energy consumption. Energy management is a crucial topic in Iot systems

Ontology	Sensor	Actuator	Energy	Device
SSN	√			√
Iot-ontology	√	√		√
OneM2M				√
Iot-O	√	√	√	√
Saref	√	√	√	√
SSA		√	√	√
OWL-Iot-S	√			√
Iot-Lite		√		√

Table 2: Key concept coverage in Iot ontologies

Middleware	Architecture	Main Application	Commercialized	References
Aura	Distributed	Pervasive computing environment	No	[6][17]
ABC&S	Service-based	Car Parking automation	No	[6][18]
Capnet	Distributed	Mobile multimedia applications	No	[6][19]
Carriots	Service-based	Smart city, Smart energy	Yes	[6]
CARISMA	Distributed	Mobile computing	No	[6][2]
GSN	Distributed	Deployment and interconnection of sensor network	No	[6][20][21]
OpenIOT	Service-based	Smart cities and mobile crowd sensing	No	[6][22]
ThingWorx	Service-based	Agriculture, Smart cities and Smart building	Yes	[6]
VIRTUS	Distributed	E-health caring	No	[6][23]
Xively	Service-based	Home appliances connectivity and management	Yes	[6]

Table 1: Well-known middlewares within Iot

C. Context awareness system

In follow some middleware proposed that are onbased context-aware:
MoCa[24] : is a service based distributed middleware,This middleware employs ontologies to model and mange context.
COSMOS[25] : this middleware enables the processing of context information in ubiquitous environments. it consists of three layers: context collector (collects information from the sensors), context processing (obtain high level information from raw sensor data), and context adaptation (provides access to the processed context for the applications).
SOCAM[25]: is ontology based middleware. It uses ontology-based method for both context modeling and context reasoning.
Hydra[2]:Hydra comprises a Context Aware Framework (CAF).CAF consists of two main components: Data Acquisition Component responsible for connecting and retrieving data from sensors and the Context Manager is responsiblefor contextmanagement,contextawareness, and context interpretation

IV. OUR PROPOSED MODEL

In this section, we present our proposed model based on semantic web and context awareness. This model is designed to be applicable in any IoT domain.

A. Functional requirements
In order to design the architecture of our proposed model, we start by defining thefunctional requirements which must be provided by the system.
Our model is based on the functional requirement used to design CA4IOT [26] :

- Ability to protect users' data.
- Ability to manage problems of overload.
- Ability to ensure the continuity of service.
- Ability to connect sensors to the IOT middleware.
- Ability to understand and maintain context information
- Ability to understand user requirement / request / problem.
- Ability to understand to fill the gap between high-level user requirement and low-level sensor capabilities.
- Ability to understand high-level context information using low-level raw sensor data.
- Ability to manage users.

B. Layered Architecture

As shown in figure 5, the proposed architecture consists of three layers: Communication Layer, Controllers Layer and Decisional Layer. However, there are two external layers that interact with the whole system: User Layer and Sensor Layer.

The following describes roles, functionalities and components of each layer as well asits interactions starting from low-level sensors to high-level applications.

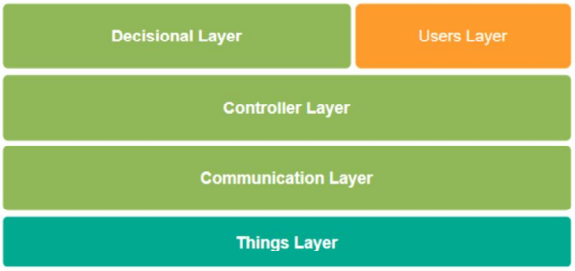


Figure 5: Layers of our proposed model

1. Things Layer
As specified in the introduction, this layer is an external layer which represents all software and hardware sensors embedded in the environment.

2. User Layer
Like Things Layer, this layer is not in the core of our system, it represents human users, applications or services interacting with the system.

3. Communication Layer
This layer is responsible for communication with thingsinstalled in Things Layer, it permitsretrieving and sending data from/to things. It should deal with the heterogeneity of communication protocol(BLE, WIFI, etc…). To do so, we can use the middleware MSOAH-IoT[5] that is designed to overcome the heterogeneity issues within the IOT, this middleware is based on Service Oriented Architecture.

4. Decisional Layer
This layer contains two components: Storage and Decision:

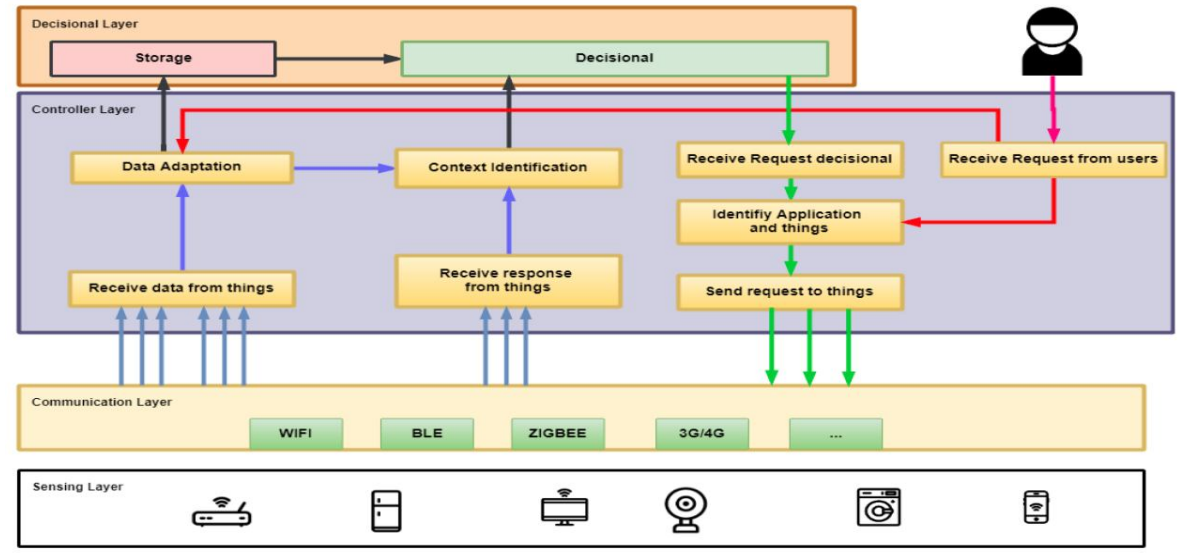


Figure 6 : Interaction between components of our proposed model

- Storage: This component is responsible for the storage of the data collected from things installed in Sensing Layer and the actions triggered by users. This data will be used by the component decision to make the perfect reactions at the perfect time.
- Decision: This component is the brain of our system, it uses the data stored to make decisions, for example: an old man is used to open a door at 7 o'clock, if he doesn't do that one day in that time, some actions must be triggered like checking if this man is in home or check his health (breath, heart rate, …).

5. Controller Layer
This layer contains many components: Receive data from things, data Adaptation, Context Identification, Receive Request from decisional, Identify Application and things, send request to things, receive response from things, Receive request from users.
The interaction among these components is showed in figure 5.

- **Receive data from things:** This component receives the data from communication layer. It must always be ready to accept data sent from things. The most appropriate technology to implement this component is Web Service.
- **Data Adaptation**: This component is responsible for modelling and preparing the data received from thingsthrough the component "Receive Data from Things". The data processed will be sent to decisional layer for storage and a copy will be sent to the Context Identification component. The most appropriate technology for modelling data is semantic web.
- **Context Identification**: This component must measure the importance degree of the data after modelling and must make decision if it must be sent to decisional component or not to permit quick decision. For example: if this component receives 50° in temperature in the kitchen, this information must be sent to decisional layer to make the appropriate decisions like launch an alarm or call the urgency.
- **Receive Request from decisional**: This component listens and receives requests from decisional Layer. For example: The decisional layer can request for the position or state of health of a user to make decision.
- **Identify Application and things**: The role of this component is to identify the list of applications and things that can be used to answer the request received from decisional layer. For example: if the decisional Layer ask for the position of a user in home, this component identify for example which lights and chairs to ask to detect the position.

- **Send request to things**: After the identification of the list of things, this component is responsible to send instructions to carry out.
- **Receive response from things**:The communication layer collects the response from things to send it to decisional layer.
- **Receive request from users**:This component isresponsible for retrieving each task executed by users.

V. CONCLUSION

In this article, we started by presenting some concepts about the internet of things, semantic web and context awareness. After that, we surveyed some middlewares proposed by researchers and finally we have presented the layers and components of our proposed model that will be based on semantic web technologies and context awareness to provide automatically services to users.

In future work, we are going to implement our proposed model and we will apply it in the smart home specifically for Ambient Assisted Living. AAL aims to improve the quality of life for older people, this interest is due to the total number of elderly people is growing more rapidly compared to other age groups.

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