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Comparative study of IoT protocols

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***Abstract*—Internet of thing, or Connected Objects (IOT) is considering a modern concept. A few years ago, the IoT has invaded our professional and personal life revolutionizing the near future. Indeed, the goal is to create an environment composed of intelligent devices and systems which can communicate with each other through computer networks. These data exchanges allow better decision-making in an increasingly complex context. The success of the Internet depends on the widespread adoption of clearly defined protocols. It represents a common language to all connected systems, regardless of brand, operating system or software tools used. In the absence of such a common language, the Internet would be reduced to a patchwork of proprietary and incompatible networks. This research analyses some of the major evolving and enabling protocols in the IoT. Particularly, it focuses on Layer Network and applications Protocols. Our study evaluates their capabilities and compares their main characteristics and behaviors in terms of various criteria of these protocols. The comparison presented in this paper would benefit researchers and developers in selecting an appropriate protocol for the IoT applications. In This paper we aim to provide first a complete overview of the IoT architecture, then the different protocols. In addition, we present a comparative of application and network layer protocols.**

Keywords— Internet of Things; IOT architecture; IoT applications; IoT protocols

I. Introduction

The Concept of the internet of objects appeared in the 90s, it is poised to become one of the future challenges and opens up prospects for technological and scientific developments [1]. Today, the Internet of Objects is mainly used in domains such as home automation. This is the extension of the Internet to physical objects which are not primarily intended to be connected to it. Therefore, embedded systems and smart sensors fall into this category and participate in the development of IoT. IoT's benefits are multiple, both from the point of view of civil users and companies such gain in efficiency, savings, reliability. The importance of this domain causes a rapid evolution of the technologies, and an integration on very varied and diversified supports. The concept of "objects" aims at posing no limit as to the feasible possibilities of implementing technological tools in everyday elements. The Internet of Things is a set of tools and technologies that should be considered in every level and aspect of a connected object, modeled as a separate system. Since the Internet of Things is a set of tools and technologies, it is necessary to take into account each level and aspect of a connected object, modeled as a system in its own right [2]. The remainder of this document is organized as follows: Section II presents the different layers of the Internet of things architecture Section III, presents the different protocols that are used in the IoTs domain. In Section IV we expose the related work. Next in Section V we detail a comparative study of the protocols of the application and network layers. We conclude study Section VI.

II. IoT Architecture

The internet of things gives solutions based on the integration of information technology, which refers to hardware and software used in storing, retrieving, and processing data and communications technology which includes electronic systems used for communicating between individuals or groups. The fast convergence of information and communications technology is built on three layers of technology innovation: the cloud, data and communication pipes/networks and device [3].

More than 25 Billion things are expected to be connected by 2020 which is a huge. So, the rapid evolution of connected objects needs adaptable and flexible architectures with different type and scope of application. There is no single consensus on IoT architecture, which is universally adopted. Different architectures have been proposed by different researchers [4]. The ever-increasing number of proposed architectures has not yet converged to a reference model [5]. We present an improved layered architecture of Internet of Things, as a survey. It summarizes the current development of IoT architectures in various domains systematically in Fig.1 [6], the internet of things layered architecture is illustrated as supposed by the ITU-T (International Telecommunications Union - Telecommunication Standardization Sector) and is composed of four layers; the top or first layer is the IOT application layer which contains the application user interface, the second layer is the services and application support layer, the third layer is the network layer which contains the networking and transport capabilities, the bottom layer is the device layer, which contains the gateways and the hardware and sensors and RFID tags and others. Along the four layers, the security and management capabilities and functions are distributed [7].

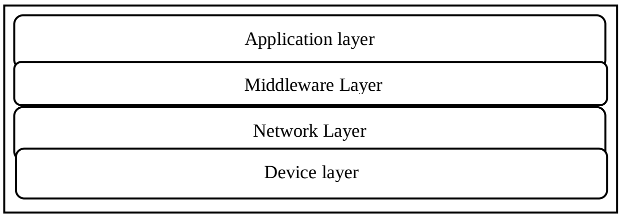

Fig1. IoT Architecture

III. IoT Protocols

Many IoT standards are proposed to facilitate and simplify application programmers' and service providers' jobs. Different groups have been created to provide protocols in support of the IoT including efforts led by the World Wide Web Consortium(W3C), Internet Engineering Task Force (IETF), EPCglobal, Institute of Electrical and Electronics Engineers (IEEE) and the European Telecommunications Standards Institute (ETSI) [8]. Protocols are competing to become the main choice for connected objects, but for each application, the most appropriate protocol will be different. This point will often make the difference between the functional prototype and the optimal solution. For example, the wireless communication technology that you will use must exactly match its use. When looking at existing wireless technologies, the choice is not obvious, because each technology has its own advantages and disadvantages. Thus, they have emerged new protocols with characteristics adapted to the needs of connected objects: low power consumption, large range, low throughput, ease of implementation, etc. According to us research we have realized the classification of almost all the protocol depending on the main layer of IoT architecture.

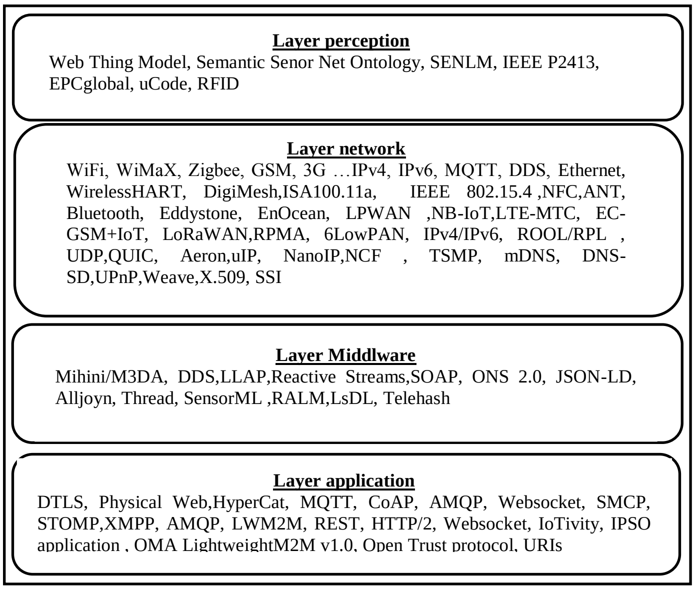

Fig.2. Protocols IoT

IV. The Related work

At the beginning, the researchers focused on the development of connected objects, after they discovered that the success of the Internet is based on the widespread adoption of protocols.So IoT Protocols has been widely investigated in recent years. the work presented by Mahmoud Elkhodr [9] makes a comparison of some protocols networks. Its main objective is to analyses some of the major evolving and enabling wireless technologies in the IoT. Particularly, it focuses on ZigBee, 6LoWPAN, Bluetooth Low Energy, LoRa, and the different versions of Wi-Fi including the recent IEEE 802.11ah protocol. The studies evaluate the capabilities and behaviors of these protocols regarding various metrics including the data range and rate, network size, RF Channels and Bandwidth, and power consumption. Moreover, the purpose of the comparative study done in [10], is to valuate and compare four communication protocols, namely, CoAP, MQTT, XMPP, and WebSocket.in order to measure their response time by varying the traffic load. In paper [11], the researchers present protocols that are utilized to connect the things but also end-user applications to the Internet. they they just highlight and compare CoAP, MQTT, Web socket among others, this comparative study based on four criteria. these previous studies are not yet complete and does not provide an advanced study of the Iot protocols that will allow the developers to choose the right protocols for such an Iot application. There are several criteria that need to be discussed and will allow the evaluation of a protocol.

V. Comparative Study

the choice of protocol for the internet of things is very important and difficult, although there are as many protocol based on the same concepts, but each with its own characteristic, advantage and disadvantage, and there are not applicable in all application of IoT. Then, at the implementation level, each protocol proposes its own practice. The application IoTs has characteristics that can be used to choose the protocol to follow during of its realization. Among the points of the success of an application IoT, it depends on the correct choice of protocol. the research question that guided this study was, which protocol choose for which application IoT it? this question led to another question that is what are the different IoT applications? the application is different from one to another and developers team when they need to use a protocol, they must study all the existing protocol. That is why we effect an in-depth study of it. In order to facilitate thorough knowledge of the most used protocols.

V.1 Layer Network Protocols

V.1.1 Criteria of comparison

A network protocol is a set of communication rules and procedures used on both sides by all stations that exchange data over the network. There are many network protocols, but they do not all have the same role or the same way of doing things. Some network protocols operate at the level of several layers of IoT architecture, others may be specialized in performing a task corresponding to a single one. So, for this study, we cited the maximum criteria that gives us a general view on the method such as Specification, Network type, Topology, Power, Data Rate, Modulation, Technique, Pread Spectrum Range, Security, Cost, Risk of data, collision, Max node count, Energy needed, Market Adoption, Application, Spreading, Network size.

V.1.2 Comparison Study

the first time we introduce all protocol in our table of comparative study the Bluetooth LE, Z-Wave, ZigBee, NFC, HomePlug GP and Wi-Fi protocols, which corresponds to the IoT network Protocols.

TABLE I. NETWORK PROTOCOLS

Protocol / Critères	Wifi	Bluetooth	LoRa	Zigbee	Z-Wave	Cellulaire	NFC	Sigfox	Neul	6LowPan
Specification	Based on 802.11n	Bluetooth 4.2 core specification	LoRaWAN	ZigBee 3.0 based on IEEE802.15.4	Z-Wave Alliance ZAD12837 / ITU-T G.995	GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G)	ISO/IEC 18000-3	Sigfox	neul	IPv6 over IEEE802.15.4
Network type	LAN WPAN/P2P	LAN	LAN	LAN	LAN	MAN	P2P	LPWAN	WAN	LAN
Topology	Star	Star	Star & Star of Star	Mesh,Star,Tree	Mesh	Mesh	Mesh	Star	Mesh	Mesh,Star
Power	Low-High	Low	Very Low	Very Low	Very Low	High	Very Low	Low	Low	Very Low
Data Rate	Up to 1.3Gbps	2.1Gbps	0.3Gbps to 100 kbps	250 Gbps	40 Gbps	Up to 1Gbps	424 kbits /s	10-1000bps	Few bps up to 100kbp	200 Gbps
Frequency band	54 Mb/s	2.4 G Hz	Various	868/915 M Hz, 2.4 G Hz	900MHz (ISM)	850/900; 1800/1900 MHz	13.56 MHz	900MHz	900MHz (ISM), 458MHz (UK), 470-790MHz (White Space)	2.4 GHz
Modulation Technique	BPSK, QPSK, OFDM, M-QAM	GFSK, CPFSK, 8-DPSK, π/4-DQPSK	**GFSK**	BPSK, O-QPSK	BFSK, GFSK	GMSK, 8PSK	ASK	UNB LTN	-	O-QPSK o Min LIFS Period
Spread Spectrum	MC-DSSS, CCK, OFDM	FHSS	Chirp	DSSS	DSSS	TDMA, DSSS	FHSS	PBSS	FHSS	CSS
Range	Up to 100m	<100m	3-5km urban area	10-20m	30km	Where signal reach	5cm	30-50km	10km	10-20m
Security	WPA and WPA2	Shared secret	Per-device AES128 keys, AES128 secret key	CBC-MAC (ext. of CCM)	Data encryption	-	-	-	-	SNMP
Cost	Low	Low	Low	good	Effective	Less and vice versa	Chip	relatively low	-	Hight
Risk of data collision	low	High	-	Medium	-	-	-	-	-	-
Energy needed	-	High	-	Medium	-	-	-	-	-	-
Market Adoption	Yes	yes	Yes	yes	Yes	yes	yes	yes	yes	Yes
Application	Any device with cellular connectivity	Network for data exchange headset	Smart city, sensor networks, industrial automation application	Senor networks Industrial automation	Residential lighting & automation	Use in wifi,ADSL,broad basnd ,digital TV&Radio	Payment Transactions, Business Transactions, Contextual Information,	Smart Grid	home automation	Senor networks Industrial automation
Network size	Medium	Small	Medium large	Very large	Large	Very large	Small	Medium	Medium	Very large

V.1.3 Discussion

The success of the Internet is based on the widespread adoption of clearly defined protocols adopted at each layer of the IOT architecture. Each dedicated to either a particular application or a specific user group. In the absence of universal protocols and standards, the development of the Internet of objects will be arrayed. As shown in the comparison table each protocol has benefits and inconveniences. Different data network protocols were discussed to present their main differences and usage in IoT. Generally, the most widely used standards in IoT are Bluetooth and ZigBee, on the other hand, they are the easiest to be used due to the existing and widely separated infrastructure of Wifi which is the most used infrastructure in other wireless applications. Newly arising LoRaWAN seems to be promising for such applications as well. The comparison is a detailed description of the protocols most used for IoT, we mention the different characteristics of each protocol, which will make it possible to choose the specific protocols for type application Iot.

V.2 Protocols application

V.2.1 Criteria of comparison

According to Gartner reports in 2020, more than 25 billion connected devices will be used. As many devices connected to the Internet increase exponentially. the use of communication protocols (application layer protocols) and the selection of communication protocols plays a crucial role in the Internet of objects (IoT). These protocols allow these devices / things to communicate with other things, also they are the ones that will ensure the transfer of data specific to the application that we wish to deploy across the network in a very short period of time and also safely. So, for this study, we cited the maximum criteria that gives us a general view on the method of the use of this protocol such as Technologies, Transport, Architecture, Aptitude, Calculate resources, Application, Security and QoS, Quality factor.

V.2.2 Comparative Study

the following comparative study provides an overview of the main differences between the application layer protocols, such as CoAP, XMPP, RESTful HTTP, MQTT, Web Socket, AMQP, DDS.

5.2.3 Discussion

In this table, we compare existing IoT application layer protocols that are utilized to connect the things but also user applications to the Internet. Each IoT application protocol has its own certain Advantages and Disadvantages. As already mentioned, the selection of application protocol is completely depending on the application. we begin with Transport Criteria Among them, we have identified CoAP and DNS as the only that runs over UDP, thus making it the most lightweight. the other protocols use TCP. Publish/Subscribe architecture that it used by WebSocket, AMQP and DDS is more suitable for the IoT than request/response of CoAP and RESTful HTTP, the other protocols mentioned use both types of architecture. the protocols that provide security and QoS are CoAP, RESTful HTTP, AMQT, MQTT.

CoAP provides authentication, data integrity, confidentiality, automatic key management, and cryptographic algorithms [11], through the use of the DLTP protocol that is proposed to secure CoAP transactions is the Datagram Transport Layer Security (DTLS). DTLS runs on top of UDP and is the analogous of TLS for the TCP. Thus, it ensures reliability by integrating its own mechanisms.

In IoT market, the two protocols MQTT and CoAP are emerging as leading lightweight messaging protocols in IoT market. MQTT is the preferred protocol for sending some piece of information constantly. CoAP is the preferred protocol if document transfer is required.

TABLE II. APPLICATION PROTOCOLS

	CoAP	**XMPP**	**RESTful HTTP**	**MQTT**	**WebSocket**	**AMQP**	**DDS**
Standard	IETF	IETF	REST	OASIS IBMs	HTML 5s	O ASIS	OMG DDS
Technologie	XML	XML	XML, HTML, JS ON	Irrespective of implementation language	XML JSON	Irrespective of implementation language	C, C ++, C #, Java, Scala, Lua, Pharo and Ruby
Transport	UDP	TCP	TCP	TCP	TCP	TCP	TCP /UDP
Architecture	response request	Publish / Subscribe Request / Response	response request	Publish/ Subscribe Request / Response	publish subscribe	Pub/Sub	Pub/Sub
2G, 3G, 4G Adequacy (noeuds 1000s)	Excellent	Excellent	Excellent	Excellent	-	Excellent	-
Aptitude LLN (noeuds 1000s)	Excellent	Just	Just	Just	-	-	-
Calculate resources	10Ks RAM / Flash	10Ks RAM / Flash	10Ks RAM / Flash	10Ks RAM / Flash	-	-	-
Application	Utility Area Networks	Remote management of consumer products	Smart Energy Profile 2 (basic energy management, home services)	Extending Enterprise Messaging to IoT Applications	Real-time application: Real-time dashboards, Teamwork	Hybrid applications:the integration of computer systems following a merger.	Distributed applications
Security and QoS	Both	Security	Both	Both	Security	Both	QoS
Quality factor	Reliability Authentication, Integrity, Confidentiality	Efficiency, Reusability	-	Reliability	Reliability	Efficiency, Elexibility, Interoperability.	Excellent quality of service levels Reliability, security, Urgency priority, Durability, reliability, flexibility, and performance
Advantages	•Multicast support •Low overhead •Minimizing complexity of mapping with HTTP •Communication models flexibility •Low latency	•Real-time •Low latency •Easily understandable •Easly extensible •Any XMPP server may be isolated	•Application is easy to maintain • No client state management on the server •No client state management on the server	•Easy to implement •Useful for connections with remote location •Small code footprint •Lightweight •Asymmetric client - server relationship	•Simplifies the web communication and co – network compatibility •Connection management	•Complex message queuing implementations •ISO standard •High routing reliability and security •Easly extensible •Symmetric client-server relationship	•Real-time monitoring of quality of service, •Decentralized architecture, •Dynamic detection of broadcasters and subscribers
Disadvantages	•Doesn't enable communication level security •Few existing libraries and solution support	•Heavy data overhead •Not suitable for embedded IoT applications	The need for the customer to locally store all data needed to conduct a query	•No error-handling •Hard to add extensions •Basic message queuing implementations •Doesn't address connection security	•Specific hardware requirements •No useful open source implementations targeted at embedded systems	•Bigger packet size than other protocols. •Doesn't support Last Value Queue (LVQ)	-

VI. CONCLUSION

To sum up, in this paper we have presented common layer of IoT architecture of all proposed modules. then we have classified Iot protocols by these layers. Next, we have presented and compared the most representative application and network layer protocols that have gained attention for IoT. As we already mentioned the previous works does not provide an advanced study of the Iot protocols that will allow the developers to choose the right protocols depending on a specific Iot application. There are several criteria that need to be discussed and will allow the evaluation of a protocol. To overcome this lack, this comparative study is to have a thorough knowledge of network and application protocols. In our next works we will extend our study in order to propose a test model of Iot Protocols.

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