The Internet of Things (IoT) Applications and Communication Enabling Technology Standards: An Overview

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The Internet of Things (IoT) Applications and Communication Enabling Technology Standards: An Overview

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Abstract — **The Internet of Things (IoT) is the most promising area which penetrates the advantages of Wireless Sensor and Actuator Networks (WSAN) and Pervasive Computing domains. Different applications of IoT have been developed and researchers of IoT well identified the opportunities, problems, challenges and the technology standards used in IoT such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. This paper is of two fold; the first fold covers the different applications that adopted smart technologies so far. The second fold of this paper presents the overview of the sensors and its standards.**

Keywords: IoT, Sensors, Actuator Networks, RFID

I. INTRODUCTION

Internet of Things (IoT) is a new revolution of the Internet. It makes Objects themselves recognizable, obtain intelligence, communicate information about themselves and they can access information that has been aggregated by other things. 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 as shown in Fig. 1. This implies addressing elements such as Convergence, Content, Collections, Computing, Communication, and Connectivity.

The Internet of Things provides interaction among the real/physical and the digital/virtual worlds. The physical entities have digital counterparts and virtual representation and things become context aware and they can sense, communicate, interact, exchange data, information and knowledge. Through the use of intelligent decision-making algorithms in software applications, appropriate rapid responses can be given to physical entity based on the very latest information collected about physical entities and consideration of patterns in the historical data, either for the same entity or for similar entities. These paves new dimension of IoT concept in the domains such as supply chain management, transportation and logistics, aerospace, and automotive, smart environments (homes, buildings, infrastructure), energy, defence, agriculture, retail and more.

The vision of IoT is to use smart technologies to connect things any-time, any-place *for anything.* The IoT was started in the year 1998 and the term *Internet of Things* was first coined by Kevin Ashton in 1999.

Fig. 1 Internet of Things

The Internet of Things has been evolved in a tremendous way over the past decade and still IoT is an emerging trend for researchers in both academia and industry. Many findings of IoT reported in literature presents meaningful definitions. According to CASAGRAS project [1]: "A global network infrastructure linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object identification, sensor and connection capability as the basis for the development of independent cooperative services and applications. CERP [2], emphasizes the internetworking between heterogeneous 'smart' devices such as sensors, actuators, computers and smart phones etc., and the use of services over the internet. Any application development framework for the IoT, therefore, needs to support these heterogeneous devices.

According to the *IEEE Internet of Things* journal, An IoT system is a network of networks where, typically, a massive number of objects/things/sensors/devices are connected through communications and information infrastructure to provide value-added services via intelligent data processing and management for different applications. The Internet of Things (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. The term is closely identified with RFID as the method of communication, although it could also include other sensor technologies, other wireless technologies, QR codes, etc. According to The Internet of Things European Research Cluster (IERC) definition [3] states that IoT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities,

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physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.

This paper presents the survey which gives a picture of the current state of the art on the IoT. More specifically, it provides clear insight to readers about the different visions of the Internet of Things paradigm and illustrates the benefits of this paradigm in everyday-life. This also provides the application domains of IoT and IT enabled communication technologies and standards used so far.

The paper is organized as follows. Section 2 describes the application domains of IoT paradigm, which are available from the literature. Section 3 covers the IoT main enabling communication technologies used so far. Section 4 describes the challenges and issues of IoT and finally the paper is concluded in Section 5.

II. APPLICATION DOMAINS

The Applications of the IoT are numerous and diversified in all areas of every-day life of people which broadly covers society, industries, and environment. All the IoT applications developed so far comes under these three broad areas as shown in Table 1. According to Internet of Things Strategic Research Agenda (SRA) during 2010, 6 or more application domains were identified that are smart energy, smart health, smart buildings, smart transport, smart living and smart cities. According to the survey that the IoT-I project ran during 2010 65 IoT application scenarios were identified and grouped in to 14 domains, which are Transportation, Smart Home, Smart City, Lifestyle, Retail, Agriculture, Smart Factory, Supply chain, Emergency, Health care, User interaction, Culture and tourism, Environment and Energy. Some of the IoT applications are briefly explained in next coming paragraphs.

Table 1. IoT Application Domains

Domain	Description	Applications
Society	Activities related to the betterment and development of society, cities and people	Smart Cities, Smart Animal Farming, Smart Agriculture, Healthcare, Domestic and Home automation, Independent Living, Telecommunications, Energy, Defense, Medical technology, Ticketing, Smart Buildings
Environ-ment	Activities related to the protection, monitoring and development of all natural resources	Smart Environment, Smart Metering, Smart Water Recycling, Disaster Alerting
Industry	Activities related to financial, commercial transactions between companies, organizations and other entities	Retail, Logistics, Supply Chain Management Automotive, Industrial Control, Aerospace and Aviation

A. Smart Cities

The IoT play a vital role to improve the smartness of cities includes many applications to monitoring of parking spaces availability in the city, monitoring of vibrations and material conditions in buildings and bridges, sound monitoring in sensitive areas of cities, monitoring of vehicles and pedestrian levels, intelligent and weather adaptive lighting in street lights, detection of waste containers levels and trash collections, smart roads, intelligent highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams. Some of IoT smart cities applications are smart parking, structural health, noise urban maps, traffic congestion, smart lightning, waste management, intelligent transportation systems and smart building. These smart cities IoT applications use RFID, Wireless Sensor Network and Single sensors as IoT elements and the bandwidth of these applications ranges from small to large. The already developed IoT applications reported on the literature are Awarehome[4], Smart Santander [5] and city sense [6].

B. Smart Agriculture and Smart water

The IoT can help to improve and strengthen the agriculture work by monitoring soil moisture and trunk diameter in vineyards to control and maintain the amount of vitamins in agricultural products, control micro climate conditions to maximize the production of fruits and vegetables and its quality, study of weather conditions in fields to forecast ice information, rail, drought, snow or wind changes, control of humidity and temperature level to prevent fungus and other microbial contaminants. The role of IoT in water management includes study of water suitability in rivers and the sea for agriculture and drinkable use, detection of liquid presence outside tanks and pressure variations along pipes and monitoring of water level variations in rivers, dams and reservoirs. This kind of IoT applications use Wireless sensor network and single sensors as IoT elements and the bandwidth range as medium. The already reported IoT applications in this kind are SiSviA[7], GBROOS[8] and SEMAT[9].

C. Retail and Logistics

Implementing the IoT in Retail/Supply Chain Management has many advantages which include monitoring of storage conditions along the supply chain and product tracking for traceability purposes and payment processing based on location or activity duration for public transport, gyms, theme park, etc. In the shop itself, IoT offers many applications like guidance in the shop according to a preselected shopping list, fast payment solutions like automatically check-out using biometrics, detection of potential allergen in a given product and control of rotation of products in shelves and warehouses to automate restocking processes. The IoT elements used in this kind of application are RFID and WSN and the bandwidth range is small. The example retail IoT reported in literature is SAP future retail center [10]. The IoT in logistics includes quality of shipment conditions, item location, storage incompatibility detection, fleet tracking, etc. The IoT elements used in the field of logistics are RFID, WSN and single sensors and the bandwidth ranges from medium to large. Many logistics IoT trial implementations are reported in the literature [11, 12].

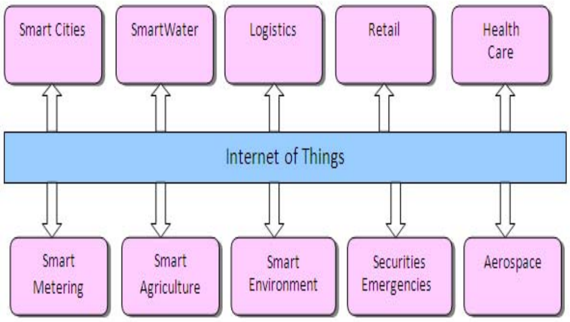

Fig.2 The IoT Application Domains

D. Health Care

Many benefits provided by the IoT technologies to the healthcare domain are classified into tracking of objects, staff and patients, identification and authentication of people, automatic data collection and sensing [13]. Tracking is the function used to identify a person or an object in motion. This includes the case of patient flow monitoring to improve workflow in hospitals. The identification and authentication includes patient identification to reduce incidents harmful to patients, comprehensive and current electronic medical record maintenance, and infant identification in hospitals to prevent mismatching. The automatic data collection and transfer is mostly aimed at reducing form processing time, process automation, automated care and procedure auditing, and medical inventory management. Sensor devices enable function centered on patients, and in particular on diagnosing patient conditions, providing real-time information on patient health indicators. Application domains include different telemedicine solutions, monitoring patient compliance with medication regiment prescriptions, and alerting for patient well-being. In this capacity, sensors can be applied both in in-patient and out-patient care. The elements of IoT in Health Care are RFID, NFC, WSN, WiFi, Bluetooth, etc. significantly improve the measurement and monitoring methods of vital functions such as temperature, blood pressure, heart rate, cholesterol level, blood glucose, etc.

E. Security & Emergencies

The IoT technologies in the field of security and emergencies are tremendously increased in which few are listed; perimeter access control, liquid presence, radiation levels and explosive and hazardous gases, etc. The perimeter access control is used to detect and control the unauthorized people entry to restricted areas. The liquid presence is used for liquid detection in data centers, warehouses and sensitive building grounds to prevent break downs and corrosion. The radiation levels application used to measure the radiation levels in nuclear power stations surroundings to generate leakage alerts and the final IoT application is used to detect the gas levels and leakages in industrial environments, surroundings of chemical factories and inside mines.

III. IoT COMMUNICATION TECHNOLOGIES

The communication enabling technologies of IoT heavily depends on rapid technical innovation in 4 fields; technology used to connect everyday objects and devices to large databases and networks, technology used for data collection with ability to detect changes in the physical status of objects, technology to take action through embedded intelligence in objects, and finally to make smaller and smaller things will have the ability to interact and connect. The combination of all these developments made the effective and efficient communications on IoT applications.

A. RFID

RFID is not new and it was popular in the early 20th century. Initially, it was based on radio waves and later radio waves combined with radar signals. They can be used to provide P2P connection between objects. RFID consists of three main components such as a transponder or tag to carry data, which is located on the object to be identified, an interrogator or reader, which reads the transmitted data, and Middleware, which forward the data to another system, such as a database, a PC or robot control system. Frequencies currently used for data transmission by RFID typically include 125 kHz (low frequency), 13.56 MHz (high frequency), or 800-960 MHz (ultra high frequency). RFID is set to revolutionize the retail sector. By 2008, according to IDTechEx, retailers worldwide are expected to account for over USD 1.3 billion of a global RFID market of USD 7 billion. RFID standards relate both to frequency protocols (for data communication) and data format (for data storage on the tag) [14]. Some of IoT applications reported in literature using RFID includes smart shopping [15], smart chips [16], arts and gaming [17], smart environment [18], RFID combats criminal activities in graveyards and sanctuaries [19], thwart baby abduction [20], smart waste management [21] and health care [22].

B. Sensors

Sensors are one of the key building blocks of the Internet of Things which can be deployed everywhere from military battlefields to vineyards. A sensor is an electronic device, which detects senses or measures physical stimuli and responds to it in a specific way. It converts signals from stimuli into an analogue or digital form, so that the raw data about detected parameters are readable by machines and humans. Sensors can also be implanted under human skin, in a purse or on a dress. Some can be as small as four millimeters in size, but the data they collect can be received hundreds of miles away. Sensors complement human senses and have become indispensable in a large number of industries, from health care to construction. Sensors have the key advantage that they can anticipate human needs based on information collected about their context. Common applications of sensors include military, environment, healthcare, construction, commercial applications, home applications, etc.

When a sensor forms part of a sensor network, it is known as a sensor "node". While it is now easy to deploy single sensors, ensuring connectivity between multiple nodes is a more challenging task. Sensor nodes can be connected to each other in two ways: wire and wireless. A sensor node in a wireless sensor network is a small low-power device with power-supply, data storage, microprocessors, low-power radio, analogue-to-digital converters (ADCs), data transceivers, and controllers. Wireless sensor networks offer solutions for a number of sectors, such as health care, security, and agriculture.

C. RFID and Sensors

The progressive combination of communication technologies and microelectronics gradually removes boundaries between physical objects and the virtual networked world. The main function of an RFID tag is to identify and track what, which and where the object accurately. Sensor technology provides information about the external environment and circumstances surrounding an object. The integration of wireless sensing technologies with RFID tags on moving objects provides a fuller picture about their location and status. The main distinguishing feature of an RFID sensor tag from a normal RFID tag is that, apart from tracking and monitoring functions, sensor-enabled RFID can take action on the basis of data collected by the sensor. These two technologies, in combination with modern wireless networks, create opportunities for a myriad of applications in national security, military field, agriculture, medicine, retail, food industry and many other sectors of the economy.

D. Sensors and Mobile Phones

Mobile phones are already an integral part of everyday life for many people. Due to their widespread use, mobile networks play a key role in bringing new "ubiquitous" communication technologies to the masses. Today, mobile phones are not only a device for making calls, but it equipped with data, text and video streaming functions. Currently, the combination of sensors with mobile phones offers several possible applications such as device for relaying data collected by sensors, touch sensors, movement recognition, sensing the status of their environment through smell sensors, etc.

E. Near Field Communication

Near field communication (NFC) is a set of standards for smart phones and similar mobile devices to establish communication with each other by touching them together or bringing them together no more than a few inches. NFC devices can be used in contactless payment systems, similar to those currently used in credit cards and electronic ticket smartcards, and allow mobile payment to replace or supplement these systems. The mobile OS Android Beam uses NFC to complete the steps of enabling, pairing and establishing a Bluetooth connection when doing a file transfer [23].

F. ZigBee

ZigBee is a specification standard for a suite of high level communication protocols used to create personal area networks built from small, low-power digital radios. ZigBee is based on an IEEE 802.15 standard. Though low-powered, ZigBee devices often transmit data over longer distances by passing data through intermediate devices to reach more distant ones, creating a mesh network. They can used in applications that require a low data rate, long battery life, and secure networking.

The table 2 summarizes and compares all communication technology standards reported in the literature with respect to network, topology, power consumption, speed, range and where these technology standards used. Table 3 provides with the communication frequency for Wi-Fi and Table 4 Provides with details of communication parameters for NFC and Bluetooth.

Table 2. Technology Standards

	RFID	NFC	Wi-Fi	ZigBee	Blue tooth	WSN
Network	PAN	PAN	LAN	LAN	PAN	LAN
Topology	P2P	P2P	star	Mesh, star, tree	star	Mesh, star
Power	Very low	Very low	Low - high	Very low	low	Very low
speed	400 kbs	400 kbs	11-10 Mbs	250 kbs	700 kbs	250 kbs
Range (in meters)	<3	<0.1	4-20 m	10-[illegible]00 m	<30 m	200 m

Table 3 WiFi Standards and Frequency Range

Aspect	Standard IEEE	Frequency
WiFi Wireless Fidelity	802.11	Channel Number 1 - 14 2401- 2473 MHz – Lower Frequency 2412- 2484 MHz –Middle Frequency 2423- 2495 MHz – Upper Frequency
White-Fi	802.11af	470 - 710MHz
Microwave Wi-Fi	802.11ad	57.0 - 64.0 GHz ISM band (Regional variations apply) Channels: 58,32, 60.48, 62.64, and 64.80 GHz
ZigBee	802.11	-

Table 4. NFC and Bluetooth Parameters

Aspect	**NFC**	**Bluetooth**
RFID compatible	ISO 18000-3	active
Standardisation body	ISO/IEC	Bluetooth SIG
Network Standard	ISO 13157 etc.	IEEE 802.15.1
Network Type	Point-to-point	WPAN
Range	< 0.2 m	~100 m (class 1)
Frequency	13.56 MHz	2.4–2.5 GHz
Bit rate	424 kbit/s	2.1 Mbit/s

IV. CHALLENGES AND ISSUES OF IoT

Although the IoT enabling technologies have tremendously increased in the past decade, there are many issues to be open and addressed. Thus this paves the new way or dimension for researchers involved in IoT. The issues and challenges of IoT include architecture, privacy and security, data intelligence, Quality of Service, communication protocols, GIS based visualization, etc.

A. Architecture

The different architectures proposed already in the literature roughly based on which application domain the IoT used. Most of the works relating to IoT have been classified in to four types of architectures ; the wireless sensor networks perspective [24], European Union projects of SENSEI [25], Internet of Things Architecture (IoT-A) [26] and cloud architecture [27] . However, these may not be the best option for every application domain particularly for defense where human intelligence is relied upon. The selection of architecture of IoT itself is the big challenge and this paves the way to develop new architecture and modify the existing architecture.

B Privacy and security

Security will be a major concern, wherever network consists of many devices or things are connected. There are many ways the system could be attacked; disabling the network availability, pushing erroneous data into the network, and accessing personal information. It is impossible to impose proper privacy and security mechanism with current already existing techniques [28, 29]. Thus privacy becomes a major concern and need to incorporate appropriate security measures.

C. Data Intelligence

There are huge volumes of data will be collected from connected from network of devices. According to a rough estimate, more than 2.5 trillion bytes of new data every day will be logged by these systems [30]. Analysis of data and its context will play a key role and poses significant challenges. The data collected through IoT devices to be stored and used intelligently for smart IoT applications. These leads to develop artificial intelligence algorithms, and machine learning methods based on evolutionary algorithms, genetic algorithms, neural networks, and other artificial intelligence techniques are necessary to achieve automated decision making.

D. Quality of Service (QoS)

The QoS of IoT applications is measured from the primary factors such as throughput and bandwidth. It is easy to provide QoS gurantees in wireless sensor networks due to resource allocation and management ability constraints in shared wireless media. Quality of Service in Cloud computing is another major research area which will require more and more attention as the data and tools become available on clouds. This leads to develop a controlled, optimal approach to serve different network traffics and better resource allocation and management [31].

E. Communication Protocols

The protocols for communication of things or devices will play a key role in complete realization of IoT applications. The protocols form the backbone for the data tunnel between sensors and the outer world. Many MAC protocols have been proposed for various domains with TDMA, CSMA and FDMA for collision free, low traffic efficiency and collision free but require additional circuitry in nodes respectively [32]. Internet Protocol Version 6 (IPv6) is the latest protocol which vastly increases the number of internet addresses, and the ability to process and analyze huge volumes of data. This IPv6 would be able to communicate with devices attached to virtually all human-made objects because of the extremely large address space (128 bit). Major goals of the transport layer are to guarantee end-to-end reliability and to perform end-to-end congestion control. In this aspect, many protocols may fails to co-operate proper end- to –end reliability.

F. GIS based Visualization

Visual communication is very much useful and understandable for any kind of people who works in and uses IoT applications. With emerging 3D displays, this area is certainly open more research and development opportunities. The data communicated by things or devices are not always ready for use to visualize. It requires further processing to make ready the data to be visualized. The data like heterogeneous spatial-temporal data [33] needs powerful techniques to do processing before visualization came into picture. New visualization schemes for the representation of heterogeneous sensors in a 3D landscape that varies temporally have to be developed [34].

V. CONCLUSION

The IoT has the capacity to be a transformative force, positively impacting the lives of millions worldwide, says Bingmei Wu, Deputy Secretary-General of the China Communications Standards Association. Not only this is the view of Chinese Government, all countries have been started and allotted more funding to carry out researches in the field of IoT in all these about said issues and challenges. Many research teams have been initiated from all over the world to carry out IoT related researches. All thier aims to add a new dimension to this process by enabling communications with and among smart objects, thus leading to the vision of ‘‘anytime, anywhere, anymedia, anything” communications. To keep this objective in mind, we carefully surveyed the most important aspects of IoT, the various applications of IoT, and the communication enabled technologies or IoT elements which are used in IoT applications. The last part of this paper also highlighted the issues and challenges related to IoT and guide the researchers on future research directions which are penetrated in IoT field.

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