A Review of IoT Models

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Abstract

IoT is seen almost everywhere and the choices are numerous. At the same time if we want to think of an ecosystem the goal should be such that independent IoT models can be taken under one umbrella. Various models can communicate with each other, that should be the goal of an IoT model. Any new IoT model should be able to attach itself with an existing model so that the ultimate purpose of advancement of IoT, which is to connect everything, can be made possible. Communication protocols play an important role in the area of IoT. These communication protocols may vary with respect to the application area and domain. This survey discusses a variety of IoT Models and their approach for the implementation. The paper discusses the differences between the models and proposes the scope of scalability and interoperability in the various Iot models. Analysis of those models with the target of finding the factors stopping IoT models to communicate with each other is presented then there is a discussion presented for scope of scalability and interoperability in the existing models.

Keywords

Internet of Things (IoT), Architecture, Scalability, Interoperability.

1. Introduction

IoT is getting more limelight because the main goal of using IoT is to resolve the existing issues of connectivity, minimize the operating cost and sometimes fast action taken on the particular situation such as medical, farming, transportation, industry, fitness, home automation, smart city etc. In doing so, various implementations of IoT are laid out. Some are implemented and many are proposed. For example nowadays the concept of smart city is acknowledged highly and IoT has a key role in fulfilling the concept of smart city. There are various models of IoT that are acting at multiple applications such as transport management, security and surveillance management, day-to-day facility management, medical requirement management and so on. If these models are not able to communicate with each other then there will be a huge dependency on manual intervention for taking day-to-day decisions as well as critical decisions. To deal with such requirements, a model of technologies termed as ecosystem is getting the attraction. An ecosystem is like an umbrella which consists of various technical pillars provided to support the various technical requirements and since all the pillars are under one umbrella they can communicate with each other. Communication between these various models is smooth and requires very less manual intervention. It is evident that all the models in an ecosystem must have a standardization to make the meaning of ecosystem successful. This standardization enhances the interoperability between different models. This is one of the examples where we can see the importance of intra-model communication is highly important, similarly there can be a number of scenarios where we need this kind of support.

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To establish communication between two or more than two devices, there should be a compatibility of technologies between them. In the current scenario when the technology is changing dynamically due to multiple players in the market, interoperability becomes a significant challenge for all. In practice where a variety of platforms, networks, programming languages, syntactic and semantic varieties are present, it becomes challenging to come to one common standard. In this paper we have analyzed various approaches to handle these challenges based on various criteria. Issues related to interoperability are addressed by many researchers. This paper is an attempt to analyse the available methodologies and techniques used for handling interoperability and identifying major issues in having a generic model of IoT to resolve interoperability issues.

2. Related Work

Various studies and research work related to interoperability and IoT models and patterns are evaluated under this study and their highlights are presented in this paper. With the increasing role of IoT, huge attempts have been made and various models are presented to tackle interoperability issues. In one of the major studies done by Jonggwan et al [1], two famous platforms- oneM2M and FIWARE were introduced. These two platforms are popular and widely used in smart city projects. The oneM2M and FIWARE provides functionalities and a platform for IoT devices and is an ecosystem in themselves. There is no mechanism available to establish communication between them and a separate mechanism is required to make the communication possible. So a well designed architecture is developed which translates the conversation between these platforms in their respective terminologies.

A different architecture based on BlockChain is proposed by Hong-Ning Dai et al [2] also termed as BCoT. It is suggested that using BlockChain technology, interoperability can be enhanced. BlockChain data is distributed among IoT devices, cloud servers and edge servers [3,4,5]. The author [6] has pointed out that the diversity among the technologies may be because of their nature of handling MAC and Physical layers, variety of bands at which they work, the size of data supported for transmission, various communication protocols at application layer, variety of error correction mechanisms and variation in security handling.Some other methods of handling security is presented in [33, 34] using semantics at sensor level and time-stamping for authentication. One of the recent studies [7] points out that IoT models also require regular rigorous testing for continuous improvement so automated testing tools are required. Basically using these testing tools, these models can be tested against the interoperability level by validating the standards they follow. The paper suggests conformance testing to find out the level of standardization followed in an application.

In this study, few IoT models were analyzed to understand the generic pattern of IoT models. One such model is given in [8] in which the author has discussed a smart railway management system. Manual management is definitely time consuming, resource consuming and costly. To solve these complexities, an IoT model is proposed in which the railway structure is categorized into 3 parts (1. Buildings, 2. Railway tracks and facility 3. Signaling and Communication technologies). A conditional based maintenance system, also known as CBM [26, 27] is proposed which basically activates and takes decisions on the basis of an event. Some other studies related to smart railways are givenin [12,13].In [6], an IoT model to study air quality in the Indo gangetic plains due to crop burning and other factors such as Diwali, etc is presented. Related IoT models with respect to air quality are presented in [14, 15, 16, 17, 18]. In the field of electrical grid, IoT can play a crucial role and this application is called smart grid [10]. Some other IoT models in the area of smart grid are presented in [19, 20, 21, 22]. Iot models are also available in the field of tracking such as parking status tracking or tracking of any movable object or person. One such example is presented in [11]. Some other tracking models are presented in [23,24,25]. In the next section detailed discussion and analysis is presented of the reviewed IoT models classified on various parameters laid out in this study. These set of parameters are:

1. *Variety of IoT Models:* Four generic categories are selected- transportation, air quality, electrical grid, tracking.
2. *Approach to Implement IoT Models:* The approach for implementing an IoT model for various models are extracted and analyzed.

3. *Factors stopping IoT models to communicate with each other:* This parameter highlights factors which are hindrance for interoperability with respect to individual models.
4. *Scope of Scalability and Interoperability:* Individual models for the scope of scalability and interoperability are reviewed.

3. Analysis of existing IoT models

In this section detailed discussion of IoT models based on the criteria as figured out in section 2 is presented, i.e. below mentioned criteria is presented. These criteria's are (a) Variety of IoT models, (b) Approach to implement IoT models, (c) Factors stopping IoT models to communicate with each other and (d). Scope of scalability and interoperability in the existing models

3.1. Variety of IoT Models

For our study, four categories of IoT application areas are selected such as transportation, air quality, electrical grid, and tracking. Though in this work various authors are available in the selected domains, the few latest and the selected ones are presented in Table 1.

Table 1
Area specific IoT models

Area	Sub Area	Author
Transportation	Smart Railway	Ohyun Jo et al. [8]
	Railway monitoring	Pengyu Li et al. [12]
	Railway track defect detection	NooraAlNaimi et al. [13]
Air Quality	Air quality sensing and reporting	Rohan Kumar Jha [14]
	Air quality monitor	Liaoyuan Zeng et al. [15]
	Air quality monitoring system	Ajitesh Kumar et al. [16]
	ML based air pollution control	Sharafat Ali et al. [17]
	Air pollution monitoring system	Swati Dhingra et al. [18]
Electric Grid	Smart Grid	Markel Iglesias et al. [10]
	Power grid condition monitoring	Tianxin Zhuang et al. [19]
	Smart grid	Yuke Li et al. [20]
	Real time demand response in smart grid	Ashish Kumar Sultania et al. [21]
	Smart grid decision support tool	Md. Rabiul Islam et al. [22]
Tracking	Parking status and dog tracking	Yi-Bing Lin et al. [11]
	Real time object tracking	AnisKoubaa et al. [23]
	Real time laptop tracking	NiritDatta et al. [24]
	Container tracking near coastline	SrikanthKavuri et al. [25]

3.2.Approach to Implement IoT Models

In this section, IoT models are observed for their architecture and design. Most of the traditional methods of maintenance in rail transportations are routine maintenance which involves huge cost and resources and does not provide any great value in case of any issues in between the routines. So Condition-based maintenance also known as CBM based techniques are getting popular [26, 27]. General CBM based techniques again goes through a procedure such as Inspection, analysis, prioritization, budgeting and execution. In this process most of the resources are exhausted up to inspection and less remains for repair which seems wrong in some sense so some enhancement is proposed in [8]. Enhancement towards more on repair work and reducing the manual intervention is proposed in [8, 9, 10]. IoT devices are installed and data is captured in various forms and the decision is taken after processing the data. As we can see in Table 2, models vary from each other mostly in terms of technology such as LTE, LoRa, GSM and some are generic as they focus on data analytics

[13]. In Table 2, basic architecture preferred in the models and key technology used is listed. Basic architecture is similar but the choice of sensors varies depending on the application.

Similarly, there are a number of IoT models available in the area of air quality [9] – [18]. Some of the models are listed in Table 3 with the observation of their basic architecture and preferred technology. Again basic architecture is followed and the variations among the models are at the sensor level, network technology and database.

Due to licensed bands and licensed free bands, the technologies vary as per the application, as smart grids are one of the mission critical applications [20] and to incorporate QOS, licensed bands are preferred. Aim of a smart grid is to distribute power equally. Basic architecture and key technology used for smart grids are listed in Table 4. Differences are at the communication level between sensors and gateway and between gateway and server and cloud application and database.

Table 5, lists the Tacking based IoT models. Differences among models are application areas like for drones we use ROS which is a Robot Operating System while non drone tracking models don't use ROS. Also variation can be found at the deployment of models in real time because depending on the requirement it varies. Like in the case of real time object monitoring using drones, we need to set up the drones manually. Cloud servers have multiple roles, like storage, interaction with the devices, analytics of data etc.

Cost efficient IoT Models are in trend and that's why too high variation in technology is seen.

Table 2

Railway maintenance IoT models

Author	**Proposal**	**Architecture**	**Technology**
Ohyun Jo et al. [8]	Enhanced CBM	Device Platform (Sensors) -> Gateway ->IoT Network -> Platform Server	LTE, LoRa, NB-IoT
Pengyu Li et al. [12]	Maintenance Free CBM	Sensors -> Readers -> GSM Communicat-ion system -> control center (Data hub)	GSM
NooraAlNaimi et al. [13]	Railway track fault detection	Camera -> Local Image processor -> Cloud Server	ML

Table 3

Air Quality based IoT Models

Author	**Proposal**	**Architecture**	**Technology**
Rohan Kumar Jha [14]	Air Quality Reporting	Sensors -> Controller -> Cloud Server	WiFi, Arduino Uno
Liaoyuan Zeng et al. [15]	Air Quality Monitor	Sensors -> Controller -> Cloud Server	Pycom, LoRaWAN,TTN Cloud server
Ajitesh Kumar et al. [16]	Air Quality Monitoring System	Sensors -> Controller -> Storage	Thing Speak Cloud storage.
Sharafat Ali et al. [17]	Low Cost Air Quality Monitor with ML based calibration	Sensors -> Controller -> Cloud Storage	LoRaWAN, WiFi,
Swati Dhingra et al. [18]	Air Pollution Monitoring	Sensor -> Processor -> Cloud Storage	Ubidots as Cloud Service

Table 4
Smart Grid based IoT Models

Author	Proposal	Architecture	Technology
Tianxin Zhuang et al. [19]	Insulation Condition Monitoring	Sensors -> Controller -> Server	NB-IoT, LoRa
Yuke Li et al. [20]	Grid monitoring	Not provided	NB-IoT
Ashish Kumar Sultania et al. [21]	Real Time Response Grid	Smart plug/ Demand Response Controller -> NB-IoT Network -> Cloud Server	NB-IoT, Z-Wave, Raspberry Pi
Md. Rabiul Islam et al. [22]	Decision Support Tool for Distributed Energy Sources and Electric Vehicles	Sensor/Meter -> Gateway/ZigBee -> Central Controller/Server	ZigBee, MQTT

Variation in cloud storage selection is observed among models. Use of Machine Learning for variation of results is in study. Different scenarios such as mobile, remote, vast busy, wave, air, static, mobility conditions are observed for variation in technology. Also due to power management, the architecture may vary. Sensors also vary depending on their power consumption and other factors. Further study can be also organized in terms of life of the sensors and scalability of architecture. Controllers are also replaced with term gateway in terms of their functionality and location of uses. Most of the models have the same objective and strive for more precision, better sensitivity etc. It is observed that all the IoT models follow the layered IOT architecture, which is sensor layer, networking layer and application layer.

Table 5
Tracking based IoT Models

Author	Proposal	Architecture	Technology
Yi-Bing Lin et al. [11]	NB-IoT Talk Device Tracker	Sensor -> Gateway ->DataBase	MQTT, NB-IoT
AnisKoubaa et al. [23]	Real Time Object Tracking using Drones	Dones -> Gateway -> Cloud Services	ROS, MAV Link Communication protocol,
NiritDatta et al. [24]	Real time Motion sensor and Alert System	Sensor -> Gateway -> Cloud Server	STM32 Microcontroller, GSM
SrikanthKavuri et al. [25]	Container Tracking Near the Shore Vessel	Sensors -> Base Station -> Server	NB-IoT

3.3. Factors stopping IoT models to communicate with each other

In this study, in the area of railway maintenance, it is found that the architecture design has some variations at the middle layer. Some models have data processing near to the sensor level and some perform these activities at the cloud level. Overall, the architecture follows the standard IoT architecture which is represented in figure 1. Depending on the model it is observed that choice of sensor varies depending upon the model. In conditional based monitoring systems for trains various types of sensor such as wireless sensors, constant powered sensors are basic differences. Due to these basic differences it is obvious that there will be some changes in the architecture at the intermediate levels. In the case of Air Quality based IoT models it is observed that most of the models are using LoRaWAN which is understandable due to the properties of LoRaWAN. At the same time the choice of cloud services also differs. Due to these choices the communication level and behavior between sensors and gateway and between gateway and server varies. Another difference is the cloud application.

Major difference observed while observing smart grid based models is the licensed and free band as a result technological preference changes. At the same time NB-IoT is found as the preferred choice for smart grid applications. Other basic differences are choice of cloud services, protocols for data delivery. Similarly for tracking based IoT Models, NB-IoT is observed as the preferred choice and at the same time choice of operating system, communication protocols and sensors is largely varied.

3.4. Scope of scalability and interoperability in the existing models

The basic architecture of any IoT model remains unchanged which is Sensor - Gateway - Database. Choice of sensor varies largely as per the requirement such as simple sensors, smart sensors [28, 32]. The variations in communication model between Sensor - Gateway and Gateway - Cloud are huge. Among the observed models NB-IoT and LoRaWAN are found preferred choices. Similarly for communication protocols, MQTT and CoAP [29] are found popular choices rather than HTTP- Rest, SOAP Web Services [30]. This behavior leads to standardization of IoT models and can be tested for other scenarios so that these models can be scaled and become interoperable.

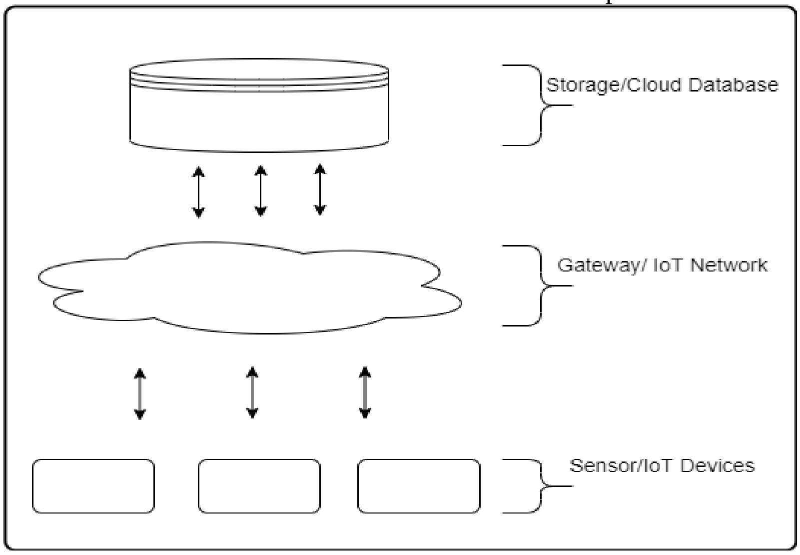

Figure 1: Standard IoT Architecture

4. Conclusion and future work

Various IoT Models under four categories are observed in this study and their analysis on specific criteria is presented. All the IoT models are studied from the point of view of their architectural model and technological preferences. During this study the approach to develop these models is observed and possible scope of scalability and interoperability is presented for the considered models. The observations of different models are carried out among four categories of IoT application as transport, air quality, electric grid and tracking. To analyze the models under these categories, two specific criteria were focused which is the basic architecture of the model and technology used.

Majority of IoT models follow basic IoT architecture which is Sensor - Gateway - Database. It is observed that having common architecture does not provide scalability of the models and interoperability among them. Scalability issue is mainly because of the application area since the IoT application area is very huge and keeps changing. Even in the area of transportation, it is very difficult to scale the existing application from railway to any other transportation field. In terms of Interoperability observed devices can't be interoperable due to reasons such as different protocols used for communication, variety of cloud storage and services available and due to security issues. It leads us to standardization of IoT protocolsat various level of IoT model.

In this study we have some preferred technologies which can make the standardization of IoT models somehow possible. These technologies are LoRaWAN, NB-IoT [31], CoAP [29], MQTT. In future we will try to build up a standardize IoT model that uses the preferred technologies as pointed out in this paper.

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