# The Internet of Things Model Architectures for Customized Applications: A Review

Kavitha B. C. [1], Vallikannu R.[2]

*Department of Electrical and Computer Engineering*
Hindustan Institute of Technology and Science, Chennai, India.
kavithabc@gmail.com [1], abiuma2008@gmail.com [2]

***Abstract*** **- The world is moving towards autonomous systems and hence all systems need an intelligent feedback control mechanism to achieve their potential for various applications. IoT is one of the leading technologies that can transform the current trends which will shape the future of industry and business in the coming years. As seen since 2017 IoT has converged with Block-chain technology which is used to track and coordinate billions of smart objects, facilitating transparency of transactions and providing better security and privacy by using efficient cryptographic algorithms. Different technologies are utilized to connect the different parts of IoT to the sensors which includes: Ethernet, Bluetooth, Wi-Fi, Wi-Max, Long Term Evolution (LTE) and the latest technology of Li-Fi. Interoperability and standardization of IoT devices and protocols are key challenging issues which deter the end users to select consumables of their choice and choose service providers based on their area and requirements. However, numerous problems and challenges raised by IoT need more attention in order for impending benefits to be comprehended. IoT has the potential to enhance customer relationships and boost the growth of business by improving quality, productivity and reliability while reducing costs, risk and accidents. This paper provides an overview of IoT and its architecture and applications, such as fully automated smart industries, smart cars and home security.**

***Keywords - IoT, Sensors, Architecture, Big data analytics, Cloud computing, Automation.***

## I. INTRODUCTION

The Internet of Things (IoT) refers to an evolution in technology where the “things” have the potential to interact among themselves with minimal or without human intervention. This has paved the way to real-time sensing, monitoring, predictive and automated decision making. There is an exponential increase in the number of devices that are connected to the Internet which results in an enormous increase in the need to send/ receive, aggregate & analyze the data and to respond to events. The true beauty of the IoT lies in the fact that invisible technology operates behind the scenes dynamically responding to situations making the “things” to act accordingly. Intelligent IoT systems enable interconnectivity of machinery, sensors and control systems satisfying the current industrial demands and enabling rapid manufacturing. Implementation of IoT helps to increase system reliability by predictive maintenance, statistical evaluation and measurements. Enhancement of plant safety and security are some of the key areas of implementation of IoT. Real-time energy optimization can be achieved by the adaptation of Smart industrial management systems which can also be integrated with the smart grid. Real time tracking of goods in transit can be accomplished by the implementation of IoT and cloud-based GPS solutions. The paper is organized as follows: Evolution of IoT, technology and applications. The applications of IoT are, but not limited to smart homes, smart buildings/cities, agriculture, transportation, health care, industrial automation.

## II. EVOLUTION AND TECHNOLOGY

### *A. Evolution*

Just a few decades ago, most of the people were “connected” to the world outside their homes in very limited ways like with landline telephones, radios and televisions. Home radios and televisions were a one-way experience where one can only watch or listen, but could not interact. This slowly changed with the advent of home computers, such as those made by Atari and Commodore in the 1980s and later the IBM PC. Since then people could interact with a machine in a more meaningful way thus connected to the outside world as well. The initial phase of Internet started with conveying static information to people and later moved on to connect people residing in many parts of the globe. The concept of connectivity still remained in its dormant stage because of slow dial-up speeds and sparse infrastructure. In the late 1990s, Internet connectivity flourished in consumer and enterprise markets, but the slow reach to the common man was because of the low performance of the network interconnect. The Internet still remains active by connecting people to physical things and also by providing connection among physical things in real time. Network of smart objects can be realized with sensors and actuators that are embedded in the objects that monitor, sense, capture, communicate and provide response to all types of data.

Reza Raji in 1994 demonstrated how automation can be realized in home and factories. This can be accomplished by the use of embedded microprocessors. In 1999 Bill Joy (inventor of Berkeley Unix and Sun Microsystems) described D2D (device to device) as an Internet of sensors deployed in mesh networks that can bring in machine intelligence in everyday life. The idea took its shape in 1999 when Kevin Ashton devised the term "*Internet of Things*" [1]. Aston described how smart objects (digitally tagged objects) could be networked together which can interact among themselves without the need for human intervention. In Ashton's words, "If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything, and greatly reduce waste, loss and cost". Ashton also added that IoT has the potential to change the world in multi-dimensions in the future and that it has gone a long way since 2009.

### *B. Technology*

Internet of Things (IoT) is a new revolution of the Internet, the goal of which is to enable things to be connected among themselves at real time using any of the available network or service .The smart objects can recognize and communicate among each other combined with capabilities of decision making. In addition to this the smart objects can access the information which has been accumulated by other objects. This has been made possible with the emergence of the concept of cloud computing and also by the transition of the Internet towards IPv6. In the near future highly prevalent techniques for computation and storage of data will be developed which will result in a large amount of decentralized resources dynamically networked. Internet plays a strong role in creating smart environments through wired and wireless broadband connections thereby providing access to information, media and services.

The following technologies enable the implementation of IoT.

*B1. Sensors:* Sensors are devices generating electrical signals out of non-electrical inputs. A sensor can retrieve an electrical, digital or optical from a physical parameter. The data obtained from sensors can be converted to an electrical signal that can be fed to smart devices to arrive at appropriate decisions. An actuator can be defined as a device which converts an electrical signal to a non-electrical signal. In practice multiple sensors each serving different purposes are used which can extract different types of information. The different factors which determine the suitability of a sensor includes accuracy, selectivity, repeatability, resolution, noise level and range. Now-a-days cheap and small sensors are available in markets but the cases of data security, power consumption and interoperability needs to be addressed.

*B2. Networks:* As from the previous discussion on sensors the signals accumulated by different sensors deployed at various locations will be of large volume which should be transmitted over long distances where they can be stored and analyzed. Routers, switches, gateways and hubs can be used to connect sensors and other devices. IoT needs to assign a unique identity for each object connected so that it is possible to identify and track the flow of data. Network protocols can be defined as a set of rules which define how the computers connected in a network identify each other.IPv4 and IPv6 are versions currently in use which comes under the classification of Internet Protocols (IP) that can provide a unique address to various types of Internet-connected devices. Depending upon the geographical area under study wired or wireless technologies can be used. The most widely preferred technologies for short range includes Bluetooth and ZigBee in wireless and USB in wired networks. For large geographical area Ethernet and Fiber optics provides a fair solution and for still large areas Internet is a better option. Data transfer rates and energy requirements should be considered while selecting network technologies. The challenges associated with network technologies include interconnections, signal penetration, security and power consumption. The concept of energy harvesting can be exploited by designing micro-strip patch antennas [28] which provide effective solutions for requirement of large amount of power for Multiple-Inputs Multiple-Output (MIMO) systems.

The network lifetime can be increased by implementing energy efficient algorithms for routing [25]. Hierarchical approach of mobile agent based layers to optimize load balancing was developed for a large scale network, which plays a momentous role in reduced energy [26]. Multi-layer upper REMA nodes were modeled as charging Mobile Power Banks (MPB) to avoid premature failure upon request was demonstrated with target detection mechanism. However, an ad hoc network performance evaluation for various routing protocols could vary not only with different mobility models, but also with simulation of different parameters under same mobility models. The mobility model adopted plays a significant influence on the performance of multi hop networks [27].

*B3. Standards:* The huge amount of data collected from different sensors deployed at different points should be aggregated and analyzed to arrive at meaningful conclusions. This process involves a variety of activities which can include data processing, data handling and storage of data for future use. Aggregation of data is achieved by selection of various standards based on the application. Technology standards and regulatory standards refer to the types of standards which are relevant for the aggregation process. The regulatory standard plays a vital role in shaping the IoT landscape which pertains to security and privacy of data. Rules and regulations need to be framed in the context of collecting, handling, utilization and sale of the data. The technology standard mainly comprises of three basic elements namely data-aggregation standards, communication & network protocols. Interoperability issues may arise as a result of the existence of multiple network protocols. Communication protocols provide a common language for communicating among devices connected via network. Identification of protocols that best suits an IoT application is under discussion among the researchers. The data acquired can be aggregated, processed and stored with the aid of data aggregation tools. For effective aggregation technical standards are needed to handle unstructured data. Data integrity can be maintained by the legal and regulatory standards. Efforts are on the way to develop widely adopted standards at the same time keeping into consideration the key issues of security and privacy.

*B4. Artificial Intelligence:* For companies to fully exploit the potential of IoT it is essential to combine IoT with rapidly advancing Artificial intelligence (AI) [3]. This will enable "smart machines" to simulate intelligent behavior and to make well defined decisions with less human intervention. In this scenario integration of IoT with Artificial intelligence is a prerequisite for the development of IoT based digital ecosystems. The development of Artificial intelligence is fuelled by the development of underlying technologies including mobile connectivity and cloud infrastructure. The development of open source software also added to the gearing up of AI. As discussed above with the intervention of AI the machines become smarter eliminating repetitive and routine manual tasks. Also in situations where the complexity of decision making is high, AI will augment human decision making. Smart machines are capable of learning, predict the situation and to make reliable recommendations thus turning autonomous. AI supports IoT by enabling predictive analytics, prescriptive analytics and adaptive/continuous analytics. Predictive analytics involves the analysis of real time data to determine the time of breakdown of a machine and to prevent the failure by proactive intervention. Accidents and disasters can be avoided by prescriptive analytics by which intelligent sensors can sense the situation and suggest immediate action. The importance of Adaptive /continuous analytics lies in the fact that the continuous data fed from sensors can enable systems to take right actions autonomously. Rising adoption of AI will trigger higher revenues, enhanced safety, reduced losses from accidents, lower costs and enhanced customer experience.

## III. ARCHITECTURE

Development of architecture for IoT started with an aim of providing solutions to enable communication between heterogeneous devices and thereby providing interoperability [7]. Different architectures have been proposed by different researchers. The first among them is a 3-layer architecture which includes perception, network and application layer [5]. The perception layer comprises of the physical layer which includes sensors and the network layer serves to connect the smart things, network devices and severs. Application layer delivers application specific service to the users. The proposed 3-layer architecture could not provide the finer aspects of IoT including data processing, security and privacy which was the prime concern of researchers.

A modification was made by introducing two more layers namely transport, processing and business layers. This led to the proposal of a 5-layer architecture for IoT. Transport layer serves to transfer the sensor data between perception layer and the processing layer via wireless, LAN, Bluetooth, 3G and RFID technologies. The processing layer also referred to as middleware layer stores, analyses and processes the big data from the transport layer. This employs technologies such as database management, cloud computing and big data processing modules. The business layer manages whole of the IoT system and takes care of the user privacy.

Cloud centric architecture mainly concentrates on three layers in which the cloud is sandwiched between the application layer at the top and the network of smart things at the bottom layer. The importance of Cloud computing lies in the fact that it offers services such as core infrastructure, platform, software and storage [13]. The Fog architecture presents a more precise architecture which includes monitoring, preprocessing, Storage and security layers between the physical and transport layers.

The initiation of IoT-A project started with formation of a stakeholders group which after repeated reviews collected hundreds of IoT related requirements [2]. This study revealed that a development of a single architectural pattern will fail to satisfy all the expectations and that development of a generalized reference model can provide effective solutions to the requirements. The IoT-A project thus aimed at gathering common requirements and defining of an abstraction layer that can provide commonalities to all the existing IoT related architectures. This initiation had an advantage of adopting to the various working solutions/standards and also ensuring backward compatibility.

IoT-A Reference model [2] (Fig.1) provides the common understanding of IoT domain and is composed of different domains. IoT domain model describes the generic components such as users, resources, augmented entities, services and devices. The data semantics typical for an IoT system are best explained by the information model. The communication model specifies the communication between the heterogeneous devices and the Internet. The functional model deals with management and security aspects.

The development of IoT-I reference model started with a survey for a common model and the analysis of different architectures.

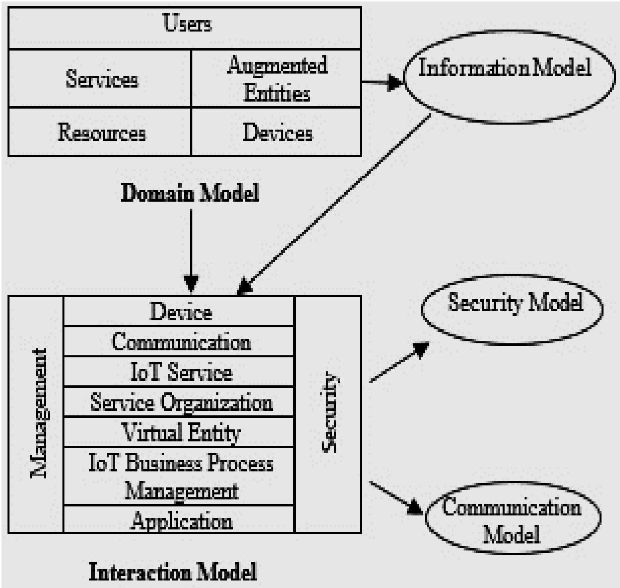


Figure 1. IoT –A [2]

A model was defined consisting of the following component models for security, interaction, communication and information [4].

ETSI-M2M defines service layer aspects of machine to machine systems [12], consisting of two domains serving for Device &Gateway as well as the Network. The FI-WARE project defined an open platform based on components referred to as Generic Enablers. This offers applications in wide spectrum of sectors enabled by its functions which are reusable and shared.

The design of IoT6 architecture [2] was carried out by exploring and adapting the outcomes of various other relevant projects such as IoT-A, ETSI-M2M and FI-WARE. The main aim of this architecture was to exploit the potential of IPv6 and other related standards such as 6LoWPAN and CoAP so as to overcome the existing shortcomings and breaking up of the Internet of Things into small capsules. Some of its main challenges and objectives includes research and to design and develop an IPv6-based Service-Oriented scalable Architecture. This also aimed to achieve integration, mobility, interoperability, cloud computing, and intelligence distribution among diversified smart things, applications and services [6]. IoT6 improves Security and service of IoT, Communication, and Service organization.

The following Table I illustrates the different types of architectures developed for IoT in various scenarios [15].

TABLE I. DIFFERENT ARCHITECTURES PROPOSED FOR IOT

| Sl. No. | Technical article | Year | Technology Involved | Limitations |
|---|---|---|---|---|
| 1 | "Research on the architecture of Internet of Things" [16]. | 2010 | Initially formulated a 3 layer architecture and later enhanced it to a 5 layer structure which included features of both Internet and Communications Network | Security threats in processing and analyzing big data. |
| 2 | "Multimedia traffic security architecture for the internet of things" [17]. | 2011 | Proposed a Framework for Security architecture which can be applied in situations handling multimedia traffic. | Security concerns in IoT which included vulnerability to attacks, data authentication and access control. |
| 3 | "Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges" [18]. | 2012 | Proposed a 5 layer architecture consisting of perception layer, network layer, middleware layer, application layer and business layer. | Scalability, reliability, QoS, adaptability and interoperability. |
| 4 | "Research of Architecture and Application of Internet of Things for Smart Grid" [19]. | 2012 | Proposed a 3 layer architecture for smart grid including perceived extension layer, network layer and the application layer. CT platform was utilized for controlling smart grids centrally. | Lacking security mechanisms and support for QoS. |
| 5 | "A Community Health Service Architecture Based on the Internet of Things on Health-Care" [20]. | 2013 | The IoT science and medical health care center can be linked with the introduction of a layer for Information perception layer in addition to the existing network transmission layer and application layer. | Privacy and security aspects were not addressed. QoS was not guaranteed for cases involving time sensitivity and mobility. |
| 6 | "Microsoft Azure Intelligent Systems: 4 Facts" [21]. | 2014 | The proposed architecture for IoT combined the features of cloud with the data management services. | Architecture is not robust and flexible and takes more time for deployment. |
| 7 | "IBM: Working Towards a Smarter Connected Home" [22]. | 2014 | Proposed architecture aims to integrate different services in the cloud other than integrating them at the edge device. The architecture is referred to as "home in the cloud" by IBM. | Lack of QoS support, data security and privacy. |

## IV. APPLICATIONS

The features of IoT can be explored and applied in day today life making our earth more green and a beautiful place to live in. IoT can lead to building a new industrial atmosphere where environmental responsibility goes in par with human safety and productivity. IoT finds applications in home automation, fitness tracking, health monitoring, environment protection, smart cities/buildings and industrial automation. However the applications of IoT are not limited to the above areas but are the core area of research towards improving the quality of human life.

### *A. Internet of Things*

IoT Can be deployed to automate the home appliances so as to act according to the convenience and requirements of the inhabitants. This is referred to as Intelligent Home automation system [8] which can be realized using cluster of sensors located at different points in the house. Large amount of data can be collected by these sensors regarding the house occupancy and utility consumption. In addition to this data is captured from surroundings which will protect the inhabitants from theft and natural disasters. This concept finds wide application in providing assistance to elderly and sick people. Systems with computing capabilities analyze the data which is used to automate the home appliances thereby supporting the inhabitants by reducing the cost and improving the living standards. A ZigBee network is established where the sensing nodes collect data and forward them to a center node. Gateway translates the ZigBee protocol data format to IPv6 format [14]. The architecture mainly consists of smart sensing devices, IoT gateway and Internet server. The QoS is determined by system reliability and throughput. Availability of IPv6 connectivity, development of compression techniques for effective storage and retrieval of data are some of the key issues of concern.

A light weight IoT framework can be integrated into smart phones and tablets by which discovery and interaction of smart things are facilitated. The concept is referred to as "Connect and Control Things" which uses SML (Sensor Mark-up Language) to connect and interact with things and sensors [9]. The technology reduces the loading on home gateways for IP communication and protocol translation. The smart device facilitates communication among the things. The soft ware drivers included in the OS aids in reducing development time and complexity since it takes care of Driver installation and system updates. The framework incorporates light weight search / reasoning engines for discovery and M2M data processing which can also provide subscription and notification services to customers.

### *B. Collaborative Sensing Intelligence (CSI)*

CSI framework which combines Collaborative Intelligence (CI) and Industrial Sensing Intelligence (ISI) aims at achieving dynamic collaboration between different objects [10]. This framework has the potential of integrating massive data from different sources at different time periods which can be utilized in building an intelligent and automated Industrial IoT (IIoT). CSI framework acquires knowledge about the dynamic industrial environment and the characteristics of industrial problems. The acquired information or knowledge is used to construct process models which can aid in automation of the industry thereby improving safety and efficiency. This involves a nonstop real time learning, massive collection, merging of data and development of algorithms based on mined information and discovered knowledge. The key issue to be addressed in this area includes development of Generic data model since the data collected from different equipment at different time periods may have different semantics and formats. Moreover a security model for ensuring data privacy and authorization needs to be developed.

### *C. Cloud of Things (CoT) and Home Management Systems (HMS)*

Cloud based solutions have been proposed to solve the performance related problems of IoT devices. The cloud based architecture of IoT is referred to as Cloud of Things (CoT) which is well suited for Home Management Systems (HMS) [11]. The cloud has the resources to monitor the smart devices at the same time providing features of collecting, storing and processing the big data. HMS provides access points to users, manages devices and policies and interfaces with the cloud services. A unique key is assigned to each of the device and employs encryption standards to assure confidentiality between end to end communications. Since large amount of data need to be send to cloud high speed, low latency Internet connection is a prime requirement. The key areas of challenges include the need of auto configuration support and auto updating of software and firmware.

### *D. Other Applications of Sensors and Devises:*

Wearable devices in association with sensors, smart phones and medical analyzers can be used in MIoT which finds application in health monitoring and fitness systems. Motion trackers, Body worn smart clothing and gas detectors aid in real time health monitoring providing efficiency with minimal power consumption [23]. Ongoing studies reveal the possibility of integrating vital sign monitoring, motion tracking and gas detection into a single device. Security issues concerning the wearable technology can be addressed by the use of novel Integrated Circuit Metric (ICMetric) technology [24] which generates an identification based on the extracted features providing provision of cryptographic services.

## V. CONCLUSION

The Internet of Things can be thought of as an ecosystem of increasing complexity which can build the next higher level of automation of each surrounding 'object' in our day to day life. IoT can integrate various devices and can provide communication between M2M, machine to people and people to people thus paving way to automation in industries and day to day life. Importance of IoT lies in the fact that it tends to make life easy with enhance safety and environment responsibility. The technology is equipped with sensing, identification, processing, communication and networking capabilities. Industrial IoT is one of the emerging areas of interest and research so as to develop industrial applications such as automated monitoring, control, management and maintenance. IoT is expected to be widely applied to industries in the near future. The evolution, technologies and architecture involved in IoT were discussed. Model architectures developed by various researchers for customized applications were reviewed. Some key applications of IoT in various fields were discussed keeping in mind the scope of further improvement. In the near future with the introduction of 'IoT as a Service' technology the possibilities of applications will increase many fold. For the dream to come true, solutions for the obstacles and barriers which may come in the way needs to be identified. This can open-up the way for future studies and research.

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