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IoT Architecture a Comparative Study

N.M.Masoodhu Banu
Professor ECE Department,
Veltech Dr.RR & Dr.SR University
Chennai

C.Sujatha
Professor, ECE Department
SSM Engineering college,
Dindigul

Abstract

Internet of Everything, the Industrial IoT, Machine to Machine, or “connected devices, all in one umbrella is called Internet of Things (IoT). IoT has the potential to transform the manufacturing world i.e. from dumb manufacturing to predictive manufacturing. However, there is no uniqueness in defining IoT architecture to follow i.e. no interoperability at communication level as well as service and knowledge level. Hence in order to have a true IoT the field should be matured in terms of understanding in the first step. Today multiple IoT Architecture from different vendors like Intel to IBM is available in the market for IoT solution. In order to help the product builder to choose from the different architecture, this paper does an analysis of different Industry standard IoT architectures and brings out the use cases when to choose what? Further the research challenges have been investigated to motivate the researchers.

Keywords: IoT, Analytics, Layered Architecture, Edge Computing

1 Need for the reference architecture

A huge burst usage of cost effective sensor based processor system rules the world now. The possibility of such sensor world is not possible without the exponential growth in semiconductor domain. This growth connected with advanced communication technologies like Bluetooth [1], ZigBee, , 3G, 4G, 5G they got empowered to do multiple things and converges into an emerging form of technological domain IoT. IoT aims to offer, a huge scale, assorted, interoperable, and context aware, and simplified application development cum deployment capabilities to the enterprises and end-users.

IoT is a parasol term that comprises diverse categories [2]: Wireless sensor/actuator networks, Internet connected wearables, RFID enabled tracking, use of mobile phones to interact with the physical world (e.g. sensing), Devices with Bluetooth-enabled mobile phones connectivity to the Internet Smart homes and Connected cars etc. Single architecture is not enough to suit all these areas for the requirements each brings. However, a modular scalable reference model that supports adding or subtracting capabilities, as well as supporting many requirements across a wide variety of these use cases is inherently is possible and if found it is valuable. The Reference model can be made to provide a starting point for architects looking to create IoT solutions and a strong basis for further development. Industries like CISCO, INTEL and IBM have come up with their own reference architectures. But lack of overall knowledge about these IoT architectures restricts researchers and enthusiasts to choose one when they are in phase with development of any product or solution utilizing IoT enabled technologies.

The scope or locality of IoT’s components should not be restricted by the Reference Model. For example, from a physical perspective, every device in the IoT could be made to reside in a single rack of equipment or it could be distributed across the world. As Internet of things coined from Internet, the study and the design of it should be from data generated by devices perspective rather than data generated by people. The internet data transmission follows the seven-layer OSI model. IoT can be compared with internet model with data generators as devices replaced by human being in internet [3]. Hence, following the internet, IoT architecture initially deigned to have 3-layer architecture and went on to become 7-layer architecture currently on the basis of protocol. The three layers and the five-layer architectures are shown in figure 1a and 1b. The three-layer architecture [4-5] was introduced in the early stages of the research. This architecture defines the basic minimal things needed for the devices to be connected to the internet. However, research always will be in search of finer things in the model and hence resulted in five-layer [5-7] and then to seven-layer. The transport layer in five-layer model does the same thing as Network model in three-layer model i.e. it transfers the data from perception layer (from device) to application layer. The additional processing layer in five-layer model stores, analyzes and process for some definite pattern which can be made useful for business layer.

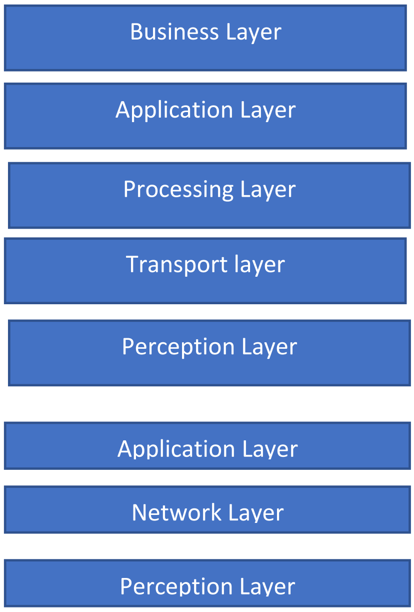

Figure 1 Reference Architecture a. 3-layer model b.5-layer model

The business layer manages whole of IoT

A question raised in the above architecture is, Where the processing layer physically presents? In an answer to these two more architectures evolved and they are called fog [8-9] and cloud [10] architecture. In some system architectures the data processing is done in a large centralized fashion by cloud computers. In cloud centric architecture the cloud is kept at the center, applications will be placed above it, and the smart things below it [10]. Cloud computing is given importance due to its great flexibility and scalability. It offers services such as the core infrastructure, platform, software, and storage. Developers can provide their storage tools, software tools, data mining, and machine learning tools, and visualization tools through the cloud. However, in data centric applications like video surveillance the data needs to be computed nearer to the device. Hence lately, IoT moved towards another system architecture, namely, fog computing [8-9], where the sensors and network gateways do a part of the data processing and analytics. A fog architecture [11] presents a layered approach as shown in Figure 2, which inserts monitoring, preprocessing, storage, and security layers between the physical and transport layers before going to cloud.

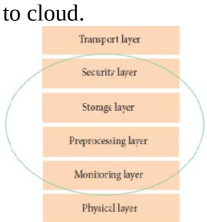

Figure 2 Fog Architecture

In a nut shell the following aspects should be considered and covered by the reference architecture i.e. cloud or server-side architecture which is used to monitor, manage, process the data from the IoT devices. A communication model, and the agents and code on the devices themselves, as well as the requirements on devices that can be supported by the reference architecture. In this aspect, this paper compares the different vendors architecture and analyses the challenges faced by IoT field. Section 1 emphasizes the need for the reference architecture along with the history of IoT, section 2 describes the industry (CISCO, INTEL and IBM) defined architectures and discusses the pros and cons of each. Section 3 addresses the research challenges still present for the researchers to further work on. Finally, section 4 concludes this paper.

2 Comparison

2.1 CISCO IoT Architecture

Cisco architecture follows Edge model. Figure 3 illustrates the IoT Reference model and its levels. The data flow follows bidirectional in IoT i.e. in a control pattern, control information flows from the top of the model (level 7) to the bottom (level 1). In a monitoring pattern, the flow of information is the reverse. The processing layer in five-layer model is divided into three layers, where data aggregation like collecting data from group of devices is done by data abstraction layer, storage is done by data communication layer and real processing is done by edge computing layer. The functions of Level 3 are driven by the need to convert network data flows into information that is suitable for storage and higher-level processing at Level 4 (data accumulation). This means that Level 3 activities focus on high-volume data analysis and transformation. For example, a sensor device at Level 1 might generate data samples multiple times per second, 24 hours a day, 365 days a year. Despite these huge data generation, the data collected are never analyzed. As many IoT solutions are extremely slow, analyzing the data will be difficult. Architecture which are using the cloud to do such analysis will bring new challenges in the years to come because of excessive data.

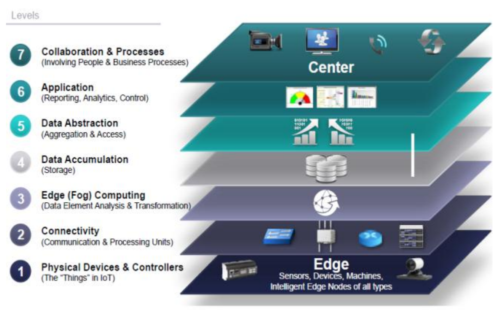

Figure 3 CISCO Architecture

The approach followed by CISCO called edge computing will solve this issue and it is about computing in real time [12-13]. For example, transmitting the videos from security cameras as it is useless, instead processed video with any event detection will be fruitful. Another example is ATM where the banks if it is made to detect fraudulent financial transactions. In this way CISCO promoting its gateways as edge computing devices and it is making trends. Initial analytics also possible with Cisco edge computing after then the analytics will be routed to the cloud. Acting on the data close to the source after some analysis enables continuous operation even if the network is down.

2.2 IBM Architecture

IBM's cloud computing architecture has been converted to model suitable for IoT with some modifications like device handling and device management [14]. In that aspect the layers where they are expert in with respect to the seven-layer model is explained here. Most of the IBM architecture for IoT deals with middleware rather than the complete architecture. Bringing the power of IBM's Watsons IoT with CISCO's Edge computing As shown in figure 4 the architecture components revolve around the four major components called connect, information management, analytics and risk management. The Connect component does the jobs necessary for device connectivity to the network like Attach, Collect & Organize, device management and secure connectivity. Storing & Archiving, metadata management, streaming data and parsing, managing the unstructured data are done by Information Management. Much of the world's cloud data is unstructured and mostly in textual content, and hence it features text analytics with library of extractors to derive meaning from text. Includes. The analytics component includes a remarkable amount of analytical functionality covering cultured text analytics, social data analytics and machine data analytics for event data.

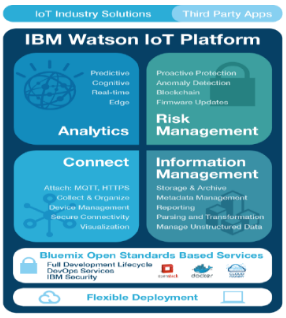

Figure 4 IBM Architecture

It has been designed to handle very high data rates to the level of millions of records per second. Organizations can more effectively forestall when a problem is likely to occur by analyzing real-time data from sensors. Also with these high-end data analytics a predictive and cognitive, real-time data can be done. The fourth component Risk Management does, data protection, auditing, Firmware Updates, Key Management and organization specific security etc. i.e. in a nutshell the device integrity is maintained by this layer.

2.3 INTEL Architecture

The INTEL System Specification (SAS) architecture features two versions, version 1 for system developers and integrators to connect the devices through an IoT gateway. Version 2 features is future looking i.e. it facilitates seamless cyber physical systems [15]. The SAS architecture shown in figure 5 is a layered architecture where the white block is user layer, the dark blue is of major run time layer and the light blue is for developers. As more and more devices are getting connected companies face increased fragmentation, interoperability and security issues. To address these issues INTEL is delivering integrated scalable hardware and software solutions. Of the eight-layer shown in figure 4 the control layer is the new one compared to the seven-layer model. It provides the guidance to separate the management and control with policy and control APIs. It can move off devices and off premises for cloud or remote control which is an essential requirement of a software defined network

3. IoT Research Challenges

The IoT domain incorporates a wide range of technologies, from constrained to unconstrained and from hard real time to soft real time. Therefore, single reference architecture cannot be used as a design for all possible implementations. However, a reference model should be identified where several reference architectures will co-exist. Architecture in this context is defined as a framework for the specification of a network's physical components and their organization and configuration, its operational principles and procedures and the data formats used in its operation

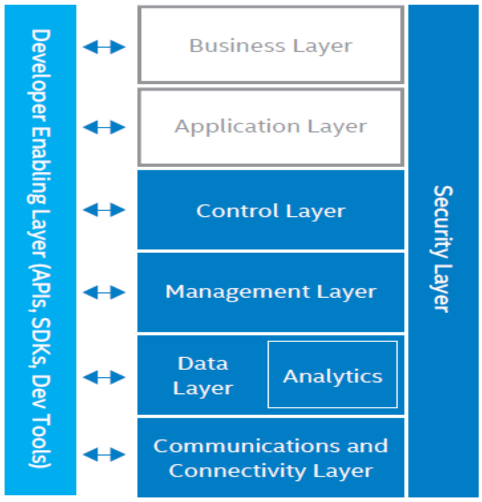

Figure 5 Intel Architecture

Similar to an internet IoT addressing needs an intense research, due to wide range of resources and computing capabilities available to IoT devices. It may require many optimized address formats, which need to be unified by a common ID-to-Address translation service.

Issues with security should be taken care as it involves massive amount of personal data as in case of IoT based patient health care system. However, for differing requirements from applications there should not be any forcing of toughest requirements to comply with.

Heterogeneous link media like RFID, GSM and WLAN should work with common networking infrastructure. To achieve this, creating systems and communications mechanisms with unnecessary dependencies between different layers and system components limits IoT ability to migrate to the most economic and efficient platforms, and limits its ability to connect as many "Things" as possible.

4. Conclusion

IoT is a vast ocean of research topic where much of the work is already been done many of the industry. Numerous research opportunity is opened at different direction from devices cognitive analytics. In this context a survey of different vendors working on IoT is presented in this paper. It is observed from the survey that Industries taken multiple approach to IoT for their establishment. For example, Industries started working on their own strengths like CISCO on gateways, IBM on cognitive data processing and INTEL on processor miniaturization. In addition to the above, big vendors understood the market and started working on interoperability through middleware and collaborative work on edge computing. There are hoping signs of maturity too. However, the application domain is still need to be explored like IoT in agriculture. Human life will have an impact through IoT in the next decade. Also, a common IoT standard addressing the above said issues in section 4 also is the need of the hour and an enormous amount of research is needed in this direction.

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