AN AMPLE STUDY ON INTERNET OF THINGS ECOSYSTEM: FUTURISTIC VISION, ISSUES AND CHALLENGES

By

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ABSTRACT

The Internet of Things (IoT) is acknowledged as a transformative technology that brings smart revolutions in all sectors of human life, industry, agriculture, healthcare, retail and much more. In fact, no IoT application do exist as a complete one promising and involving all necessary enabling technologies till now. The lack of true IoT ecosystem till date is the only cause for the fragmented nature of IoT applications, which needs to address various challenges in availability, data storage, integration, performance, processing, reliability, security and privacy issues. This work presents a comprehensive framework that imposes a true IoT ecosystem with solutions to above mentioned challenges through associating human body ecosystem with major enabling technologies of IoT. To arrive such futuristic framework, researchers' contribution on reputed journals on these techniques and internet survey reports over trends in recent technologies are being intensively investigated. Spotlights on the environmental issues need to focus on applying the IoT applications over the society presented with a sense of achieving sustainable development by incorporating renewable and recyclable resources.

Keywords: Internet of Things (IoT), Ecosystem, Enabling Technologies, Framework, Reliability, Security, Privacy.

INTRODUCTION

In general, Internet of Things (IoT) is a modern technology that gathers data from the self-configuring physical objects of an environment by establishing a Wireless Sensor Network (WSN) among them and disseminate the collected data as intelligent information to the real world object with the help of internet (Ali et al., 2015). Aligned with the definition, IoT can be expressed as the simple equation given below,

$$IoT = Smart\ Objects + WSN + Internet \quad (1)$$

IoT is a form of ubiquitous computing, that enables communication from anyone, anywhere to any place, anytime through any network (Čolaković & Hadžialić, 2018). According to Gartner and Forbes, the IoT will add a fund of $1.9 trillion to global economy and $117 billion towards the healthcare industry. This aligns with automotive news, that the count of connected cars around the world will rise up to 152 million by the year 2020.

The Figure 1 captures the Statista research report and predicts that the number of connected devices for building an IoT environment around the world will go up to 75.44 billion by the year 2025 (Alam, 2019). This tremendous amount of device inclusion, further complicates the unaddressed IoT challenges in every processes of its application such as identification, processing, and performance (Ali et al., 2015; Čolaković, & Hadžialić, 2018; Alam, 2019).

IoT holds its scope of development in bringing a connected world through fine tuning its adaption in various applications ranging from smart home, smart industry pronounced as Industry 4.0 to smart city (Zeinab & Elmustafa, 2017).

Though many companies started IoT initiatives, still it has few challenges to be solved for its successful realization. Technologies related to identification, integration, compatibility, connectivity, data handling, intelligent analytics, security, precision, privacy and consumer

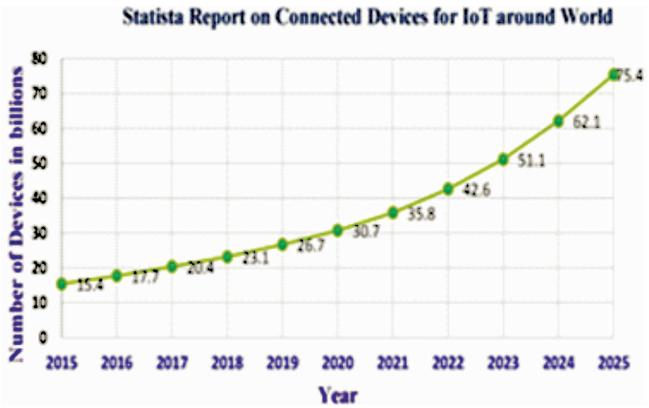

Figure 1. Report on Futuristic Growth Rate of Connected Devices (Source: Statista.com, n.d.)

awareness are the most common challenges.

In general, an ecosystem is a collection of all living and non-living things in a particular environment, which do interact and survive among themselves. An ecosystem can be any size, and its components has a specific role and depend on each other throughout a survival cycle. Aquatic and terrestrial ecosystems are considered as the major examples.

The aim of this research is to bring unique ecosystem that promises a dynamic and real IoT application in practice.

1. Literature Review on Enabling Technologies of IoT

The key technologies contributing to the progress of building real time IoT applications and its scope of adaptation level are discussed in the following sections.

Table 1 highlights the summary of review as below.

1.1 Artificial Intelligence

Artificial Intelligence (AI) is a branch of study of computer science that accentuating in bonding intelligence with machines through various phases like learning, reasoning and self judgement. Through the acquired knowledge imposed by the AI technologies, machine perform and execute critical tasks as similar as human beings. AI is broadly divided into following three categories based on its capability imposed (Choi & Lee, 2018).

- Artificial Narrow Intelligence (ANI): Here, the name suggest that it designed to execute one specific task as human think.
- Artificial General Intelligence (AGI): Here, machine can not only think, but has cognitive/ analytical skills like human.
- Artificial Super Intelligence (ASI): These are fully automated super computers, which execute the applications with self-decision without human intervention.

AI revolutions crosses over centuries and the current revolution focuses on techniques for universal connectivity with exciting levels of automation. In recent years, the coordination of AI for IoT has been highly recommended and utilized to bring smartness in various applications including fraudulent detection (Choi & Lee, 2018; Tzafestas, 2018).

Author's Name (in Chronological Order)	Major Enablers					
	AI	Big Data	Block-chain	Cloud	Edge / Fog	Wireless
Choi and Lee (2018)	✓					
Hassan et al. (2018)					✓	
Shradha et al. (2019)				✓		
Kundhavai and Sridevi, (2016)		✓				
Brinda and Heric, (2017)				✓		
Kachhavay and Thakare, (2014)						✓
Marjani et al. (2017)		✓				
Ali et al. (2018)			✓			
Mahmud et al. (2018)					✓	
Sharma et al. (2014)						✓
Beck et al. (2016)			✓			
Tzafestas, (2018)	✓					
Duong and Vo, (2019)						✓
Zhenget et al. (2018)			✓			

Table 1. Summary of Literature Review

1.2 Big Data Analytics

IoT devices produces voluminous, different types of data, which are frequently generates over time, with no accuracy. To turn those kind of data into valuable information, big data analytics offers tools to handle massive amount of data frequently generated by the IoT devices and algorithms to convert data into predictable graphs, patterns or information to be used by the application (Marjani et al., 2017; Kundhavai & Sridevi, 2016). It helps in optimizing the performance of the devices devoted for that task.

Big data challenge began from the 1880 U.S. census, and lately evolved, provided with methodologies and platforms to offer solutions to today's data center issues and progressing in the direction to handle futuristic real time IoT applications as well.

1.3 Blockchain

IoT scenario involves enormous power constrained hardware devices coordinating through untrusted network are highly vulnerable to security attacks. Blockchain renowned as a security mechanism avails protection through hashing, digital signature and consensus algorithms (Zheng et al., 2018).

Bitcoin, also known as first cryptocurrency was regarded as the primary presentation of BC developed in 2009. Many industries have adopted blockchain for their financial transactions. Hacking attempts recorded in year 2011, have awakened the need to strengthen the methodologies in Blockchain (Ali et al., 2018). Blockchain has the potential to ensure security for the following domains beyond cryptocurrencies: finance, IoT, public services and reputation systems (Beck et al., 2016). Blockchain can offer solutions for security issues in IoT scenario from device identity, access control, integrity and availability.

1.4 Cloud Computing

The IoT environment is made up of interconnected embedded devices, which are smaller in size and provide with limited memory and processing power. The incompatibility issue poses data management challenges, which requires a platform to offer a remote management over IoT data collected by the devices (Shradha et al., 2019). Cloud computing is a platform designed to provide efficient storage and computing services on-demand to users.

As a result of Bain cloud computing survey, the current maturity state of cloud is arrested in Figure 2 with its Compound Annual Growth Rate (CAGR), which is a business term tells the constant rate of return over the time period (Brinda & Heric, 2017). The formula used to obtain CAGR is projected as equation (2).

$$CAGR(t_0, t_n) = (V(t_n)/V(t_0))^{1/t_n - t_0} - 1 \qquad (2)$$

The survey results many companies adopted cloud environment to save huge cost of investment and the

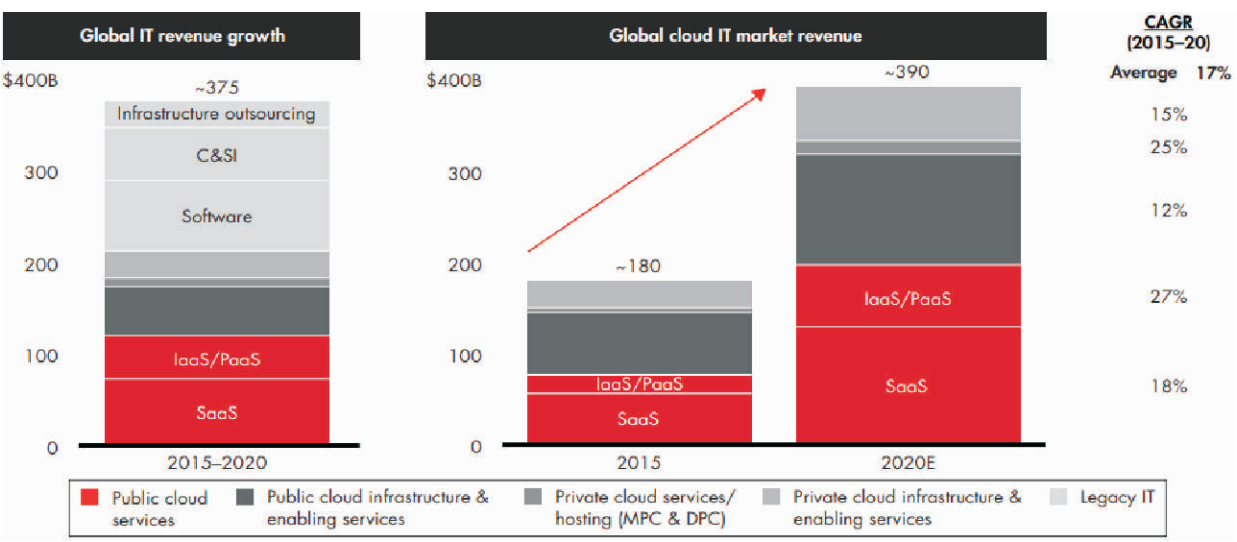

Figure 2. Expected Cloud Adoption State in IT Market during 2015 - 2020 (Source: Brinda & Heric, 2017)

adoption level is increasing annually because of considerable features apart from the security issues.

1.5 Edge/Fog Computing

In the purpose of reducing latency or delay in data processing at cloud sever, though it is located far away from IoT devices, Edge/Fog computing is introduced and grasped the attention of researchers and developers. This novel computing allows the processing happened as closer to the IoT sensing layer by equipping the edge devices computational infrastructure (Hassan et al., 2018). Earlier research addressed that interoperable capability of cloud and fog computing in IoT enabled health care services with its performance achievement (Mahmud et al., 2018). Table 2 provides the major difference between the edge and fog computing. The time critical IoT applications are in demand of these computing paradigm in realizing proficiency.

1.6 Wireless Technologies

The progression of wireless technologies with its future scope (Sharma et al., 2014; Kachhavay & Thakare, 2014). 5G technology is going to offer ultimate data transfer rate accessible over worldwide. We are very near to exploit the power of fast and reliable 5G network, a unified global standard. It is anticipated to suffer from 10,000 times the growth traffic accumulated by enormous mobile devices by 2030. To address such challenges, optimized technologies to be kept in track to achieve efficacy in adaptation of 5G (Duong & Vo, 2019).

2. Proposed Framework Adhering True IoT Ecosystem

The enabling technologies discussed in the previous section paves a way to arrive a true IoT ecosystem. A common framework aligned the ecosystem is proposed in this section.

Edge Computing	Fog Computing
Edge computing is a concept of bringing data storage and computation facilities as close to the sources producing it	Fog computing is a standard defines how edge computing works
Need not to be connected with cloud or centralized server system for its functions	Fog, the term created by cisco in the year 2014, in bringing centralized cloud computing capabilities as close to the network edge
Guarantees reduced latency	In addition to reduced latency, provisions security layer too

Table 2. Difference between Edge and Fog Computing

2.1 Ecological Anatomy of IoT

In general, ecosystem is identified as a system that specifies the communication pattern engrained between living and nonliving components in the environment. Human body is one of the ecosystem. The design of IoT ecosystem highly depends on the domains namely market expectation, platform for building applications, and network effects. Likewise the most important biological system of human body are circulatory, nervous, muscular, respiratory, skeletal system and skin. In obtaining the proposed IoT ecosystem, the major enabling technologies of the three domains are matched with the six important biological systems of human body and it is conveyed as IoT ecosystem in Figure 3.

- Customer request will be the oxygen support, without needy, none can be implemented. The growing demand for smart applications from customer end only indicates the liveliness of the object and influences the active progresses in all other
- AI functions as the nervous system, which necessitates all conscious and unconscious tasks of body through sending signals to all other units. AI promises the expected actions of application

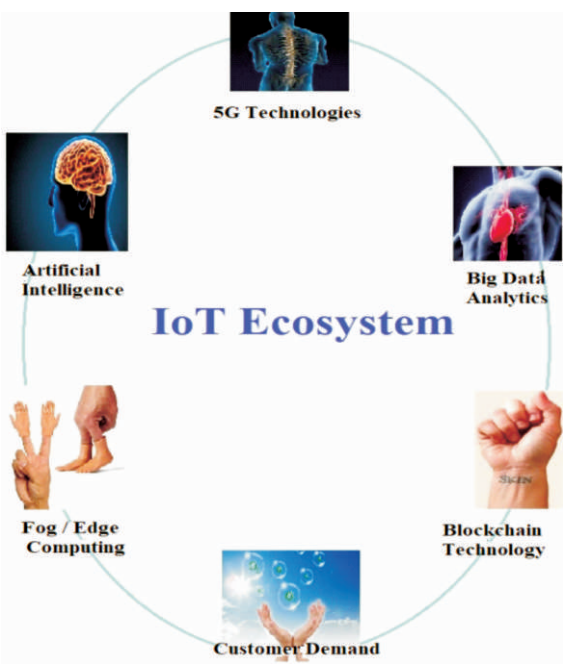

Figure 3. An IoT Ecosystem

through managing innumerable connected devices for the same

- Big data analytics are related with the circulatory system of human being, which supplies blood, oxygen, and nutrients to every part of entire system. Likewise the analytical algorithms mines, filters and delivers information in an effective form to be used with the application
- Network technologies acts as backbone and facilitates the skeletal support as IoT cannot be realized without network facility
- The computational (Edge, Fog and Cloud) platform offers muscular functions that coordinates smooth bodily movements. In that way, computing facility regulates the necessary actions to be obtained efficiently as possible
- Like Skin, blockchain technology avails security and protects from any vulnerable attacks.

2.2 Proposed IoT Framework

With reference to IoT layered architecture, the solution framework is designed and presented as Figure 4. The physical layer comprises of trillions of IoT devices like sensors, actuators, wearables and embedded systems. IoT devices generates the immense amount of data. The millions of edge devices in network layer is used to pre-process the data that filters noisiness and bring it in unified format. With few thousands of fog nodes built among edge devices, the fog services further extending the capabilities of cloud computing facility offers data processing solutions enabled with analytics and security in faster manner. High-end applications processing solutions with hundreds of cloud servers involves in historical and constant monitoring of data analysis is achieved at offline mode.

Edge computing with no centralized computation facility, is designed to perform pre-processing of data to greatly reduce its huge size into manageable one and

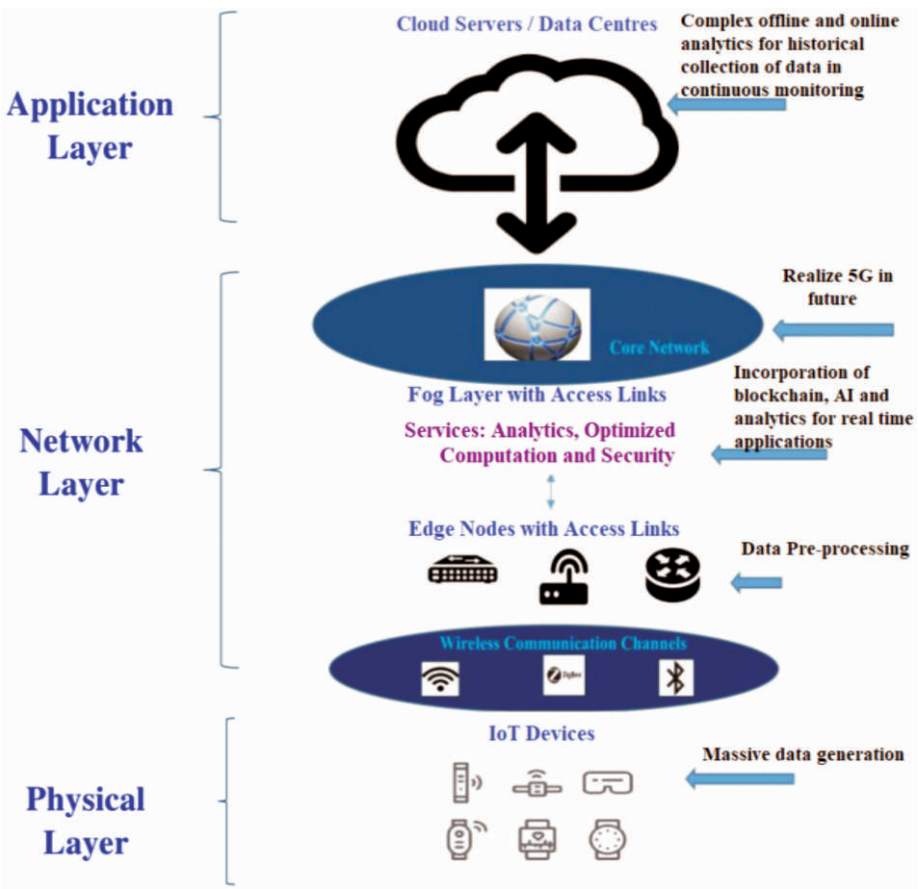

Figure 4. Mutual Solution Framework of Futuristic IoT Applications

addressing the same in mutual layout. Fog service layer enriched with necessary technologies of blockchain, big data analytics and AI to obtain the result of patterns of real time application with reduced latency.

2.3 Environmental Challenges

All smart transformation in every sector of human life by IoT applications are going to be ruled by significant amount of electronics equipment around our living environment, which consumes more energy and are susceptible for higher radiation emittance that pollutes the space. Implementation of such smartness which in turn spoils the atmosphere and brands the galaxy unworthy to live by our next generation. Hence, recent focus is being applied in the direction of green IoT that promises the sustainable environment. Arshad et al. (2017) detailed the key technologies for green IoT, recent trends and issues. The technologies for green IoT, further to be investigated and invented with great interest of transporting ecological sphere serves for all living things.

3. Results and Discussion

A genuine survey is carried out on internet to arrive at the maturity level of the components of IoT ecosystem with reference to the literature material for the study. In Figure 5, the result of exhaustive survey proposed over the major enabling technologies is illustrated with a focus on futuristic adaptation level of the same.

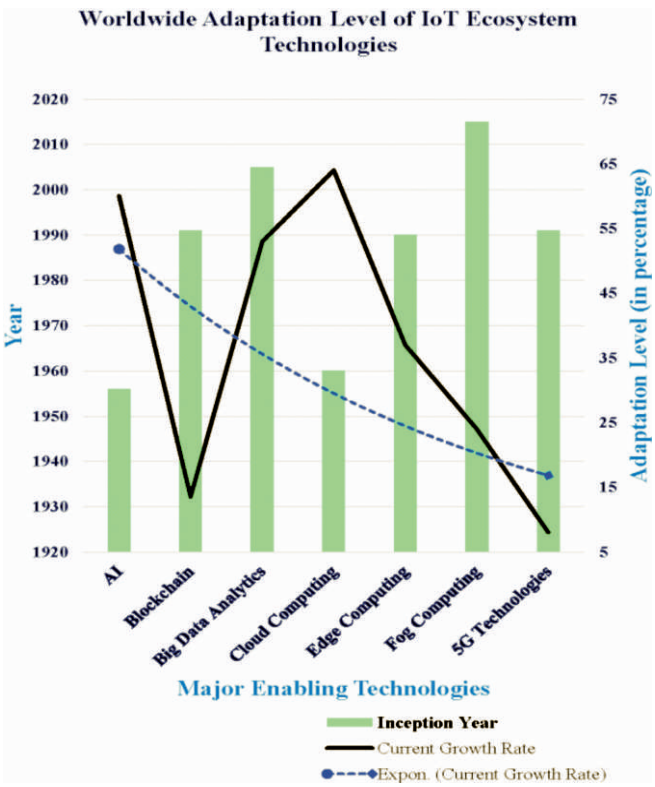

Figure 5. Maturity Assessment of IoT Ecosystem Technologies

An analysis is aimed to capture the evolution trends from its initial point to current state and it is mapped with its industrial or real life usage pattern. 5G technologies will be in realization path by 2020 and nearly 10 years ahead, it will reach major utilization rate as more than 40% globally. AI and cloud computing attained greater level of utilization as more than 60% and attracted the IoT developers in designing applications that incorporating the both together. Big data analytics is one of the leading technology, grasped the attention of IoT giants in using the same to avail better insight and visualization of the voluminous data. Currently, it is found to be in the utilization rate of 54%. Edge computing rooted from cloud computing paradigm, to reduce the data traffic and process latency, allows decentralized form of computation as near to the data sources through improving edge device infrastructure. Whereas, fog computing integrates the computational capability of edge devices with the centralized cloud server in obtaining lower latency with security. The utilization rate of edge (34%) and fog (27%) shows the readiness of adapting it in future with folds of improvement. Blockchain from being utilized as digital ledger, recently preparing itself to afford the complete security management for IoT devices with the current rate as 13.5% as well.

Conclusion

This paper presents an ecosystem for IoT through a complete study made on contributing technologies of present and future inline with human eco system. A common framework is designed, adapting current trends of the ecosystem. They are analyzed and discussed. In implementing the same in real world, the challenges to be considered also elaborated. It helps to opens a doors to promote IoT applications as sustainable, ecological and environment friendly ones.

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