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A New IoT Architecture for a Sustainable IoT Adoption

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Abstract: **Internet of Things (IoT) is currently changing the world, In addition, its applications cut across all human endeavors. The challenges are: how can IoT become a successful and sustainable technology in the nearest future just like its mother the "internet" and any other successful technologies? How can IoT successfully be an integral part of our daily lives in a sustainable manner? This paper proposes new IoT architecture with design styles at each layer of the architecture. The architecture is proposed with the aim to facilitate sustainable adoption of IoT, applications in our society. It looks more into bridging the gap between IoT demands and supplies by connecting public and business values of IoT on one hand and technologies and applications of IoT on the other. Recommending architecture design styles at each layer will ensure rapid development and reuse of IoT solutions and the platform layer where IoT is offered as service will encourage more access to and development of IoT applications and services. It takes care of security and privacy issues at every layer of the architecture.**
The main objective of this paper is to propose a new architecture and architectural design styles to ensure increased and sustainable adoption, rapid development and reuse of IoT systems and applications.

Keywords: **IoT Architecture, architectural design style, IoT adoption and sustainability, IoT business model.**

I. INTRODUCTION

While the IoT is machine-to-machine technology, it is also an evolution of the Internet. IoT brings the Internet out of the computer and puts it into the real world. This merging of the physical and online worlds gives us not only greater control, but also greater insight into how our world works. With this new understanding, we can improve efficiency in all aspects of a business and our society. Its applications bring convenience and sustainability to the world. But, a lot has to be done for sustaining IoT as part of our lives and the society.

1.1 Technology adoption theory:

The work of Geoffrey Moore's has proven that technology penetration into the society with time reveals the pattern of S-curve (or sigmoid curve) as shown in Figure 1. Further, IoT is not going to be an exception. There is high tendency for IoT to follow this same pattern.

Figure 2 illustrates that technology adoption/penetration passes through different stages that can be identified. Each stage is peculiar to a group of people. According to Moore, there are five groups; each stage is for each group. They are: innovators, early adopters, early majority, late majority and the laggards. So, the technology innovation starts with the innovators (technology innovators), and quickly get adopted by the visionaries (early adopters/economic buyers), who envision the strategic advantage of the potential technology.

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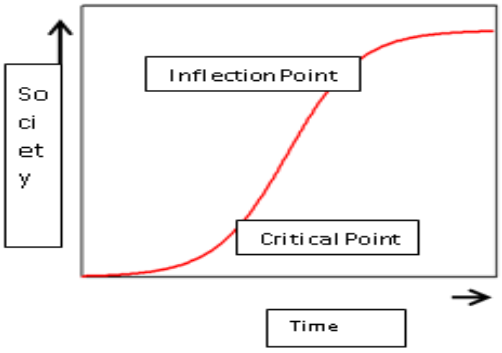

Figure1. Critical point and inflection point

The visionaries determine whether the technology potential advantage is worth assuming the adoption and cost-benefit is feasible. If it is worth being invested, the adoption begins. In that case the rate of adoption starts slowly at this initial time. Then, the technologist enthusiasts (early majority/technical buyers) expect and appreciate the new technology, and will investigate in its merits. The most difficult step is making the transition between visionaries (early adopters) and pragmatists (early majority). This is what Moore refers to as CHASM. Crossing the Chasm is passing through the critical point. Beyond the critical point, the technology adoption grows by itself and moves rapidly. Early majority begins to adopt the technology and growth continues until it passes through a point called inflection point where late majority begin to adopt the technology. After this point, its increase slows down (increases at a decreasing rate) [1].

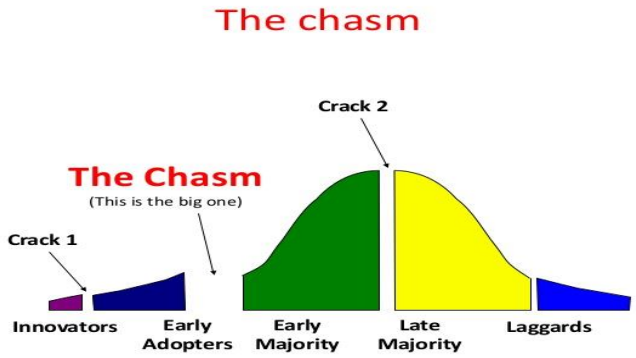

Figure 2. Geoffrey Moore's Group of technology adopter by Henrik Berglund

Just before these two points, adequate measures are needed to be taken to cross the chasm and also maintain the level of success after the inflection point. With all indications it is evident from [7], [8], [9] and [10] that IoT is still at the early stage and it has not crossed the CHASM. Also, Gartner in its 2016 hype cycle, indicated that it will take IoT 5 to 10 years from now to reach the plateau [12]. Measures should be taken in the of form of policy, standards, guidelines, frameworks, awareness, sensitization etc. Few cities [2] and top organizations are currently adopting IoT for operations. For IoT as a technology to pass the critical point identified by Moore, deliberate actions are needed to be taken. This is why this paper proposes a new architecture and architectural design styles as contribution to ensure increased recognition of benefits, sustainable adoption into the society, rapid development and reuse of IoT systems and applications.

II. LITERATURE REVIEW

2.1 Related Works: IoT Architecture in Retrospect:

In retrospect with IoT architecture, the various proposed architectures are almost similar. In the past, the most common generic architecture has the following layers: sensing/perceiving/access, internetnetwork/interconnecting/transport, service/application layers respectively [2] [3] [4]. Recently, a new development was just added to IoT architecture in [5]. This article suggests business layer as part of IoT architecture. However, the business layer suggested in that article is more inclined into business reporting of IoT services and activities based on the data generated at the sensing layer. Also, most of the architectures did not really consider security layer as integral part of each layer of IoT architecture. Finally, there is need to look in the direction of having IoT as service for rapid deployment of IoT applications.

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III. PROPOSED IOT ARCHITECTURE WITH ARCHITECTURAL DESIGN STYLES

This architecture is aimed at bridging the gap between IoT demands and supplies by connecting public and business values of IoT on one hand and technologies and applications of IoT on the other hand. This could be achieved by adopting a sustainable architecture that could bridge the gap between IoT business value and its applications. Recommending architecture design styles at each layer will ensure rapid development and reuse of IoT solutions and the platform layer where IoT is proposed to be offered as a service will encourage more access to and development of IoT applications and services. It takes care of security and privacy issues at every layer of the architecture. The business layer is proposed to ensure user-led innovation and maximum values derivation from IoT as well as overall goal of having a single global IoT [10]. The four lower layers of the architecture will leverage on the existing IoT protocols, open standards in the industry to ensure interoperability, compatibility, security, privacy etc. with consideration on the constrained nature of IoT devices.

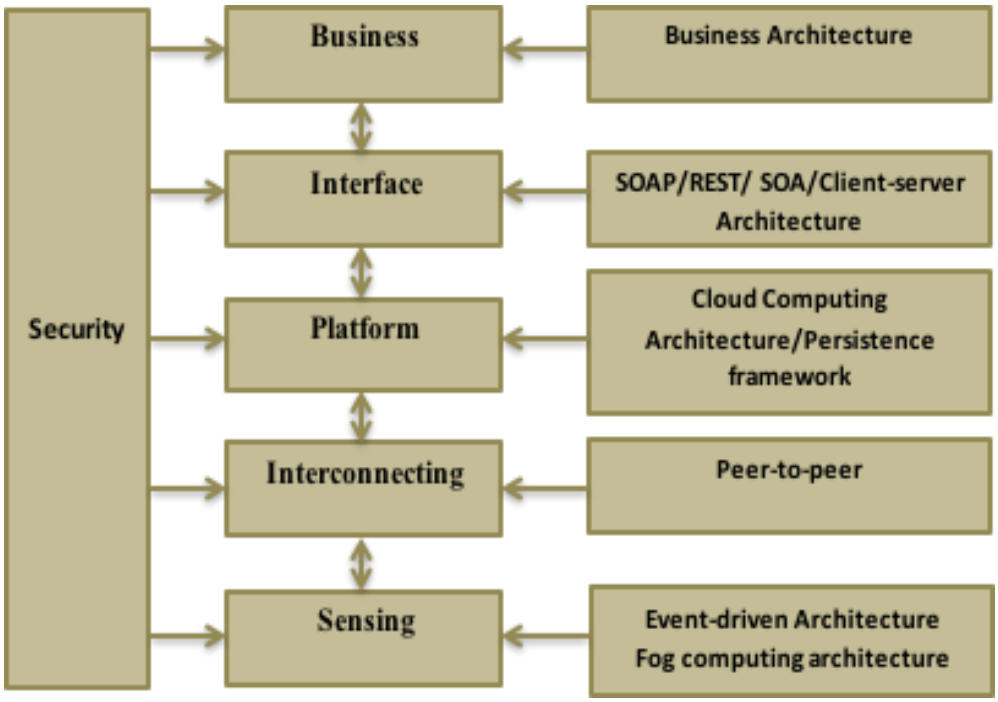

Figure 3. The proposed IoT Architecture with architectural design style

Business Layer: This layer serves as a means to demonstrate and analyze investment opportunities and risks to the potential investors, organizations and governments who want to invest their scarce resources in IoT applications and solutions. This means that there should be a global, regional, country or sector specific IoT business model that is enough to guarantee investors of a return on investment. Also, this will serve as checklist for IoT devices manufacturers, IoT application developers when conceptualizing IoT solutions by creating win-win business relationships with the stakeholders and build what users want to use. It means IoT researchers and application developers need to work closely with businesses and governments. There is need for a common platform that brings academia, innovators, business and government on a round table for deliberation on major innovations in IoT industry from public-values rather than technology-applications perspectives. This layer will as well take into consideration the issue of IoT governance at global, regional, country or sector levels respectively. IoT governance will be able to address other issues such as interoperability of existing but dispersed IoT solutions, scalability and sustainability of IoT at different levels of society.

This will immensely contribute to the success of IoT in the nearest future by bridging the gap between IoT technologies/ applications and public/business values so that IoT solutions will always meet organizations and governments needs/requirements at a given point in time. At the same time, this will motivate organizations and governments to develop their organizational or national IoT policies and investment plans.

Ultimately, this layer makes claim for the need to recognize and make provision for IoT as a global critical infrastructure since the goal of IoT is to connect everything; meaning society will heavily depend on it. A new IoT business architecture and governance models is a research recommendation for the future.

Interface Layer: This is where services and applications are defined based on requirements from investors, users, organizations and governments. The services should be accessible, cost effective and sustainable. Also, it's a medium through which users interact with the Platform layer through well-defined interface requirements that support variety of technology platforms. SOAP, REST, SOA, Client-server design styles are recommended at this stage.

Platform Layer: This layer serves three purposes. First, the requirement here should ensure that IoT is provided as a service through service providers. This will ensure rapid deployment of IoT applications and services by the developers. It will also make it easy for all developers to seamlessly integrate IoT solutions into the platform. Second, the platform is required to manage those services being provided at the interface layer. Lastly, the platform is to store lower layer data into the database. In addition, this layer is required to have capability to retrieve, process, compute information, and then automatically decide based on the computational results to help the business and organizations make decisions.

Analytics is at the heart of any IoT solution. This will also ensure real time monitoring of IoT devices and sensors. These are key requirements for making the promise of the IoT a reality. Cloud computing architecture design style and persistence framework are recommended in this layer, therefore security of this layer with sophisticated and advanced hybrid threat modeling might be favourably considered [11].

Interconnecting Layer: This layer is the connecting link between the sensing layer and platform layer. Its role is to transfer information from the sensing layer to the central information processing system at the platform layer. Example of IoT technologies and protocols at this layer are: Cellular Network (2G, 3G, LTE etc.), Satellite and/or LPWAN, IPv4, IPv6, 6LoWPAN etc.

Peer-to-Peer architectural design style is recommended at this layer. Peer-to-peer consists of independent components connected through network protocols. It is based on IPv4 and IPv6 and other routing protocols.

Sensing: This is the outmost layer of IoT, which is responsible for perceiving and responding to state changes. This is where all sort of devices are connected and data are generated. The primary functions of this layer include 1) perceiving the state changes of the thing itself or the environment, and transmit the information to the interconnecting layer in specific format; 2) receiving commands from the information processing system layers, and making responses according to commands [2]. Example of IoT technologies and protocols at this layer are: Geomatics or 3S (RS, GIS and GPS), RFID, sensor, WSN, WPAN, 802.15.4, Zigbee. Z-Wave etc. Event-driven architecture style is recommended at this layer.

Security: This layer is an integral part of all the layers described above. Security and privacy has been a major issue in IoT world. This layer defines specific security policies, standards, frameworks and challenges at each of the above layers.

IV. CONCLUSION AND FUTURE RESEARCH

Internet of Things (IoT) is going to be one of the most successful technologies the world has ever known if proper measures are put in place for its sustainability. This paper proposes the architecture for its sustainability taking into consideration factors such as public/business values in relation to the IoT applications, security at all layers of the architecture and service platform for rapid deployment of IoT solutions where IoT can be offered as a service.

The business and the platform layers proposed in this paper with their functions are aimed at making sure IoT cross the chasm in the shortest time possible and penetrate into lower rank of the society as well. In the nearest future, there is need to conduct detailed research into the business aspect of IoT to canvass for a standardized IoT-Big Data Analytics business model for investors and users (Government and private sector organizations) to guarantee return on investment and build trust between IoT applications developers and businesses. In order to also build trust and privacy in global IoT market, there is need to proffer security solutions at each layer of the architecture. More researches need to be carried out on standardized IoT security.

Most importantly, there is need to research more on the platform layer for a need to have decentralized yet interoperable platforms that constitute global IoT platform. The proof of concept for the architecture is being carried out on application specific cases for future publication. The proposed design styles as they are related to each layer is also next future research work.

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