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Internet of Things: Impact on Economy

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Abstract

The Internet of Things is expected to bring a revolution in the way objects around us communicate with one another and human beings and the way this information will be gathered and distributed. This also means a resultant increase in internet usage and the challenges of securing information over the internet. This paper looks at what components make up the internet of things and its business viability in our ever changing world. Despite security challenges of communicating over the internet, it still remains the leading means of communication and our dependence on the internet and mobile technology is only expected to increase.

Keywords: Information and communication technology; internet of things; protocols.

1 Introduction

The advent of the internet and continuous advancements in information and communication technology (ICT) has led to more effective and efficient modes of communication. Handheld devices, such as mobile phones and tablets, have made ubiquitous information processing feasible.

In addition to handheld devices, more objects are becoming embedded with sensors and gaining the ability to communicate. Conventional modes of information gathering involve proprietary

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information stored in databases before being analysed. This information is generally gathered externally from public sources, the net or information vendors. These ways of transferring information are already changing: objects in the physical world are becoming sources of information [1]. Michael further explains the Internet of Things as sensors and actuators embedded in physical objects and are linked via wired and wireless networks generally based on the same Internet Protocols (IP) that connects the internet.

Once something has a unique identifier it can be tagged, assigned a uniform resource locator and monitored over a network. The Internet of Things (IoT) has also been defined as a scenario in which everything has a unique identifier and the ability to communicate over the internet [2]. It has also been coined as the ability to seamlessly gather and use information from objects in the surrounding environment [3].

For the purpose of this paper, IoT can be defined as objects that are embedded with microchips that allow them to gather and communicate required information to various servers and databases for processing over the internet. Objects or things, in this context, range from people, household appliances, animals, cars, servers, and park benches to any conceivable object (See Fig. 1).

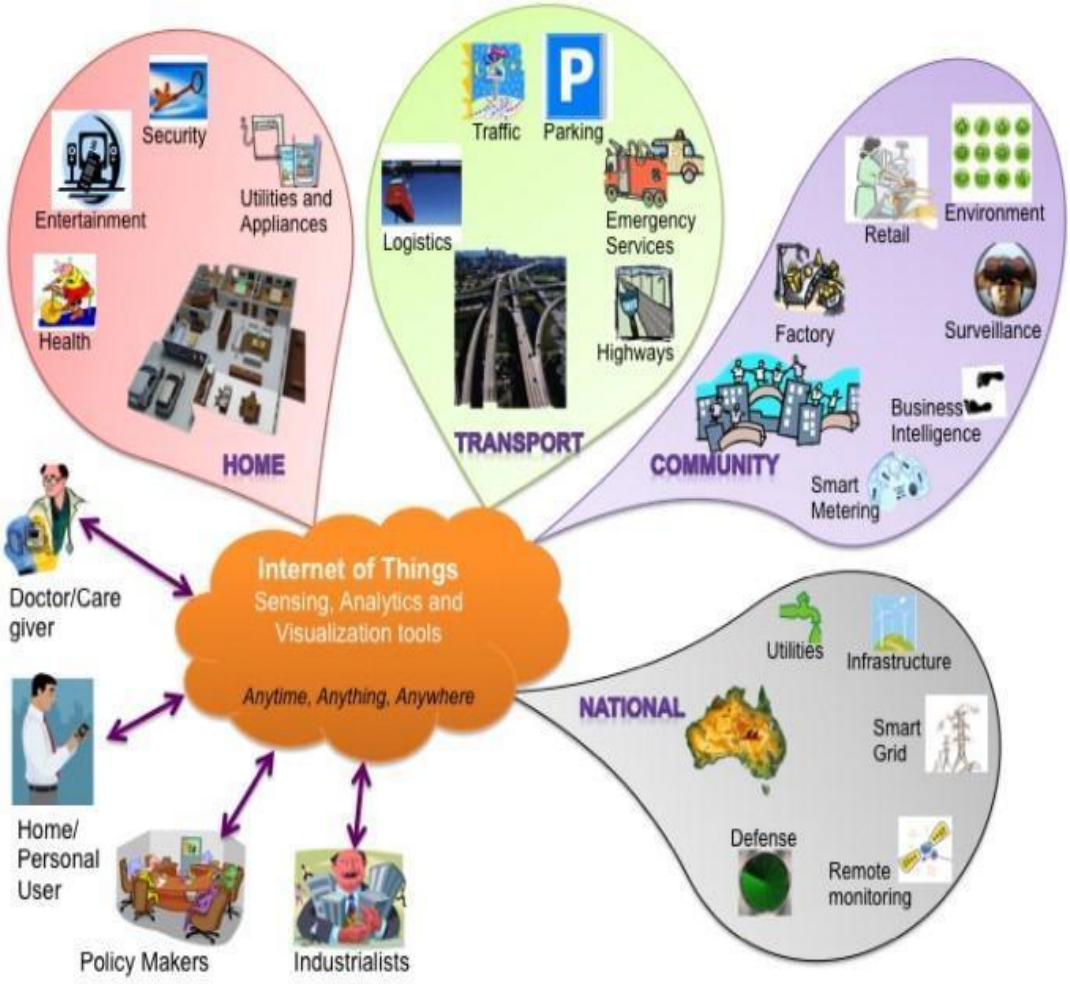

Fig. 1. Source [15]

This paper takes a look at the various technologies that make up the internet of things, the IoTs impact on the society and the economy; some challenges of IoT and the future evolution of IoT with a view to finding how it can affect the general the economy and the way we do things.

2 Technology Behind Internet of Things

For multiple devices to communicate there are challenges of device communication management. The IoT unlike normal computing devices that have a time scale based on entry and completion of tasks, devices will be connected at all times throughout the year sending information to various locations constantly [4]. This in turn implies that devices have to provide some smart functionality. Generally, there could be over 100 household or company devices simultaneously connected to the internet (lights, refrigerators, ovens, TVs, games, etc.) [3].

According to Chavez, smart functionalities for devices are generally grouped into five categories:

1. Information Storage,
2. Information Collection,
3. Communication,
4. Information Processing and
5. Performance of Actions.

2.1 Information Storage

Traditionally information is stored in databases or on database servers depending on the size of the organisation or what the information is required for. Information stored by these smart devices can either be static (e.g., production/expiry date, inventory records, and owner) or dynamic (e.g., temperature, location, appliance in use or static). This information can be stored in various ways ranging from read-write or read-only and can also be stored in drives, barcodes, etc. [3].

A team of researchers from Microsoft and the University of Texas at Austin have developed a filing system called “bolt.” This system combines and filters information from various disparate sensors allowing various electronic devices such as refrigerators, surveillance cameras or heaters stream data into a secure remote storage location, such a cloud system, for sharing with other devices at other locations [5].

2.2 Information Collection

Devices may also be required to autonomously gather information for various reasons. Such information could include, room temperatures for heating devices, locations or even time or durations. Aside from monitoring object locations information can be gathered for maintenance checks [3].

Knightscope, a company founded by William Santana Li, created a line of “Autonomous Data Machines” namely the k5 and k10. These machines are expected to gather environmental information and feed them back to organisations that own them to aid in building their data assets and improve critical decision making. The creators expect these devices to be used in areas such as construction sites, to monitor construction progress, to aid in keeping inventory in industries and even for various research purposes such as statistics gathering [6].

2.3 Communication/Protocols

The ability for components to communicate with one another and servers across the internet or other communication platforms is achievable in a wired or wireless scenario. Wireless

communication is possible using radio, light waves or sound waves. Device communication is important for alerts and notifications to other devices or the users of such devices as well [3].

For systems to communicate over the internet certain protocols are used to govern such communications. Various forms of communication that exist include Device to Device (D2D), Device to Server (D2S) and Server to Server (S2S). Governing protocols contain:

- **XMPP**- Extensible Messaging and Presence Protocol (an open technology for real time communication D2S),
- **MQTT**- Messaging Queuing Telemetry Transport (a lightweight D2S/D2D publish/subscribe messaging transport),
- **DDS**- Data-Distribution Service for Real-Time Systems (an international middleware standard addressing publish/subscribe communications. It's also a fast bus for the integration of intelligent machines D2D.)
- **HTTP**- Hyper Text Transfer Protocol (for communication between devices and servers over the internet D2S/D2D/ S2S)
- **AMQP**- Advanced Message Queuing Protocol (a queuing system that connects servers to other servers and also messaging orientation and routing S2S). These are just a few of hundreds of protocols supported by the IOT [7].

2.4 Information Processing

IoT harnesses the data gathered from various devices for decision making and predefined actions. The processor of a digital computer processes information to produce understandable results. Processing includes, information gathering, recording, assembling bits of data together, retrieval or dissemination of information [8].

IoT means that many items in a given environment will require internet access and data processing. Large amounts of data will require processing at a time making it necessary to have sophisticated microcontrollers and microprocessors that can possibly communicate with other devices in their environment [3].

2.5 Performance of Actions

Objects fitted with IoT microcontrollers may also have the ability to take action based on actionable data provided. Such actions could include, turning on a sprinkler or heater or even locking doors or setting of alarms and includes any action that could affect the current state of the real world.

3 Impact of IoT on Society

Some have tagged IoT to be bigger than the industrial revolution and the resulting innovation that will follow as a result. Basic home and office appliances are already communicating with one another. Such systems are already creating large amounts of data on us making the information a marketer's gold mine [9]. He adds that tech giants have already joined together to make the IoT a reality in our homes, cars and lives. These mammoth companies include Cisco, Panasonic, Sharp and others fitting their various devices and appliances with compatible network communicating devices to allow for device to device communication.

IoT has also been identified in Gartners' IT Hype Cycle as one of the emerging technologies (see Fig. 2.). A Hype Cycle is a way to illustrate the emergence, adoption, impact and maturity of emerging technologies [15].

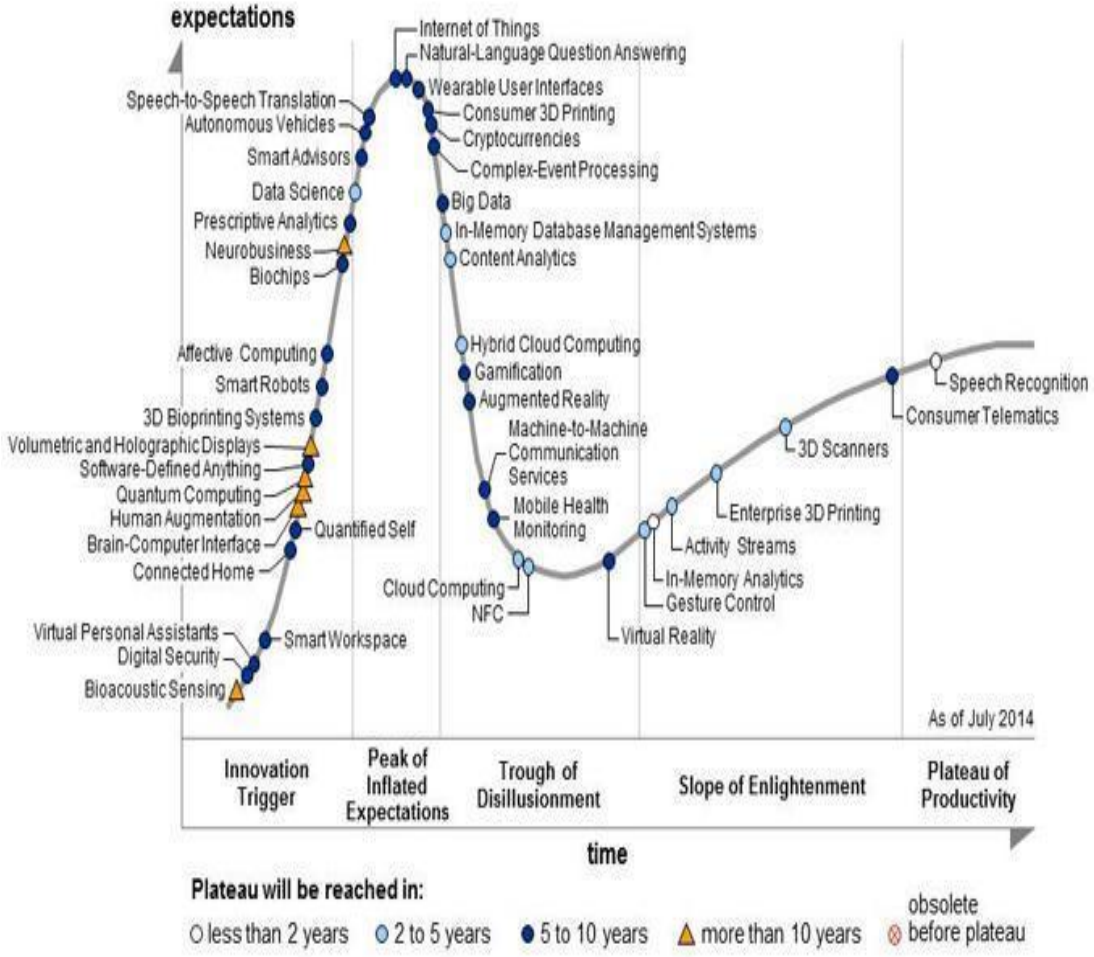

Fig. 2. Gartner 2014 hype cycle of emerging technologies

Some of the changes that could be coming to our everyday lives could include:

1. **Auto tune ups**; where your car would pre-emptively alert you and your mechanic on when a tune up is required or a part needs replacing.
2. **Health Monitoring**; using connected RX bottles, appointments could be made with physicians when prescriptions are running low. Doctors can also know how often you are taking your medication.
3. **Energy Consumption**; high energy consuming appliances such as light bulbs and thermostats would adapt themselves to your habits. Knowing what time you usually arrive home or go to bed and other details could influence when they turn themselves on and off to save energy costs.
4. **Traffic Jams**; traffic lights will be able to adjust themselves to traffic based on time of day or sensors to inform the system of what area of oncoming traffic needs to be attended to longer.

These and many more similar systems will come into play in our everyday lives. It is highly likely that smart phones will soon become a remote control to our daily lives.

John Chambers, Cisco's CEO, believes that in ten years the "internet of things" is going to be 10 times bigger than the internet in terms of impact. Chambers added that when he first joined Cisco there were about a thousand things connected to the internet now there are over a billion [10].

According to the latest Strategy Analytics data, in 2013 alone over 1.9 billion Wi-Fi enabled consumer electronic devices were shipped placing the estimated average number of Wi-Fi enabled devices (other than computers) at 7 in the average home. A study conducted by Wi-Fi Alliance shows that Wi-Fi connectivity has already become a purchasing norm for 77 percent of consumers when choosing new products for use around the home [10].

4 Challenges of IoT

IoT also comes with some challenges and disadvantages. There are currently no international standards for compatibility of IoT components. Standardisation is a process that takes time and requires collaboration from various bodies and vendors especially manufacturers.

Since communication is largely machine to machine there is the possibility of a hacker hacking the system and changing information such as medical prescriptions, orders, delivery addresses and so on.

IoT also has the downside of increased points of failure. This is so because each independent device or access point can potentially fail leading with the option of redundancy meaning only an increase in the number of devices and the complexity of the system. [16]

5 Positive Impacts of Internet of Thing on the Economy from a Broader Spectrum

Internet of things is still in its infancy as some of its concepts and technologies that would enable its full implementations have not yet become household concepts. It will take a gradual process before the concepts of autonomous embeddable device to device communication – (the bedrock for IoT) become part of the daily lives of the internet users but until then, the IoT will first find its acceptances in mini networks, in industrials, household appliances, etc. In the long run, when it eventually gain acceptance and full implementation, there is likely going to be a boom in certain markets involving certain key players in the industries; these are

5.1 Telecommunication Industry

It is recognizable that with the IoT billions of devices will be online and network connectivity will be required by these devices to communicate. More device connectivity means more subscription for data services from telecommunication providers.

It has been found that the total traffic volumes for mobile phones in 2012 alone exceeded all the previous years combined and global data is projected to grow by 66% per annum through 2012 to 11.2 exabytes per month – this is equivalent to more than 5 billion hours of HD video [11]. This increase is fuelled by the increase in the number of connected devices to the internet. More and more smartphones that are actively connected to the internet are appearing. According to [12] there were 500 million devices connected to the internet as at 2003, by 2010 this number grew to 12.5 billion and this growth was majorly fuelled by the explosive growth of smartphones and tablets PCs. With the advent of smartphones and tablets PCs and advancement of IP technology services like VoIP, Internet Streaming, Instant Messaging, and new evolutionary services still springing up, the prediction by the Mobile Economy of over 11.2 exabytes per months by the year 2018 can be

easily justified, by the way, this estimation is even without the full implementation or introduction of internet of things.

The obvious extrapolation and possibly next question will then be, what would be the growth of the subscriber base and total volume of traffic with the introduction of IoT? Cisco's IBSG already predicts that there will be 25 billion devices connected to the internet by 2015 and 50 billion by 2020. This is estimate according to IBSG does not even take into account advances in internet or device technology. When advances in technology and the population of connected persons are factored into estimating the growth of the number of devices connected, it will probably exceed the estimated 50 billion by 2020. It is commonly deduced that the number of actively connected devices to the internet the more traffic volume generated. This forecasted trend is good for business especially the internet providers and mobile operators who charge per data transmitted and received. Therefore the overall business market of connectivity for these devices is surely going to thrive.

5.2 Hardware Manufacturers

The proliferation of microchip and microprocessor technologies have brought about a tremendous growth in hardware manufacturing as smaller devices are now possible because of the reduced size of the average microprocessor. This can lead to a reduced cost of hardware manufacturing especially when the cost of materials is also reduced.

However, majority of these hardware devices range from mobile to personal computing devices. Even though wearable devices are still finding their way into the technology market, it hasn't fully penetrated every corner of the world especially Africa. With internet of things, it is expected that billions of devices would fill the internet superhighway and these embeddable devices would have to be produced by hardware manufacturers. Already, there is a huge increase in the number of connected devices [12], so the market is obviously booming for hardware manufacturers already and with IoT things are likely to get even better.

5.3 Information Miners

The internet itself contains a plethora of information that can be mined and put to use in several spheres of the society. Already, enabling technologies, such as web services, semantic web, and data mining tools leading to artificial intelligence can leverage complexities of data and make machine to machine communication less complicated. The next major step is to have a scenario where data transfer, collection and analysis is not initiated or triggered by humans but by machines. With internet of things information gathering and analysing can be initiated by machines embedded with sensors and actuators that get triggered based on certain scenarios or events [3], therefore eliminating the need for human involvement in the data transmission and processing chain. This will in-turn make it possible to get real-time data analysed on the fly and information from these analyses can be channelled to various areas of human development.

Atzori et al. [13] already outlined the huge impact data obtained from internet of things would have in our daily lives. With the proper data mining tools and real-time analysis of data in these domains, the advantages are enormous. He outlined several domains in which IoT can have profound impact in our lives, these areas are; Transport and Logistic Domain, Healthcare Domain and Smart Environment.

i. **Transport and Logistic Domain:** The applications of IoT in these areas would mean having a large volume of data generated. Take for instance, in the transportation and logistics domain where cars, bicycles and roads are equipped with sensors, actuators and processing power to be able to send real-time data to traffic systems to better manage road traffic. This information could help provide data as to density of traffic situation in a

city which will in turn provide information as to the estimated amount of gas a city is expected to consume, the estimated rate at which cars would break-down due to overheating in long-traffic jam, the real time population of road users and more
Also with transport vehicle and goods tags, data mining subsystem could act on information generated to analyse shortage or surplus of certain goods in specific region so as place appropriate pricing based on demand and supply.

ii. **Healthcare Domain:** In the healthcare domain, Atzori et al. [13] outlined patient/staff monitoring, authentication and authorization as part of the benefits of Iot. As real time data is transmitted from patient to monitoring devices and doctors, real time analysis/patterns can also deduced. However, industries in charge of providing drugs can better analyse patterns of illness to determine production quantity in order to prevent wastage from expiration, insurance company can monitor trends and health pattern to provide an efficient premium rate. IoT in the healthcare domain would also bring about a plethora of sensing/tracking devices; this in turn will also boost the manufacturing and telecom industries outlined in the previous headings.

iii. **Smart Environment (Home, Office, Plant) Domain:** One of the benefits that a smart environment brings is efficiency, for example, it is economical for autonomous devices to sleep during inactive periods and resume during active periods. This will save energy and in turn save cost of providing energy to power devices.

5.4 Advertising Industry

Advertising will take a different dimension. The conventional mode of advertisings has always been a scenario where an advertiser creates a platform to advertise goods and services channelled to their appropriate receivers. The apparent question in advertising in an IoT world is how to penetrate the seemingly closed market. With object connecting to objects and leaving room for less human intervention, how can marketers advertise their products to a specific audience? However, this will turn out not to be the case because, even though the network seems autonomous in a way, it will still have some level of information feedback from end users which will eventually enable manufacturers and advertisers tap into the market.

Plowman, 2014 describes a situation where consumer moods can be read by autonomous devices and the data transmitted. This will allow advertiser to better channel their advert to the areas of need. In general, with Internet of things it is possible to get information and tie advertisements into the day to day lives of consumers and this way it is most certain to have sales increase because of the awareness of the trend of the market.

5.5 Big and Unexplored Market for Security Software Companies

The sensitivity of data generated in IoT makes it inevitable to place security measures that guard against attacks on personal information and even the devices themselves.

Majority of the devices that partake in IoT are most likely going to be devices with low compute power and memory, therefore it becomes difficult to implement compute intensive and/or memory intensive security algorithms on these devices. These limitations coupled with the predominantly wireless mode of node communication in IoT, brings to the fore, the problem of “man in the middle” attack on the network of nodes. Hence, a node with a much more high processing power and larger memory can be maliciously inserted into the network of nodes to intercept and corrupt data transfer from one end to another.

IoT is likely to bring about a whole new way of security data opening up research with the possibility that the first breakthrough will eventually lead to a boom in the security industry due to the number of possible devices that are likely to participate in IoT.

6 Future evolution of IoT

From the business perspective, the Internet of things is a fantastic phenomenon that will transform the way the internet is seen and experienced across the world. Businesses that revolve round the internet will experience a whole new feel of the internet and in general internet of things will bring about a positive drive to the economy.

However, the road is still not smooth for its full adoption and acceptance. Hence, there are limitations and drawbacks. These drawbacks can be seen from two angles;

1. **Technological Limitations:** For Internet of things to become a reality, several issues bothering, data integrity, communication, privacy and security would have to be resolved.

Due to the high number of devices that will be involved in an IoT scenario, it is possible that as data is routed from one point to another, its content can be tempered with by "man in the middle attack". This will mostly likely affect outcome and inference generated by intelligent machines and if these outcomes influence decision making in an establishment, then to a great extent integrity of the system will be compromised and will eventually lead to a massive loss of income.

On the other hand, Communication among the devices in IoT is not trivial. If network providers are to reap the benefits of IoT then there has to be stable and reliable mode of communication among devices in IoT. Already, there is a shift from IPV4 to IPV6 to solve the problem of addressing devices in IoT but a great subset of IoT devices would involve devices with low energy, memory and processing power making it hard to put existing network protocols into these devices. As an example, RFID tags uses 64-96 bits identifiers based on the EPCglobal standards for addressing as opposed to the 128 bits identifier required by an IPV6 network [13,14]. According to Atzori et al. [13] several solutions have been proposed but these solutions haven't effectively tackled the problem of mobility of RFIDs. Also, if IoT devices are to participate in the existing internet then there would have to be a way to resolve names and IP addresses among these participating devices. A lot of research is still needed in network communication among IoT devices before the great economic benefits can be achieved.

2. **The Human Factor:** For any technology or innovation to take the mainstream, the main parties involved would have to first of all accept the technology. Internet of things proposes a revolutionize way of life where machines or devices play active roles in human life by monitoring patterns, behaviours and responding to event based on the observed phenomenal. The question then is, to what extent would humans accept to have devices imbedded to their daily lives?

The guiding factor to accepting a technology is the notion that privacy and security is guaranteed. In the case of mobile phones, information can to an extent be kept private within the mobile phone even if the phone is a node in the "Internet of thing". However, technologies like RFIDs, CCTV cameras are the direct opposite when it comes to privacy and security of information.

Even though the advantages of these technologies greatly outweigh the disadvantages, it still places a strong drawback as users have to be guaranteed privacy and security of their information.

Take for instance, when a traveller arrives in a smart hotel room, it would be desirable if the room could check back with the smart house for preferences regarding temperature, lighting and configuring the television set with the right set of channels. It is therefore necessary that access to the smart house is granted to the hotel device so as to get these room settings but in the event that there is lack of trust, it becomes impossible for this to happen. Another instance is in the case of accidents, when an accident occurs, the victims would like their medical records to be available to the arriving ambulances to ensure that optimal treatment can be provided. In a medical scenario

such as this, it is therefore important for the participating party to trust the information coming from these devices.

However, it is difficult to advocate for trust when nodes in IoT are highly susceptible to attacks. Trust can be boosted by the development of better security software per node or better hardware that guard against attacks on data transmitted across nodes. Therefore, until a significant threshold level of IoT security is achieved, it may be bias to require humans to give up their privacy and place more trust on IoT.

7 Conclusion

Internet of things is a revolutionized concept with a lot of positive impacts in the society and looking at its benefits from the economic standpoint, it is even clearly visualized.

Already, there are enabling technologies to make the concept of Internet of things a success but until the bottleneck involving human acceptance which borders on security and privacy is addressed, the benefits it will bring will further be slowed.

In this paper, we have discussed the underlining technologies that drive the concept of Internet of things; we have also discussed the huge positive impact the full penetration of the concept of internet of things will have on the economy. We also outlined some of the drawbacks which will slow down the full penetration of the concept of Internet of things. Future research is also planned for IoT and its impact on society and other challenges that IoT may face.

Competing Interests

Authors have declared that no competing interests exist.

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