Industry 4.0: The Fourth Industrial Revolution And How It Relates To The Application Of Internet Of Things(IoT)

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***Abstract*— The fourth Industrial Revolution which is the Industry 4.0 in relation to the trending concept in the software engineering industries known as the Internet of Things (IoT) has a tremendous impact in our world presently. Internet of Things IoT emerged in the early 2000s and its beneficial application in various industrial sectors is discussed in this paper. The term IoT is an interconnected network of objects of different forms such as the wireless sensors network, electrical, electronic and mechanical devices, and their interaction with virtual data and environment via the internet. Internet of Things facilitates the communication processes of CPS on the basis of SMART concepts. This work also provided some statistical analysis using charts representation of data.**

Keywords— Wireless sensor networks; Internet of Things; CPS; SMART

I. INTRODUCTION

In the pursuit to achieving a high-technology strategy for year 2020, the concept of "Industrial 4.0" appeared first and was published in an article by the German government in November 2011[1]. After mechanization, electrification and information, the fourth stage of industrialization was named "Industry 4.0". In April 2013, the term "Industry 4.0" appeared again at an industrial fair in Hannover Germany, and quickly rose as the German national strategy [2]. This concept has being discussed vastly in recent years, emerging as the connecting access for most information industry and other industries globally therefore making "Industry 4.0" a new industrial revolution which will have a tremendous impact on international industry. The building of a Cyber-Physical System (CPS) to realize digital and intelligent factory, in order to change the manufacturing level to becoming highly digitalized, information-led and green mainly depends the concept of industry 4.0 which focuses on integrating information communication and technology (ICT) and industrial technology. Industry 4.0 which is led by intelligent manufacturing is considered to be the fourth industry which was created from the industrial revolution. Industry 4.0 is aimed at connecting systems and equipments to facilitate high product customization and automation, making mass production more flexible, effective and efficient. The industry 4.0 target is to develop a highly supple model for the production of personalized digital products and services in the production phase to enable interaction between people, product and devices in the real-time [3].

The efficiency through the use of hydropower, increased use of steam power and development of machine tools was achieved by the first industrial revolution; the second industrial revolution brought electricity and mass production of assembly lines; the automation using electronics and information technology was furthered accelerated by the third industrial revolution, and recently the fourth industrial revolution (Industry 4.0) is emerging which is led by CPS technology to integrate the real world with the information era for future industrial advancement. Cyber-physical systems (CPSs) are an emerging discipline that involves engineered computing and communicating systems interfacing the physical world. Cyber-physical systems (CPSs) perfectly integrate computation with physical processes, provide abstractions, modeling, design, and analysis techniques for the integrated whole. CPSs require computing and networking technologies to embrace not merely information, but also physical dynamics. The interactions among control, computing, network, and physical systems require new design technologies [4-5]. The levels of industrial revolution are illustrated in figure.1:

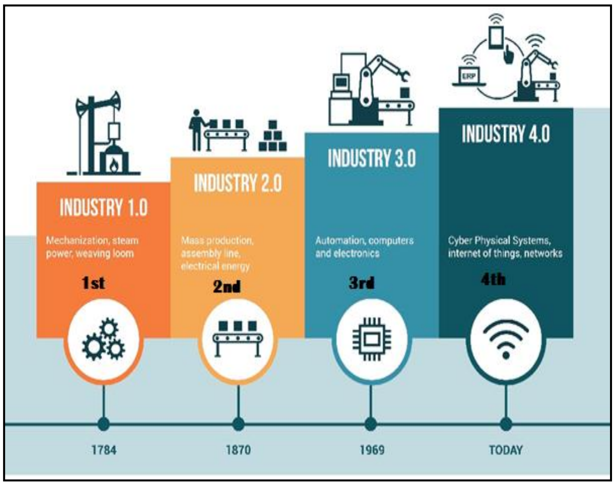

Fig. 1. *The Four Levels of the Industrial Revolution [11]*

The concept of Internet of Things (IoT) dates back to the 1999 and was originated by Kelvin Ashton a British technology pioneer. Most physical objects were made “SMART” by connecting them to the internet and also utilizing ubiquitous sensors; this became one of the factors leading to the gradual substitution of conventional computers and major changes in every aspects of our daily life today [6]. In the United States, the concept of SMART is adopted by the non-profit Industrial Internet Consortium (IIC) which is presently working on the future of manufacturing. Several technological concepts operates on Industry 4.0, including the fore mentioned cyber-physical systems and the already popular Internet of Things. This concept termed IoT facilitates the communication and cooperation processes of CPSs. Common IoT technologies such the wireless networks, intelligent or smart objects, sensory technology and the actuating element are used in Industry 4.0 by most Smart factories [7]. GSMA Connected life defined Internet of Things (IoT) as the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects. IoT is expected to spread rapidly over the coming years and this convergence will unleash a new dimension of services that improve the quality of life of consumers and productivity of enterprises [8]. CISCO referred to IoT as the networking of physical objects accessed via the internet, as defined by technology analyst and visionaries. These objects contain embedded technology which interacts with the internal states or the external environment. CISCO buttressed on their definition that when these objects can sense and communicate, it alters how and where decisions are made, and who makes them [9]. The International Telecommunication Union (ITU-T) viewed IoT as a global infrastructure for the information society, which enables advanced services by physical and virtually interconnecting things based on existing and evolving interoperable information and communication technologies ICT. ITU-T defined the things with regard to the IoT as an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks [10].

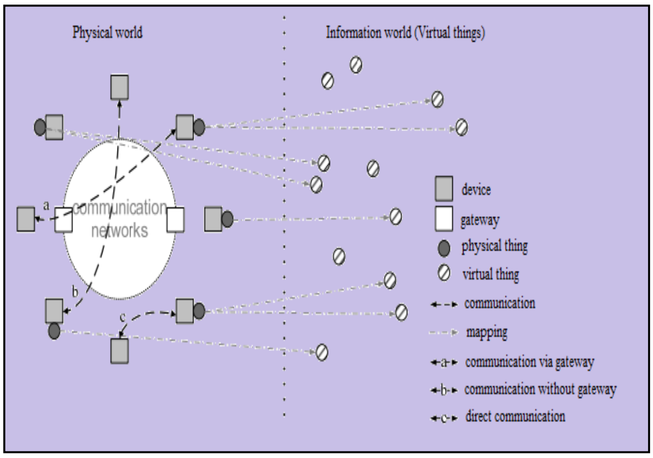

Fig.2. *Technical Overview of IoT [10]*

II. EVOLUTION OF INDUSTRY 1.0 TO INDUSTRY 4.0 .

- **Industry 1.0:** The use of water and steam power engine for mechanization of production.
- **Industry 2.0:** Mass production with the help of Electric Power.
- **Industry 3.0:** The Digital Revolution from analog to digital devices and signals. Use of Electronics and IT to further Automate Production.
- **Industry 4.0:** The combination of industry, automation, digitalization and the current Internet of Things (IoT) technology. It is also termed as the fourth industrial revolution.

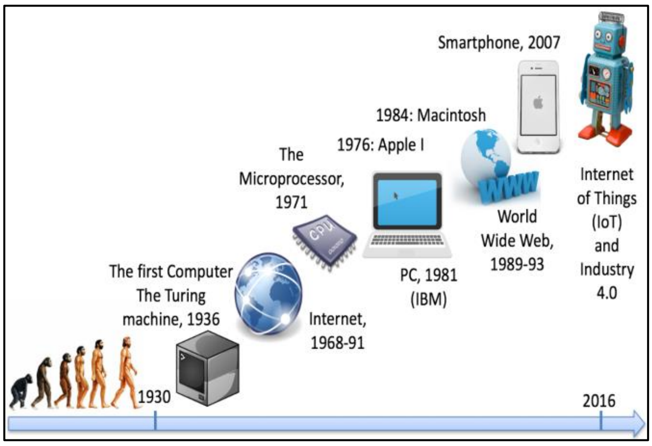

Fig.3. *Evolution of Industry 1.0 to Industry 4.0 [17]*

In addition to the evolution of Industry 1.0 to the Industry 4.0, some key terms are vital to the fourth industrial revolution (Industry 4.0) which includes [4]:

- **Big Data Concept**: Big Data in regard to Industry 4.0 refers to the user's behavior analytics, the predictive analysis, and other means that use large data sets and types to produces meaningful metrics and outputs.

- **Cloud Computing:** is the access to configurable resources which can be quickly managed with minimal interaction, using Internet infrastructures.

- **Cognitive Computing**: includes the processing of signals and also artificial intelligence systems such as natural language processing, recognition of speech, human-computer interactions.

- **Cyber Physical System:** The National Science foundation defines CPS as a system that contains both physical and software components which are intertwined, communicating with each other but the scale of operation is different and also exhibit multiple functions and output depending on the context of the situation [19].

III. UNDERSTANDING THE KEY FEATURES AND CHARACTERISTICS OF CPS AND IOT

Cyber-Physical-System (CPS) is made up of two main functional components: (1) The connectivity which is advanced and it majorly ensures real-time data acquisition from physical world and the information feedback obtained from the cyber workspace and (2) Intelligent data management, analytics and computational capability which construct the cyber space. When the capabilities and connectivity of a computational system is increased, it promotes the emergence of new systems with a typical features and characteristics of CPSs [12]. These are the characteristics of CPSs: (1) The CPS deployment in the applications of mass products such as the SMART-phone enabled services access; (2) The emergence of new cross-domain applications, for instance, the intelligent transportation systems; (3) The increase in openness, adaptability and autonomy. F.-J Wu stated that CPS applications have some unique features [13]:

1. User contribution and cooperation through give-and-take-like models: Participatory sensing would be common in CPS.
2. Cross-domain sensor sources and data flows: Multiple types of sensors will be adopted at the same time in intelligent CPS applications. Moreover, these cross-domain sensing data will be exchanged over heterogeneous networks.
3. Embedded and mobile capacity sensors: High-degree mobility of sensors based on the mobile devices makes sensors have the capacity of mobile sensing coverage over time.
4. Elastic loads requiring cloud-supported storage and computing capability: With the maturity of cloud computing, the pay-as-you-go concept is likely to be adopted in CPS to serve storage, computing, and communication needs.
5. Rich Interactions among many objects and things through the internet (such as IoT): A lot of sensor-sensor, sensor-actuator, actuator-actuator, actuator-user, user-user, user-object, object-object, object-thing, thing-thing, and thing-user interactions may occur in CPS applications. Such rich and complex interactions demand flexible communication channels like the Internet, to facilitate our applications.
6. Accumulated intelligence and knowledge through learning and data mining technologies: Under high dynamics and uncertainty of data in CPS, learning, and data mining technologies can be used to retrieve useful knowledge. Then, the feedback from user and actuators may help us to accumulate, or even discover unknown knowledge.

IV. APPLICATIONS OF CPS AND WHY IOT NOW?

The question "Why IoT now?" can be answered based on the following factors: (1) Ubiquitous Service and Connectivity; (2) widespread adaption of IP; (3) Computing Economics; (4) miniaturization; (5) Advances in data analytics; (6) Rise in cloud computing [14]. The application of CPS has been achieved in various sectors, these sectors include the reliable medical devices and systems, traffic control and safety systems, advanced automotive systems and process control systems, environmental control, energy conservation, instrumentation, critical infrastructures control, distributed robotics, smart building structures, manufacturing, smart grids, military and defense [15,16].

V. UNDERSTANDING THE APPLICATION OF IoT IN VARIOUS INDUSTRIAL SECTORS.

The application of IoT can be traced to the early stage of market and economic development which is the Machine to Machine (M2M) solutions, a subset of the Internet of Things – already use wireless networks to connect devices together and over the internet, with direct human intervention at minimal level, to deliver services that meet the needs of a wide range of industries. The Internet of Things represents an evolution of M2M through the coordination of multiple vendors' machines, devices and appliances via multiple networks and connected over Internet. There will be a reduction in utility outages and billing due to the connected smart devices, while the home security will be improved via the use of remote monitoring. An intelligent platform will establish innovations in management of energy, security and traffic management, sharing the benefits derived from technology across the society with the help of the smart grids development in the cities, the analysis of data and the autonomous vehicles [8]. The IoT SMART Cities application is illustrated in Figure 4.

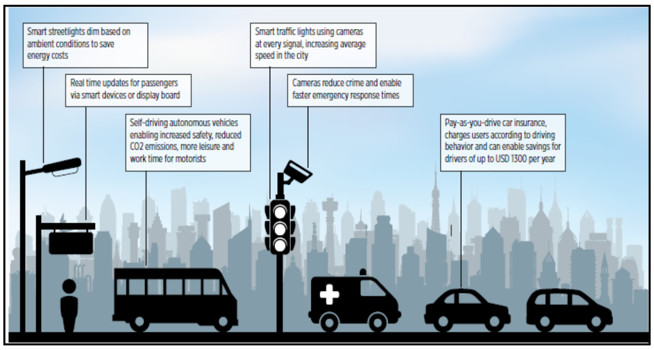

Fig.4. *IoT SMART Cities Application [8]*

The health and educational sector quality has been accessible and likewise been improved with the application of IoT. The challenges in the health sector in improving and enabling the monitoring of chronic disease and ailments conditions will be addressed with aid of connected SMART devices. By this, there is development in the quality of care and life for patients, while drastically reducing the stress on the wider healthcare system [8]. The IoT Health application is illustrated in Figure 5.

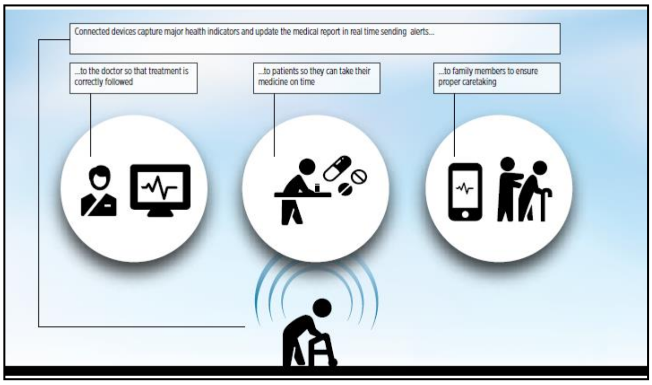

Fig. 5. *IoT SMART Health Application [8]*

The overall proficiency of student's need has been improved with the IoT application, by creating a link between the physical lecture rooms and virtual to ensure that learning process is more convenient and accessible. The IoT SMART education application is illustrated in Figure 6.

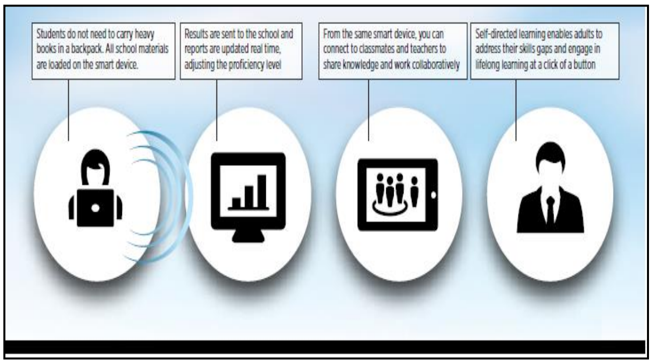

Fig. 6. *IoT SMART Education Application [8]*

In most meteorological sectors, the IoT application plays an important role; with the invention and innovation of ambient umbrella to gather constant updates about the weather forecast. The ambient umbrella is a technological advance device that provides information about the weather conditions to humans. A wireless data-radio chip is embedded into the handle of the umbrella to receive automatically data from the website. The handle of the umbrella continue to glow intelligently when snow or rain is detected in the forecast. This has help people and saved the stress of sitting long hours on the television or other media source to be informed about the weather [18].

Fig.7. *IoT SMART Weather Forecast with Ambient Umbrella*

STATISTICAL ANALYSIS.

Some statistical analysis were utilized in this work by the use of Bar-Chart, Pie-Chart, Radar or Web Chart and Line flow chart which was obtained from the data in the GSMA Connected Living on the Machine to Machine M2M connection by some regions.

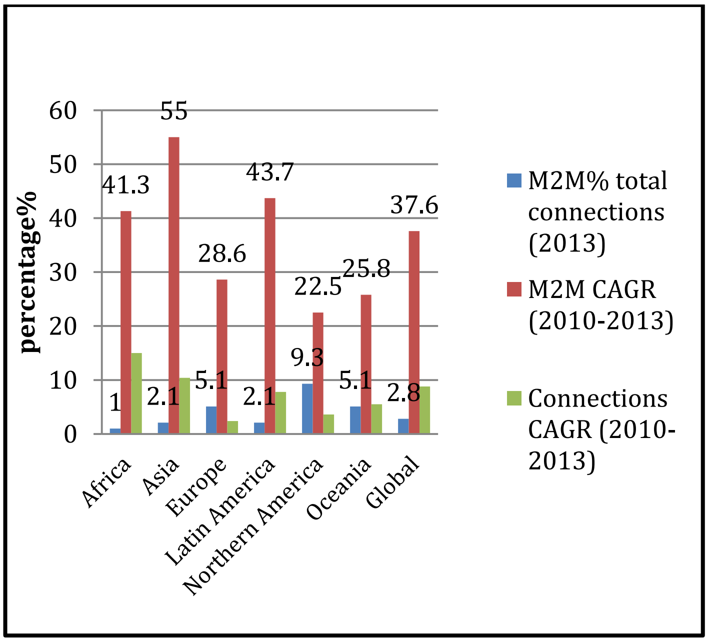

Fig.8. *Bar Chart of M2M Connection by Region.*

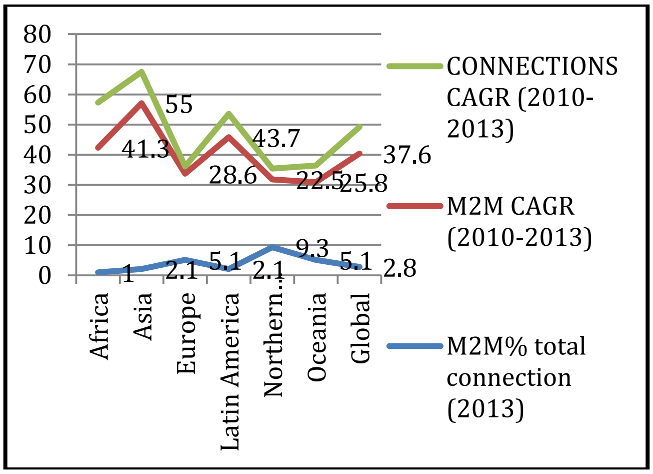

Fig 9. *Line graph showing the M2M Connection by Region*

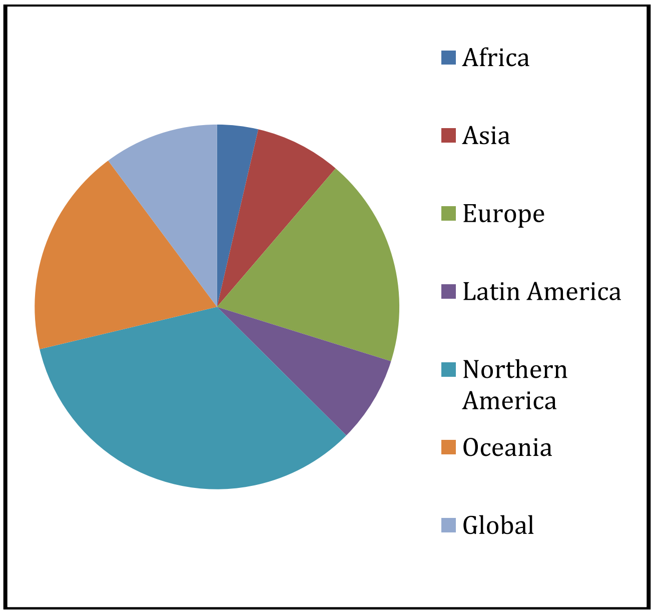

Fig 10. *Pie Chart of the M2M % total connections (2013)*

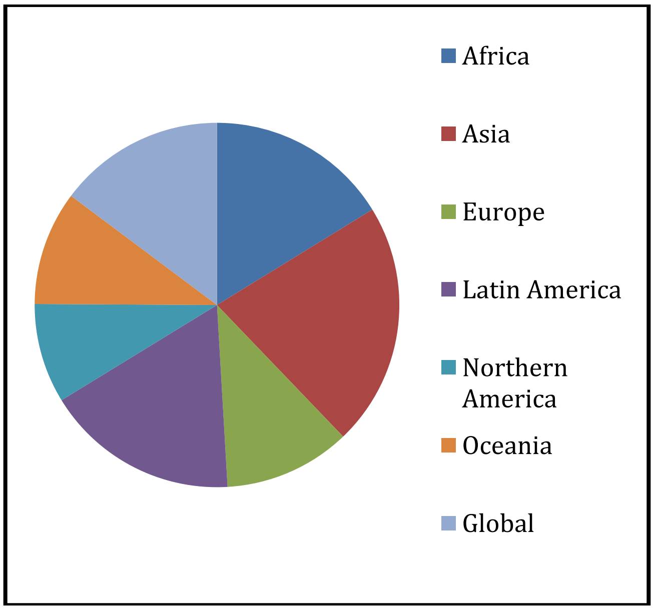

Fig 11. *Pie Chart showing the M2M CAGR (2013)*

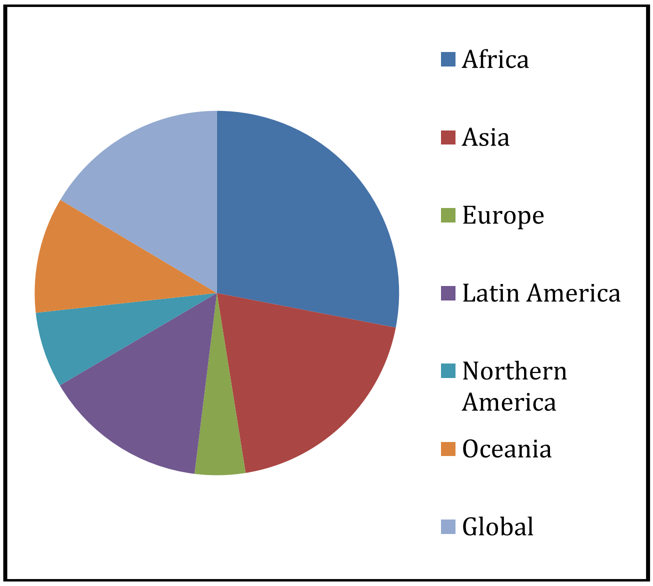

Fig 12. *Pie Chart showing the M2M% total connection (2013)*

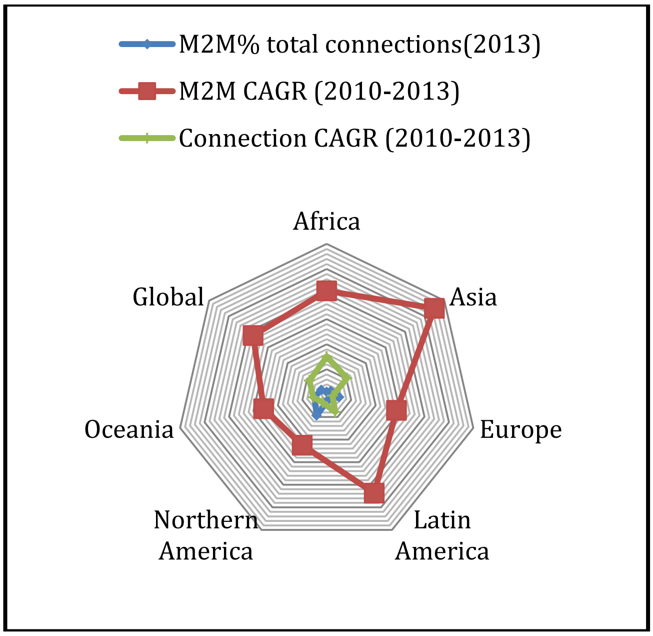

Fig 13. *Web chart showing M2M Connection by Region.*

CONCLUSIONS

The Internet of Things (IoT) is the foundation behind these two terms called the fourth industrial revolution and the Industry 4.0 which are the latest trends in the software engineering field today. In recent times, the implementation of IoT based on the SMART technology has tremendously improved and impacted in the new developments in our industries. Industry 4.0 is the one of motivating factors that will help in our factories today and in the future discover new ideas for manufacturing. Internet of Things has given us a step of change in the quality of individual's standard of living and the productivity of enterprises across diverse sectors today.

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