Emerging Advances and Trends in Internet of Things

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Abstract - With the advent of Internet, the world witnessed a revolution in terms of knowledge explosion and technological innovation, which evolved numerous inventions that found no frontiers in terms of advances and developments in the technological and scientific arena. One such modern industrial revolution is 'Internet of Things' (IoT), which signifies the operation, control, monitoring, regulation of devices using wireless sensor network (WSN) that ensures safety, security, process, control and operation in accelerating, enhancing efficiency and effectiveness of automation. For instance, influence of IoT in the fields of agriculture, construction, healthcare, space technology, defense, logistics, automation, remote monitoring, infrastructure, smart home, smart city, traffic management, transportation, process and appliance control, entertainment, and in many more domains ensures productivity without human intervention. In this paper the recent development and in trends of IoT viz., 'Digital Twins', 'Mesh Networks' and 'Edge Computing' is overviewed along with its applications in various domains in automation. Discussion and conclusions are drawn in highlighting these developments in racing towards automation that can minimize the dependence on human effort in creating an automated and sustainable world.

Keywords - Digital Twins, Mesh Network, Industrial IoT, Edge Computing, IoT Trends, IoT Analytics, Automation.

I. INTRODUCTION

The objective of 'Internet of Things' (IoT) being to sense, communicate and share information, which are all interconnected over public or private Internet protocol (IP) networks. These interconnected objects have data regularly collected, analyzed and used to initiate action and used for intelligent way of planning, managing any task and in decision making.

The IoT incorporates multiple long range, short range and personal area wireless network and technologies into the design of IoT applications. The different wireless technologies adopted in IoT being 'ZigBee', 6LowPAN, Bluetooth low energy, LoRa and various version of Wi-Fi including the recent IEEE802.\\ah protocol. These technology capabilities and performance about various metrics such as data range and rate, network size, RF channels and bandwidth and power consumption are evaluated.

The inference being that there is a requirement to develop a multi-faceted technological approach to enable and also to ensure interoperable and secure communications in the IoT. According to 2014 data, world's mobile data traffic was at 2.5 Exabyte per month and this will grow to 24.3 Exabyte per month at a compound yearly growth rate of 57 % in 2019 [1]. IoT is the fastest growing heterogeneous network of connected sensors and actuators attached to a wide variety of everyday objects. The estimated growth of IoT by 2020 is reflected as shown in Table 1.

Table.1 Distribution of Internet of Things (IoT) in Different Domains

S.No	Domain Name	Percent Share	Growth by the year 2020
1	Business & Manufacturing	40.2	• Number of connected devices: 50 to 200 Billion. • Estimated spending: $ 1.7 Trillion. • Cars connected by devices: 90 %. • Wearable devices: $ 1.74 Trillion.
2	Healthcare	30.3	
3	Retail	08.3	
4	Security	07.7	
5	Miscellaneous	13.5	

II. PREVAILING SCENARIO IN INTERNET OF THINGS (IoT)

The term of IoT was coined in 1997 by Kevin Ashton. The IoT is a network consisting of many objects with an on/off switch that connected to the Internet. Machines are connected to other machines and devices via sensors, sharing data and information with one another without human intervention. By connecting things, the system of machines becomes self-reliant, self-fulfilling and self-monitoring.

The IoT sensors are physical sensors, which digitally communicate the data and information they collect via Internet. Some type of sensors are used to track a number of metrics, while specific sensors meant for a particular application and the sensor transmits data by Wi-Fi, Bluetooth, cellular and by other methods. Sensors can sense factors pertaining to pressure and force, light, flow, sounds and vibrations, motion and displacement, electronic and magnetic position and proximity.

A. IoT vs. IIoT - Basically IoT and IIoT are same at their foundation and function. The IIoT is industry focused subset of IoT, while IIoT meant for the collection and distribution of much more complicated data than the consumer version.

B. IoT Microtrends - An interconnected communication made up of devices and nodes-physical, redistribution points that receive and transmit wireless signals is known as 'mesh network'. The mesh networks facilitate the signal to take small steps from device to device, boosting the signals and

enables the devices to be connected at reliable signal strength irrespective of their proximity to the network source. For effective functioning of a mesh, the nodes should be relatively unmoving to make the network stabilize such that the data delivery is ensured in an uninterrupted stream.

Mesh networks are relevant in business and in any other situation, where a series of connected devices in needed in a distributed computing environment. A mesh enables the IoT with huge number of objects to work in a single network and functions at the same level regardless of physical location. When a mesh is extended with additional devices, it can continue to carry original network signals at endless range.

These networks are vital for the efficient performance of IoT, as they enable devices to be more consistently connected to a strong and reliable signal. For example a small scale consumer-level mesh network is setting up a 'smart home' with interconnected devices viz., lights, ceiling fans, thermostats, fridge, etc., by this a home is interconnected through a signal access point. For a larger example a wind form with 40,000 acres can be connected via mesh network.

C. IoT Analytics - The IoT analytics encompass with huge data collected by hundreds of thousands of sensors for business, R&D, weather forecasting and these data analyzed for utility to arrive at decision or processes is significant. Frequently, sensor data can be coupled with other type of data viz., image and video analytics, geo-location information and machine log files. Mosaic of these data infers complete information of physical objects, how human beings and environment are interacting with these objects. The IoT analytics can manage 'business intelligence platforms' that merges sensors and machine data with other business data such as a firm's ERP system, CRM software or supply chain suites. The sensor data can be voluminous, then 'big data analytics' tools offers means of obtaining data trends, pattern and anomalies to make use of data or information as inferable data visualizations.

D. IoT Trends - A 'digital twin' is nothing but an exact digital replica of a product, process or service, which connects the physical and digital identity of a product. In this technique, IoT connected objects are replicated digitally, which enables simulation, testing, modeling and monitoring based on data collected by IoT sensors. Sharing and analysis of digital twin data enable firms in decision making that influences as indicators of performance. The aim of digital twin is to create test and build an object or equipment in a virtual environment [3].

III. DIGITAL TWINS

The digital twins technology was developed by NASA to assist in operation, repair and maintenance of spacecraft moving outside the range of physical monitoring. For instance, applying this technique, the ill-fated Apollo-13 was brought back to earth safely with craft and crew. Later on NASA used digital twins gathered sensor data and instructed the crew members to carryout remedial actions in case of any problem or crisis. The digital twin technique enables to design and build any object or machine virtually, prior to its physical manufacturing. According to Gartner's forecast that by 2021 about 50 % of large industrial firms would use digital twins, resulting in 10 % improvements in effectiveness of products [3, 4]. A typical illustration of a 'Digital Twins' indicating a physical asset that has to be rectified due to malfunction and the virtual asset of the same identity to diagnose the problem and then needed rectification or remediation is identified and executed to make the physical asset to function normally is as shown in Fig. 1.

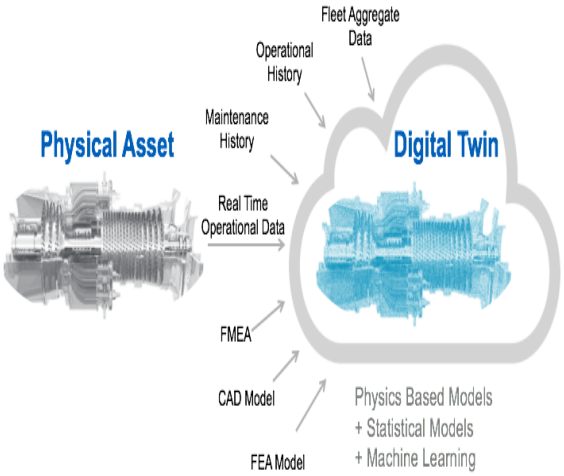

Figure 1: Digital Twins for Internet of Things [3]

The application of digital twins in a variety of domains viz., healthcare, manufacturing, automotive, etc., are indicated with salient examples. Interconnected digital twin systems can render its assistance by representing an entire hospital with equipments to the operations team to create a safe environment and expedited patient care. Digital twins can make virtual human twins and organs that can be completely studied and procedures can be simulated and tested prior to the actual task carried out on the patient, which minimizes mortality rates and to improve patient's treatment outcomes. Advances in IoT applications of health care is highlighted such as a bandage size sensors that could monitor a person's vital information viz., heart rate, blood pressure and oxygen levels and these data can be connected to a digital twin created exactly of a person's body to analyze the data by software to caution the doctor in case of any anomalies. Using AI integration, the software program can make diagnostic recommendations is viable at anytime, anywhere and not necessarily at the hospital.

The manufacturing industry is predominantly uses digital twins to address the issues related to manufacture of quality products on time, monitoring performance in real time to infer processes, ensuring output efficiency updates without the interruption of normal workforce using millions of data points collected throughout the plant area. Another domain

where digital twins application can be vital is automotive industry, which manufactures the autonomous vehicles i.e., self-driving cars. It is estimated that by 2020 there will be 10 million such automobiles on the road. Automobile producers can create a digital twin of every autonomous vehicle it sells, enabling to analyze the car's performance in its physical environment in its operation to ascertain its unfitness. The autonomous automobiles fitted with sensors to control the car's critical systems constantly and when the car is to be serviced, the auto-shop mechanic runs a diagnostic and indicates what is to be repaired. The next step being the data will be transmitted automatically to the manufacturer and the analysis of data, and then predictive analysis can suggest smart and safe driving tips to the car owners.

IV. EDGE COMPUTING

The 'edge computing' minimizes the quantum of time required to store and process the data from IoT devices, which are usually fixed where connectivity is unreliable and the data can be processed prior to its travelling/reaching to a cloud or data center. Data is the driver of IoT and the collection, transmitting and processing of massive data makes the firms to be more intelligent, smart and to arrive for better decisions. However, transmission of huge data to the traditional cloud networks can results in latency (delay in transfer of data). Edge computing is involving around IoT sensors to decrease latency and also to improve the efficiency. As per IDC (International Data Corporation), 45 % of all data generated by IoT devices will be stored, processed, analyzed and functions close to or at the edge of a network by 2020 [2].

Edge computing is a mesh network of data centers, which process and store data logically prior to transmission to centralized storage center or cloud. Edge computing optimizes cloud computing system to prevent disruptions or slowing in transmitting data or receiving data. Edge computing is executed on the 'edge' or 'periphery' of a network rather than data being sent back to the cloud or data center. Facilitating the computing power at closer proximity to the device sourcing and use the data, network latency can be reduced and sensors can function efficiently to share and receive critical operating data, which drives the business operations. Edge computing can be applied in many applications, but in case of IoT, it enables IoT devices to process the data closer to where it is fixed and operated and by storing some data locally, it expedites the process of gathering and sharing large data, which can be associated with an IoT linked device. Edge computing is very effective for IoT devices and applications, which rely on machine learning and extends large amount of data in case of a facial recognition, intelligent navigation or spatial awareness.

Edge computing is an evolution of the cloud computing model and both complement each other in terms of storing and processing of data more effectively. Edge computing provides stability and reliability, which enables businesses to automate data-driven decisions. Reduced latency where immediate data analysis is essential such as a machine has to be stopped prior to its overheating with faster response time is viable by edge computing. Sensitive data of organization (cyber security) can be effectively impacted by edge computing as the data is maintained close to the source prior to its transmission to cloud. Application of edge computing in various domains such as file storage and sharing (Dropbox Company), home automation devices (Nest Security Systems), etc.

General Electric's IoT platform 'Predix', which can support edge device up to 200,000 connections to single console, which enable faster and efficient processing at a low latency resulting in more powerful data generation and analytics. In manufacturing industry, machines uptime and functionality is significant in maintaining safety and productivity, which is enabled by edge computing effectively to access IoT data rapidly compared to cloud computing. Edge computing in conjunction with IoT sensors helps in identifying the exact location of objects in real time. It also used in 5G mobile network development, which cloud support enhanced data transmission speed, quality of service, network coverage, mobility, reduced network congestion, etc.

V. MESH NETWORKS

Mesh networks are networks consisting of devices and nodes (physical redistribution points, which receive and transmit wireless signals), which revolutionize the capabilities and scope of IoTs. Wireless mesh networks enable IoT devices to function in remote areas and expected to grow at a rate of 9.6 % compound annual growth rate (CAGR) during the forecast period from 2017 to 2023 [2].

The difference between traditional wireless network (TWN) and mesh network (MN) being the TWN transmit a signal from a central router, forming a radius in which device can be linked directly to the source and to receive signal, whereas MN is like woven fabric in which devices are interconnected. The diagrams of both TWN and MN are as shown in Fig.2a and Fig.2b respectively.

Figure 2(a): Traditional Wireless Network Diagram [2].

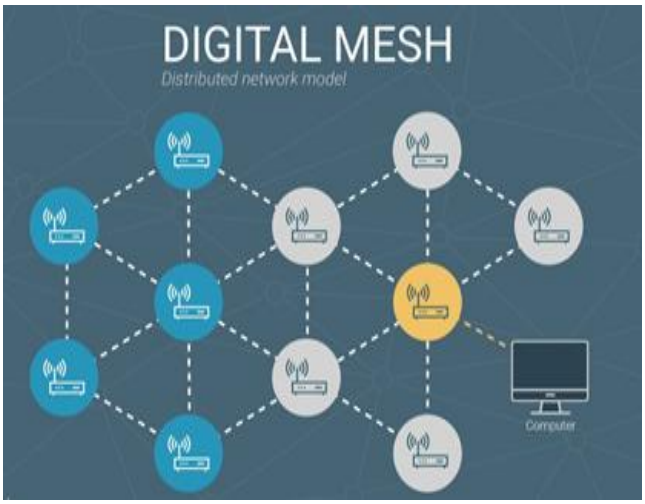

Figure 2(b): Digital Mesh Diagram [2].

In TWN wireless signal is sent from the modem to a router, which then sends signals to each Wi-Fi enabled device. In case of MN signals are passed to and from each individual node, or connected device, creating a web of connected devices. If one node is removed or has an outage, the mesh network is self-healing and wireless signals are sent to another device.

In TWN, farther away devices affected by attenuation in signal strength, at a certain distance the strength of a signal becomes weak for a device to connect. In the case of MN, nodes create network links with another node around them, in which signals passed from node to node in a number of paths throughout the mesh. In this configuration there is no loss of signal strength as mesh networks continues to scale endlessly, maintaining signal strength and the ability to send and receive data.

The IHS (IHS Markit Company) forecasts that the IoT installed growth of 15.4 billion connected devices in 2015 to 75.4 billion deices in 2025. Further growth of IoT devices would be 5 times in a ten years span and the mesh networks will enable consumers and businesses to link their devices without the requirements of dedicated hubs, which enables for the proliferation of network connected things.

VI. IMPACT OF MESH NETWORKS ON MODERNIZATION OF BUSINESS

The network is a critical consideration for a firm or establishment looking for digital transformation. Networks are basic facility for the collection and transmission of critical and confidential or sensitive data, which is essential to inform and evolve strategic, achieving efficiency, dynamic progress, smart development, skills enhancement, process modernization, etc. These required strategic for the dynamic growth and development is viable only with technology adaption and implementation, by mesh network enabled automation. Also to optimize the business processes, empowering of workforces and access for more business critical data, can be envisaged by switching over to mesh network business strategies and development.

VII. PROS AND CONS OF IoT

Automation of daily tasks and deeds in personal and professional life, in business, industry, governance, logistics, monitoring, etc., facilitates efficiency, effectiveness, hassle free work style, which are all essential aspects of people, organizations, for a nation and also for the world. According Gartner Inc., it is estimated that 26 billion devices will be connected by IoT by the year 2020. The pros and cons of IoT are as listed [5]

A. Pros of IoT -

i). IoT facilitate automation and control the tasks that are to be done on every day without any human intervention.

ii). The machine to machine (M2M) communication ensures transparency in the processes, which also maintains uniformity in work, quality of service and also very helpful in case of emergencies.

iii). The M2M interaction enables better efficiency that results in accuracy and rapidity in turn saves time and provides opportunities for professional to involve in creative work rather than routine tasks.

iv). Optimal utilization of energy and resources is enabled by adopting IoT technology, which monitor the devices, processers, operations, etc. Also it alerts in case of breakdowns, damages, bottle-necks that indicate the precautions to be adhered to take of mishaps and results in savings in money, time, etc.

v). Switching over to IoT in any domain reduces the risks, damages, breakdowns, etc., which enhances comfort, convenience, better management that improves the quality of life.

B. Cons of IoT -

i). Sensitive and confidential information, top secret communications, etc., have provision for hacking as the devices and sensors data, etc., can be accessed by Internet, unless the data and information are protected.

ii). As the devices from different manufacturers are interconnected, the problem of compatibility in tagging and monitoring may arise unless care is taken on this issue.

iii). Malfunctioning of devices due to power fluctuations and power failure may lead to failure of devices or bugs in software and hardware may cause havoc in functioning of IoT systems as it is diverse and complex.

iv). Implementation of IoT in any domain may lead to unemployment of menial staff viz., workers and helpers due to automation of daily activities.

v). The emerging technologies influences human life, living styles and leading to mechanical life and as such any technology would have pros and cons. Any one should not become addict, but how effectively make use of IoT is significant to achieve progress and success.

VIII. DISCUSSION

Technological inventions and innovations are part of human development and since recent times, which all attaining greater heights with knowledge explosion and inventions. One such thing in the past two decades being 'Internet of

Things' (IoT), which is emerging with more innovations such as IIoT, mesh network, digital twins, edge computing, IoT analytics, etc. Further, various technological innovations such as virtual reality, augmented reality, cognitive computing, quantum computing, advanced robotics and many more technologies are emerging for the benefits of humans. Applications of IoT in India are catching up and mainly driven by Government, Industries and startups. Government's initiatives in developing IoT in India by 2020 is about $ 15 Billion, which is mostly in industrial applications and also in the development of 100 smart city projects in India. Hence, the domains of IoT, IIoT, 'Digital Twins', 'Edge Computing', 'Mesh Network' would open technological flood gates, which envisages huge opportunities for the professionals in India and also in the world.

IX. CONCLUSIONS

A. The IoT enables communications to anything and anywhere, using Internet and connecting devices with sensors by a variety of wireless and mobile technologies for various tasks such as collection and transfer of data over network without human intervention that leads to automation in many domains.

B. The spectrum of IoT encompasses linking of physical devices equipped with sensors connected to Internet can perform various automated operations such as process control, monitoring, data transmission, etc., to list a few.

C. Use of mesh network boosts the signal strength and enables a large number of devices that are connected in a single network irrespective of their proximity to the network source and ensures efficient performance of IoT.

D. The IoT analytics manages business intelligence platform, which merges sensor and machine data in ERP system, CRM software or supply chain suite.

E. Digital Twins' technology application in healthcare, manufacturing, automotive, space science, etc., evolves automation in many domains to investigate and analyze problems and to formulate remedies to set right the hitch in the performance of the device or organ in case of health care can be carried out efficiently, effectively to reduce the breakdown maintenance in case of machines and minimizes the mortality of patients in healthcare.

F. The evolution of edge computing expedites the storing and processing of massive data at rapid pace compared to cloud networks and reduces latency.

G. The growth of IoT is phenomenal in many domains and in a true sense it has evolved 4th 'Industrial Revolution' in the digital era and resulted in automation that offers numerous advantages that can transform the technical arena, which is a dynamic and smart technological innovation for all the stake holders.

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