Internet of Things (IoT) : A Boon for Supply Chain Management

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Abstract

Data is the the new oil. The more data one has, the more powerful one is. According to knowledge (DIKW) pyramid, wisdom helps move human race forward, but data is at the base of the pyramid. Internet of Things (IoT) is capable of collecting vast amount of real-time data through sensors and convert data into information. Information gives way to knowledge and wisdom. Technology is beneficial as it saves time and provides comfort. So, the Internet of Things (IoT) with its evolution is rapidly becoming a basic feature from an optional or luxury feature.

Manufacturing, logistics, and supply chain enterprises are aggressively moving to embrace modern technologies. Internet of Things (IoT), Machine Learning (ML), Artificial Intelligence (AI), Cognitive Intelligence (CI), and Big Data (BD), and Robotic Process Automation (RPA) are all buzzwords of today's supply chain management. Among all, IoT and Big Data are two fields of technologies which seem to be evolving very fast.

IoT in supply chain can help organizations manage their operations from production through to delivery. RFID, GPS, and IVMT provided real-time data is helping supply chain managers to take smart decisions. Cloud based IoT coupled with data analytics and big data is definitely the next big thing in supply chain management. IoT provides end-to-end visibility in a supply chain from manufacturing through to delivery, hence, it provides accessibility to real-time data, hence, enabling quick decision making based on variations. This article talks about applications of IoT with special focus on supply chain management.

Keywords: Global Positioning System (GPS), Internet of Things (IoT), In-vehicle Monitoring System (IVMS), In-vehicle Monitoring Technology (IVMT), Radio Frequency Identification (RFID)

I. INTRODUCTION

Manufacturing, logistics, and supply chain enterprises are aggressively moving to embrace modern technologies. Internet of Things (IoT), Machine Learning (ML), Artificial Intelligence (AI), Cognitive Intelligence (CI), Big Data (BD), and Robotic Process Automation (RPA) are all buzzwords of today's supply chain management. Among all, IoT and Big Data are two fields of technologies which seem to be evolving rapidly.

Internet of Things (IoT) is a massive network of connected devices, such as air conditions controlled through smart devices, smart watch tracking our daily activities, and physiological processes, mobile apps controlled room lighting systems, and many more. It is influencing us to such a great extent that it is determining the way we behave and react to things and situations.

With the advent of cloud technology, capturing, and storing even exabytes of data has been made possible with less cost and effort.

Until recently there was more focus on manufacturing processes to improve efficiency and save cost. Of late, organizations have been realizing that supply chain and related areas can offer tremendous opportunities to contribute to the bottom-line. There has been a lot of focus on supply chain to be more and more efficient, and demonstrate cost saving potential through applications of modern trends and technologies.

Internet of Things (IoT) provides end-to-end visibility in a supply chain from manufacturing to delivery, hence, it provides accessibility to real-time data, thus, enabling quick decision making based on variations.

II. INTERNET OF THINGS : ORIGIN AND DEFINITION

The internet today is omnipresent and universal. This

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is one of the most transformative technologies to have been conceived in the 20th century. Human beings struggle to imagine their presence without internet. Internet has been around for a long time now, and has been associated with data, games, people, communication. It is mostly connected to people and is called as 'Internet of People'.

Internet now is and in future will be about 'connecting with things, knowing about things, managing, controlling, and making them work the way we like'. This is known as Internet of Things (IoT).

The Internet of things (IoT) is the extension of internet connectivity into physical devices and everyday objects. Embedded with electronics, internet connectivity, and other forms of hardware (such as sensors), these devices can communicate and interact with others over the internet, and they can be remotely monitored and controlled [1].

Sophisticated sensors powered by softwares and embedded in things around us such as mobile phones, cars, refrigerators, TV's, AC's, washing machines etc. continuously collect and emit data onto a common platform called the Internet of Things platform. The useful data is processed further to be utilized in many beneficial ways. IoT enabled things can sense, communicate and share their experience and this is a great phenomenon of this century.

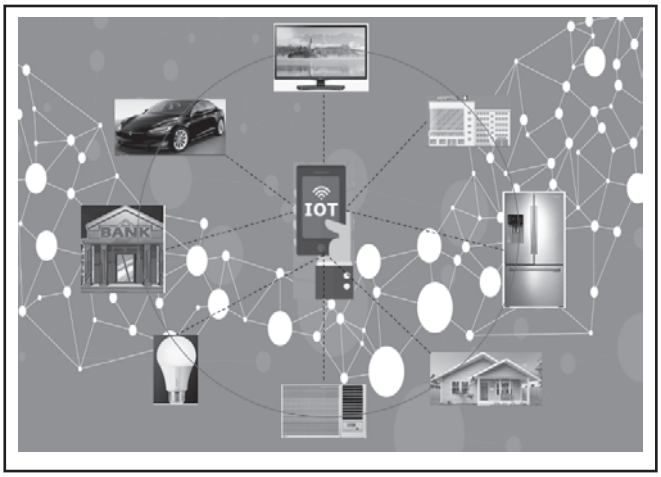

Fig.1. A Representation of the Internet of Things

The field of IoT has evolved due to the availability of advanced sensors, strong, stable, and wide network connectivity, and technologies like machine learning, artificial intelligence, big data analytics, business intelligence etc.

The concept of a network of smart devices was discussed as early as 1982, with a modified Coke vending machine at Carnegie Mellon University becoming the first internet connected appliance able to report its inventory, and whether newly loaded drinks were cold or not. Mark Weiser's 1991 paper on ubiquitous computing, "The Computer of the 21st Century", as well as academic venues such as UbiComp and PerCom produced the contemporary vision of the IoT. In 1994, Reza Raji described the concept in IEEE Spectrum as, “moving small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories”. Between 1993 and 1997, several companies proposed solutions like Microsoft's at Work or Novell's NEST. The field gained momentum when Bill Joy envisioned device-to-device communication as a part of his "Six Webs" framework presented at the World Economic Forum at Davos in 1999.

The term Internet of Things was likely coined by Kevin Ashton of Procter & Gamble, who was MIT's Auto-ID Center in 1999. At that point, he viewed Radio-Frequency Identification (RFID) as essential to the IoT, which would allow computers to manage all individual things [2].

III. FEATURES OF IoT

The following are the main features of IoT [3]:

1. Connect: Connects numerous things to the IoT platform.
2. Device visualization: Standardize integration of devices with the IoT enterprise. Compatible devices can be brought onto the IoT cloud platform.
3. High Speed Messaging: Enable reliable, secure, and bi-directional communication between devices and cloud.
4. End Point Management: Manage device end-point identity, metadata, and life cycle states for all devices. It is very important to identify from which device which data is coming. The system will not succeed without this.
5. Sense: Sensors sense the surrounding events of the physical environment and continuously collect data.
6. Analyze: Analyze the data collected and convert it into useful information using business intelligence and analytics.
7. Stream Processing: Real-time analysis of incoming data streams with event aggregation, filtering, and correlation.
8. Data Enrichment: Enrich raw data stream with contextual information and generate composite streams.

9. Event Store: Query and visualize massive amounts of data with integrated BI cloud support and big data analysis.
10. Integrate: Integrate various models to improve overall user experience in a holistic way.
11. Enterprise Connectivity: Dynamically dispatch critical IoT data and events to applications and process flow.
12. REST APIs: API-based integration with cloud apps and IoT devices.
13. Command and Control: Send messages to devices from enterprise and mobile apps, independent of device connectivity.

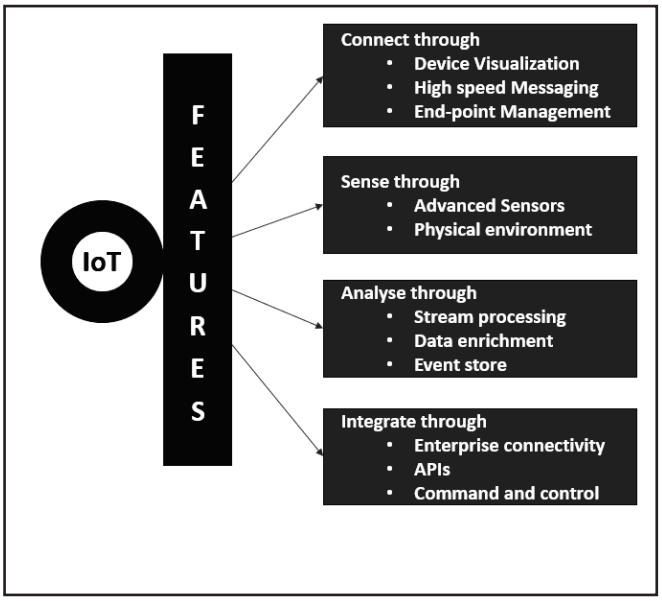

Fig. 2. Features of IoT
Source: Eureka Tec

IV. TOP IoT SERVICE PROVIDERS

Given below are the top 10 IoT platforms for 2018 that you can use for building an app [4]:
❖ Microsoft Azure IoT
❖ Amazon Web Services or AWS
❖ Google Cloud Platform
❖ ThingWorx
❖ Cisco IoT Cloud Connect
❖ HP's Universal of Things
❖ SAP Cloud Platform
❖ Oracle Internet of Things
❖ Bosch IoT Suite
❖ IBM Watson Internet of Things

V. IoT OPERATING SYSTEMS

The following are the popular operating systems used in IoT applications:
❖ Windows 10 for IoT
❖ Google Brillo
❖ RIOT OS
❖ ARM mbed OS
❖ RealSense OS X
❖ Raspbian OS

VI. APPLICATIONS OF IoT

Majority of IoT devices find their applications in consumer and home appliances, connected vehicles, wearable smart devices, health appliances, and industrial appliances, etc.

A. Consumer and Home Appliances

1) Smart Phones: Most common example is the smart phones we use. It can sense light through adaptive brightness. It also has features like voice detection, touch sensor, and face recognition. It can judge direction through mobile gyroscope, GPS tracking etc. These features interact with each other, e.g. based on the direction the phone is held, it changes the picture orientation, and adjusts the brightness.

2) Smart Homes: Smart homes can have features like when we wake up, it sends a message to the bed lamp to be switched on. When we are feeling cold, it sends a message to the AC thermostat to increase the temperature. Next, it sends a message to the coffee maker to prepare coffee with favourite beans. The water heater readies the hot water for bath. One may like to listen to some of his favourite music or may want to watch a TV series just by hitting a button on his smart phone. The list goes on and on.

B. Healthcare Appliances

1) Track Infants: Tags attached to infants in hospitals not only help in tracking their well-being, but also help track their movement, potentially preventing any mishaps.

2) Arm Bands: Health band/arm band can sense when someone sleeps and wakes up. How good did he sleep? Later in the day, how many steps he takes, how many calories did he take, and how much calories were burnt? These are a few fascinating features of a simple IoT device. This device can send a signal to the hospital when the person's heart beat seems to be erratic or BP shoots up

abnormally high. The physician can take necessary action immediately.

3) Smart Healthcare: IoT based digital healthcare system, connected to multiple devices, continuously monitor vital body statistics, and keep track of the functioning of the body.

4) Smart Cities: More than 50% of the world population is living in the cities. Mega cities continuously tend to become more and more crowded. Managing vehicles, people, and resources would help better manage mega cities. This is possible with IoT.

C. Industrial Appliances

1) Manufacturing and Logistics: IoT is gradually witnessing a lot of usage in the fields of manufacturing, transportation, and logistics. This is being possible by seamless integration of various industrial and digital devices with the capability of sensing, identifying, analyzing, communicating with the IoT platforms.

Apart from the previous examples, IoT is also witnessing potential in areas such as agriculture (Smart farms), energy management, environmental monitoring systems, etc. This list goes on and on.

Fig. 3 shows different applications of IoT and their popularity scores:

VII. ADVANTAGES OF IoT

Most of the advantages of IoT are derived from the applications discussed earlier, such as:

1. Health: IoT wearable devices have been very popular and are contributing towards healthy living.
2. Safety: Smart homes based on IoT platforms have a lot of safety features such as fire alarm, anti-theft alarm, earth-quake alarm, etc.
3. Comfort and Convenience: IoT technology has been deriving its popularity from comfort and convenience, it has been able to provide to people.
4. Efficient Utilization of Resources: We can understand how interdependent things work together and accordingly, can be utilized to their fullest efficiency. IoT helps us achieve true potential of resources around us.
5. Minimal human effort: When most of the things are connected on the common IoT platform, and they interact with each other, human effort to operate and control them reduces. One smart device can control all other connected devices. Parallel processing, and remote sensing help things work fast.

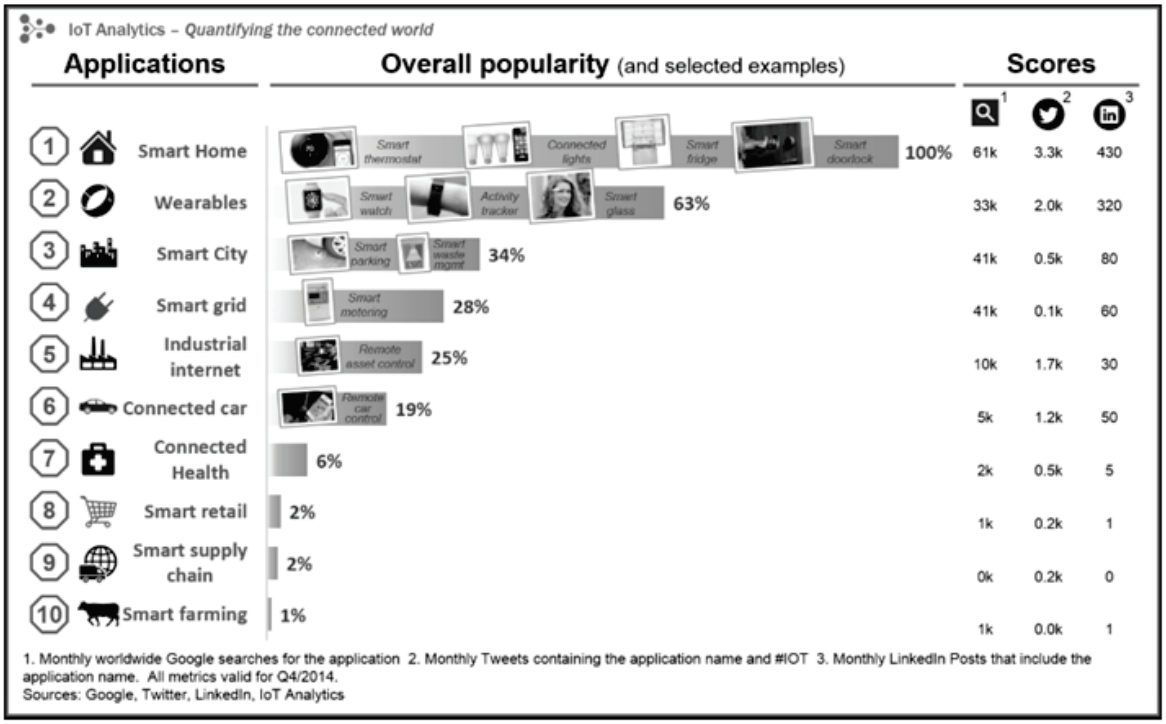

Fig.3. IoT Applications
Source: Wikipedia

VIII. LIMITATIONS OF IoT

A. Resistance

Similar to any other technology, the time taken from invention to wide-spread use has been slow with IoT. When a technology sees wide-spread acceptability and use, it becomes more affordable for the masses.

B. Privacy and Security

Data privacy and identity has been the biggest concern with IoT. This to some extent, stems from the fact that IoT software and hardware providers are in the race to provide lowest price.

As long as personal information is secured, technology is fine to be used. However, the way IoT is collecting data and if it goes into wrong hands, it is disastrous. Hence, data safety and security is of paramount importance. For example, we do a lot of banking activities and financial transactions through the internet, assuming that the information is going to remain safe.

People buy IoT devices like a childcare device or a thermostat. This device collects data and shares it with a cloud platform. Sometimes, the companies steal data and sell it to outsiders and then it is available in a wrong hand.

Once a device is hacked, then the whole system of data is compromised. Data theft or identity theft can be a very draining experience for the user personally. It takes a long time to get it back into shape.

Data security and cyber security in industrial IoT are generally much tougher as they do not use the network in isolation and many devices and people try to get access. It needs cyber security experts to create robust security systems which is expensive.

C. Maintainability

Configurability, upgrades, scalability, support are the areas which need to improve a lot.

IX. IoT IN SUPPLY CHAIN

Supply chain professionals are under constant pressure to increase the supply chain efficiency and improve margin by reducing cost. This can only be achieved through effective planning and decision making based on visibility into real-time data. Uncertainty is the only certain thing in today's global business. Supply and demand picture keeps constantly changing. Successful and competitive businesses need agility to make dynamic decisions based on the situation. To create a more responsive and synchronized supply chain plans, professionals need to gather deep insights into business drivers.

IoT and big data based analytical tools provide decision making platform to executives, which in turn help to constantly evaluate and react to changes in the business environment. This reduces chaos and noise in supply chain and assists in its smooth operation.

Any organization in which business functions like sales, finance, marketing, operations, etc. operate in silos, tend to develop inefficient plan, and forecast. A single source of truth is essential for more accurate SCM planning and forecasting.

In a typical organization, the following departments get involved in SC planning:

1. Sales and Marketing Department: They fall into the group of demand planners in an organization. Demand forecast emanating from sales and marketing is commonly based on historical data. They require access to proper data to recognize and project trends.

2. Sourcing Department: Purchasing and sourcing departments are the supply planners and they need real-time access to supply chain data so that they can create well-informed and accurate supply forecasts. This can effectively mitigate the risk of shortages and stock-outs leading to revenue loss for organizations.

3.Sales and Operations Planning Department: An effective S&OP planning process is essential for the sustainability of an organization. Here, there is a requirement of a single and unequivocal source of information.

IoT and data analytics working hand-in-hand help to break the data silos and lead to an integrated source of information, and hence, unambiguous SCM decision making, planning, and forecasting.

A. Advantages of IoT in SCM

Internet of Things (IoT) has so far witnessed a wide range of applications from home appliances to self-driven cars. One of the most promising areas of impact is supply chain application. IoT has the potential to make supply chain more communicating, collaborative, and transparent.

A vast amount of supply chain data is collected through the use of IoT. This data is useful only when it is actionable. Main advantages of IoT in SCM are as follows:

1) Operational Efficiency: IoT in manufacturing industry can help improve productivity and operational efficiency in multiple ways [5].

2) Asset Tracking: Tracking numbers and bar codes for managing goods throughout the supply chain are no longer the most convenient. New RFID and GPS sensors can track products from floor to store. At any point in time, manufacturers can use these sensors to gain granular data like temperature at which an item was stored, how long it spent in cargo, and even how long it took to fly off the shelf. The type of data gained from the IoT can help companies get a tighter grip on quality control, on-time deliveries, and product forecasting.

3) Vendor Relations: The data obtained through asset tracking is also important because it allows companies to tweak their own production schedules, as well as recognize sub-par vendor relationships that may be costing them money. According to IBM, upto 65% of the value of a company's products or services is derived from its suppliers. That is a huge incentive to pay closer attention to how your vendors are handling the supplies they are sending you, and how they are handling your product once it is made. Higher quality goods mean better relationships with customers and better customer retention overall.

4) Forecasting and Inventory: IoT sensors can provide more accurate inventories than humans can manage alone. For instance, Amazon is using WiFi robots to scan QR codes on its products to track and triage its orders. Real-time data obtained through IoT devices can be used to plot trends and patterns. Real-time information literally remains at the finger-tips of the managers and decision makers.

ERP system can be programmed to automatically create and release a purchase order when RFID tags in warehouse indicates that inventory level has gone below certain level. Digital inputs from the connected fleet can be used to provide information to the receiving system regarding the delivery times or lead times.

5) Connected Fleet: As the supply chain continues to grow upward and outward, it is even more imperative to ensure that all your carriers such as shipping containers, suppliers' delivery trucks, or your van out for delivery, etc. are connected.

This data can be utilized to get urgent deliveries quicker and find a better route in case of a traffic jam or road mishap to get better products to customers faster.

6) Scheduled Maintenance: The IoT can use smart sensors on its manufacturing floors to provide patterns and trends. Hence, better manage preventive and predictive maintenance and avoid down-time that can cost revenue to the company.

7) Production Scheduling: Through integrated network of complex sensors we can measure humidity, temperature, and other environmental conditions to determine certain production activities such as heat treatment, painting, drying, etc. This can contribute to process efficiency.

B. Revenue Opportunity

IoT helps to know customers more and understand their buying habits, and then we can plot trends associated with them. This information is invaluable, and it allows businesses to form stronger relationship with customers and, market to them in novel and improved ways. More than just using the data for improved efficiencies, businesses can improve supply chain transparency. They can build a reputation of social responsibility by allowing customers to access real-time data to verify the source of the product, the workforce who made it, and the living and working conditions of the workers.

C. Brand Equity and Customer Satisfaction

With the application of IoT in manufacturing and supply chain, brand image, and brand value get a definite boost as enterprises can showcase corporate social responsibility and transparency, resulting in improved customer satisfaction.

D. Current Status of Supply Chain From IoT Point of View

As per fig. 3, IoT applications in the previous section show that when it comes to supply chain, it is far behind in terms of IoT application. However, some researches show that retail and manufacturing are quite ahead of SCM.

For IoT to be truly effective, end-to-end processes must be inter-connected and brought onto the same IoT platform. In an age when companies are beginning to embrace technologies like blockchain, artificial intelligence, big data, robotic automation and so on, there is so much potential that lies ahead of us in terms of mobility, transparency, efficiency, cost-effectiveness than ever before. Perhaps that is where IoT works as the baseline and provides foundation for other technologies to succeed.

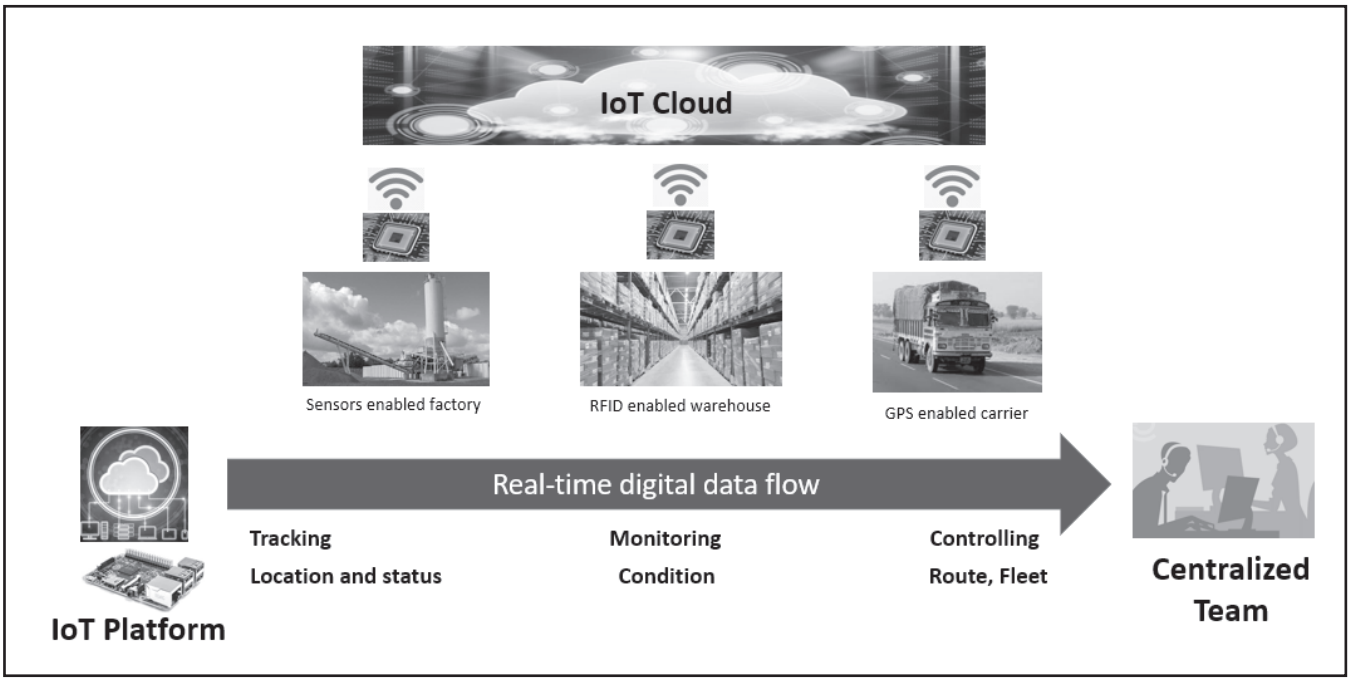

Fig. 4. Schematic Representation of IoT in Supply Chain

E. Applications

Supply chain and logistics fields can be augmented to a great extent with the application of IoT by the use of Radio frequency identification (RFID), Global positioning system (GPS), and in-vehicle monitoring technology (IVMT) or in-vehicle monitoring system (IVMS).

1) Real-time Tracking: Movement of products and things are tracked with the help of RFID tags on a shop floor and across logistic route. The tag carries information such as name, description, dimensions, origin, batch number, etc. Scanners are used to send the digital data stored in tags to the digital system.

2) Operations Control: Machines, assembly lines, conveyor belts, material handling systems, etc. can be equipped with embedded sensors. The sensors sense real-time data and continuously send the same in digital form to the IoT based platforms. The bi-directional interaction helps the machines work in a more controlled and intelligent way.

3) Supply Chain Visibility: Supply chain visibility in logistics and transport industry can increase many folds by making extensive use of RFID, GPS, IVMS. This helps companies track products from 'floor to store'. Also, manufacturing, shipping, delivery, and routing can be effectively planned in case of eventualities.

Cloud based IoT platforms can provide greater flexibility and scalability to modern supply chain management. Cloud solutions are especially relevant when supply chains extend beyond just one enterprise. Upstream, there may be independent suppliers of raw materials. Downstream, distribution including shipping and intermediate storage may be handled by a third-party logistics (3PL) provider. Separate retail partners may take and manage stock, as well as generate product returns. Even a manufacturing stage may involve several different companies, all working in sequence as part of the same overall supply chain. A secure cloud system can then offer a neutral, easily accessible IoT platform for all partners to use together [6].

IoT empowers supply chain to be more dynamic, agile, and responsive. It helps to do things more efficiently. End-to-end visibility in a supply chain makes the process lean and mould it into more of a pull model rather than push. Real-time data obtained through IoT supports quick adjustments in production and distribution, thereby, positively influencing efficiency.

F. Success Factors

1) Reliable Connectivity: A stable connectivity is the basis of a successful IoT. It helps organizations scale up their IoT initiatives.

2) Information Security: Solid security system not only

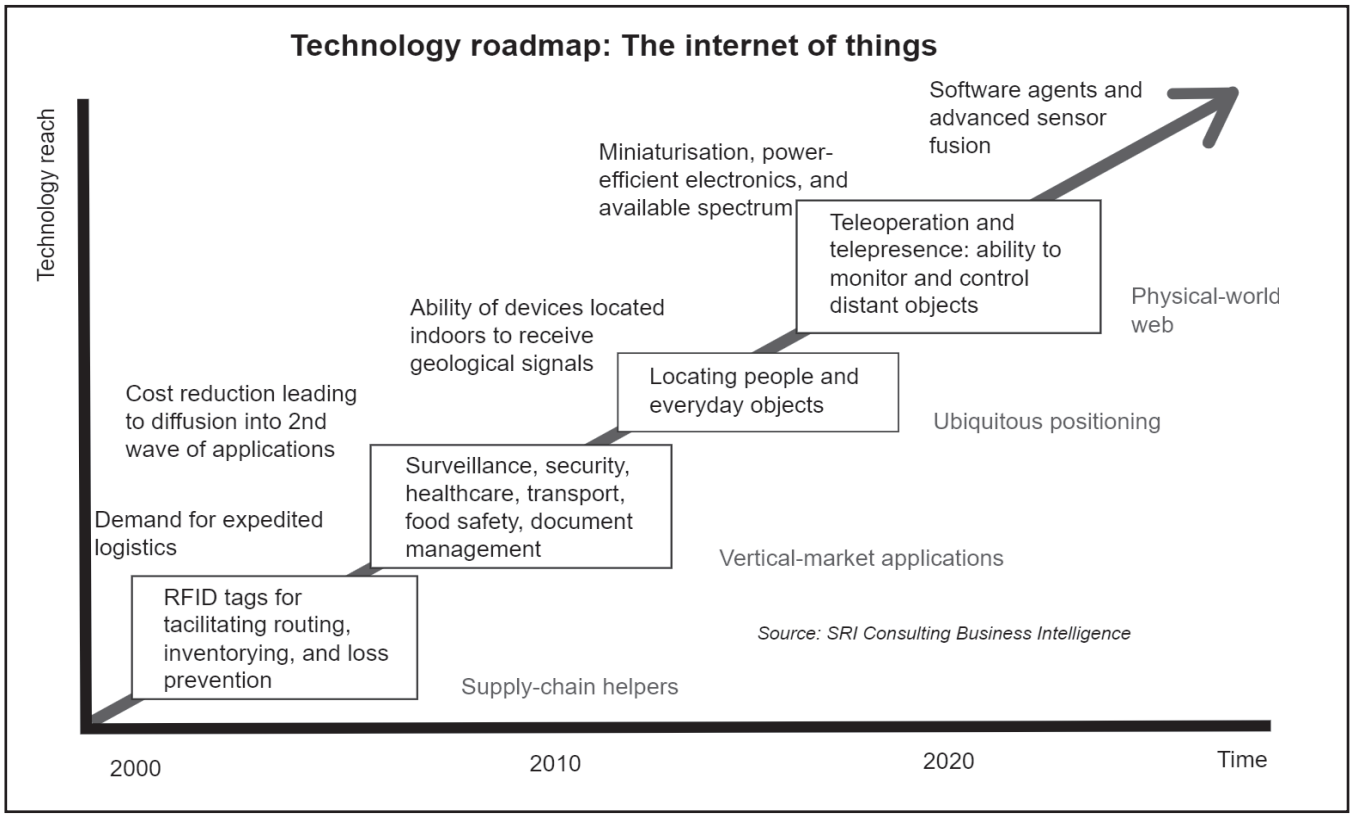

Fig. 5. Technology Roadmap: Internet of Things

Source: Wikipedia

prevents threats but also helps in identifying imminent risks.

The following are a few ways to improve security and counter identity theft:

- ❖ Use complex passwords and strong firewalls
- ❖ Carefully choosing devices, apps, and softwares
- ❖ Keeping the softwares and antivirus system updated
- ❖ Avoid linking unnecessary accounts and devices
- ❖ Purchase identity theft coverage for your system

3) Complete Process: To get maximum benefit out of IoT, it is worthwhile to have end-to-end process covered under technology.

G. Internet of Things: Trends and Statistics

Billions of devices are linked with IoT. The number of IoT devices increased 31% year-over-year to 8.4 billion in the year 2017 and it is estimated that there will be 30 billion devices by 2020.The global market value of IoT is projected to reach $ 7.1 trillion by 2020 [7].

According to Gartner, there will be 26 billion devices on IoT by 2020. According to a report by Progressive Policy, IoT is expected to contribute $ 600 billion to $ 1.3 trillion to the U.S. economy in 2025.To reinforce the fact that IoT has a great future in coming years, a few big acquisitions have been illustrated as follows:

1) Google's Nest Acquisition: Nest labs is a manufacturer of high-tech thermostats and smoke detectors. Google acquired Nest Labs for a staggering $ 3.2 billion. Through this acquisition Google aims to gain strong-hold in the growing market for web-connected household appliances.

2) Samsung's Harman Acquisition: Samsung Electronics acquired Harman International Industries in a deal worth $ 8 billion as part of its overall push to autonomous vehicle.

Verizon's acquisition of Skyward, Intel's deal of Mobileye are a few more examples in IoT field.

IoT's major significant trend in recent years is the explosive growth of devices connected and controlled by the internet. The wide range of applications for IoT technology mean that the specifics can be very different from one device to the next, but there are basic characteristics shared by most.

The IoT creates opportunities for more direct integration of the physical world into computer-based systems, resulting in efficiency improvements,

economic benefits, and reduced human exertions [8].

X. CONCLUSION

Data is the new oil. Companies and individuals are making tons of money with the help of data collected through IoT. Today, approximately, 4,000 exabytes of data is available on cloud. Filtering out useful information from the huge dumps of data is the toughest task.

IoT is capable of collecting any amount of real-time data through sensors and convert data into information. Information gives way to knowledge and wisdom. Wisdom helps the human race move forward.

Experts estimate that in the next 15-20 years, approximately 3,000-5,000 objects around us will be on IoT. Will it make our lives too much complex? Most probably not as technology is supposed to make things easier for humanity. IoT will definitely influence our lives in many ways in the near future.

Technology is beneficial. It saves time and provides comfort. With its evolution, IoT technology is rapidly becoming a basic feature from an optional or luxury feature.

IoT in supply chain can help organizations manage their operations from production to delivery. RFID, GPS, IVMT provided real-time data is helping SC managers to take smart decisions. Cloud based IoT coupled with data analytics and big data is definitely the next big thing in supply chain management.

Data security is of prime importance for IoT. Data security and risk mitigation on the back of technologies such as DLT are crucial to deter risk of data theft. IoT companies are spending enormous amount of money to build their credibility. While buying any technology which may make business vulnerable, it is very important to take a judicious decision. If security and compliance can be properly managed, supply chain can greatly benefit from IoT by becoming more responsive and flexible with changes in its environment.

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