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Intelligent Supply Chain Systems – A Research Framework Using Internet of Things (IoT)

Parthasarathi Ramakrishnan[1], Yongsheng Ma [2]

Research Assistant, Dept. of Mechanical Engineering, University of Alberta, Edmonton, Edmonton [1]

Professor, Dept. of Mechanical Engineering, University of Alberta, Edmonton, Edmonton [2]

ABSTRACT: Internet of Things (IoT) has been used in various businesses for the daily operation of organizations and has accrued substantial benefits even though; the potential application of IoT in Supply Chain Innovation (SCI) and Supply Chain Management (SCM) has not been completely discovered in the modern business world. Therefore, this paper divulges on IoT, SCI and SCM as well as investigating the potential impacts of the IoT on the Supply Chain Management. It will also come up with a conceptual framework that builds a system connecting the different four aspects making up the supply chain that are (warehouse, supplier, logistics and client) with the aid of IoT. Basically, the framework shows how IoT could be applied in SCM which further can improve overall performance, sharing of information, loss reduction and efficient use of resources in the supply chain. This framework consists of devices for the information collection, network for information transmission and the system for the integrated information management for the end user.

KEYWORDS: Resource tracking, Internet of Things (IoT), Supply Chain Innovation, conceptual framework, Supply chain management

I. INTRODUCTION

A. Supply Chain Management

Given the fastest growth in industrialization, Supply Chain Management has been perceived as the pillar for improving the overall organization performance. Over the years, this approach has gained a considerable research from various expertise [1]. Hence this approach has a few things to be ameliorated. In definition, SCM can be defined as the integration of major business process from users of products to the supplier providing the products, services, information that help in value addition to the end users and other stakeholders. According to [2] SCM is "A concept, whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers."

Supply chain can also be described as the process where raw materials, various intermediate products or final products are obtained, manufactured, kept in a warehouse, and sold following a given channel [2]. This process is needed in the entire cycle of a give product that is from procurement of materials, manufacturing, product distribution, and customer service and finally the stages of disposal and or recycling. It can be further classified into two; internal SC that requires flow of resources within the organization and external SC organization for the flow of resources outside the organization [3].

Figure 1 depicts the overall flow of SCM. This SCM is closely connected to financial optimization through the implementation of the actual cost of production to the integrated information flow used to minimize costs and maximized profit [4]. (SCI) is the inventive or discoveries for promoting the available SCM opportunities for competitive advantages in the industry [5]. It involves a supply chain networking through collaboration and interaction supply. On the other hand, [6] suggest that SCI can develop and improving SCM paradigm in existence even though, there is need for carrying out more research for the implementation of more practical SCI.

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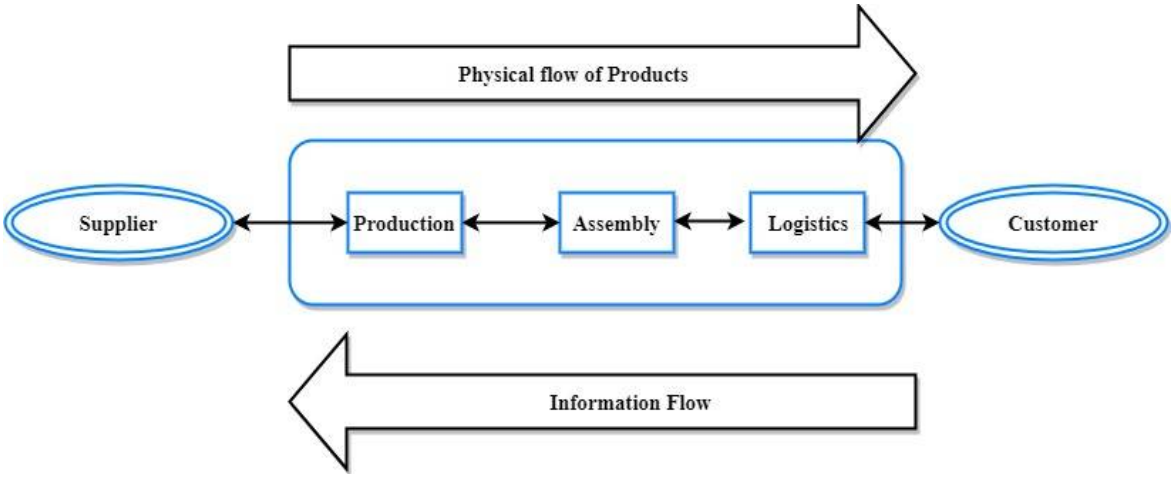

Fig.1. General flow of SCM [2]

B. **Internet of Things**

Through the internet connectivity that has been advanced worldwide an innovation; IoT is an internet concept connecting a range of electronic devices to products and people which has been prompted through technologies such as sensor devices, devices for data storage, decision making and intelligent analytics. The IoT is "The inter-networking of physical devices, vehicles (also referred to as 'connected devices' and 'smart devices'), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data" [7]. This device has improved the connectivity through other advanced technologies such as GPS, GSM, Bluetooth, Wi-Fi, ZigBee, NFC, RFIDs, and QR Scanners that are nearly present in most devices. It is also considered the "Next Big Thing" invented [8] and it is predicted that 7 trillion wireless devices will be in use by 2017. It is expected to expand by 2020 to 26 billion and helping in monitoring of human machines and activities [9].

According to [10], IoT is likely to expand the corporate world and market by twenty-one percent and $19 trillion dollars respectively. It has numerous benefits with positive impacts to supply chain management and it is also being adopted in other industries in their supply chain [11]. Other applications are shown in Figure 2. Additionally, some organizations still use traditional techniques that are unreliable and costly to track their products in supply line and this has led to a few challenges such as lack of sharing of information, inefficient resource use and decision making. It has further limited Supply chain Management operations and its innovativeness [12]. Generally, this paper consists of introduction, literature of IoT, proposed framework and supporting technologies and lastly the conclusion.

II. LITERATURE REVIEW

A. **IoT in improving in transit visibility**

There has been a lot of transformation in the Supply chain management over the past few decades as a result of technology [13]. The most notable innovation in SCM is the big data, analytics and IoT [14]. Incorporated systems of IoT are used to achieve better visibility and responsiveness for the supply chain management [15]. With IoT advancements, there has been adequate transformation in SCM system impacting various sectors [16]. Nearly 63% of companies regard improving SC visibility a priority in reducing the cost and enhancing operational performance [17]. IoT has the potential to resolve the demands for many companies to address supply chain visibility using IoT sensing devices such as RFID, QR codes, Bluetooth [18]. Through, IoT devices, it is possible to automate the SC hence increasing visibility of products [19].

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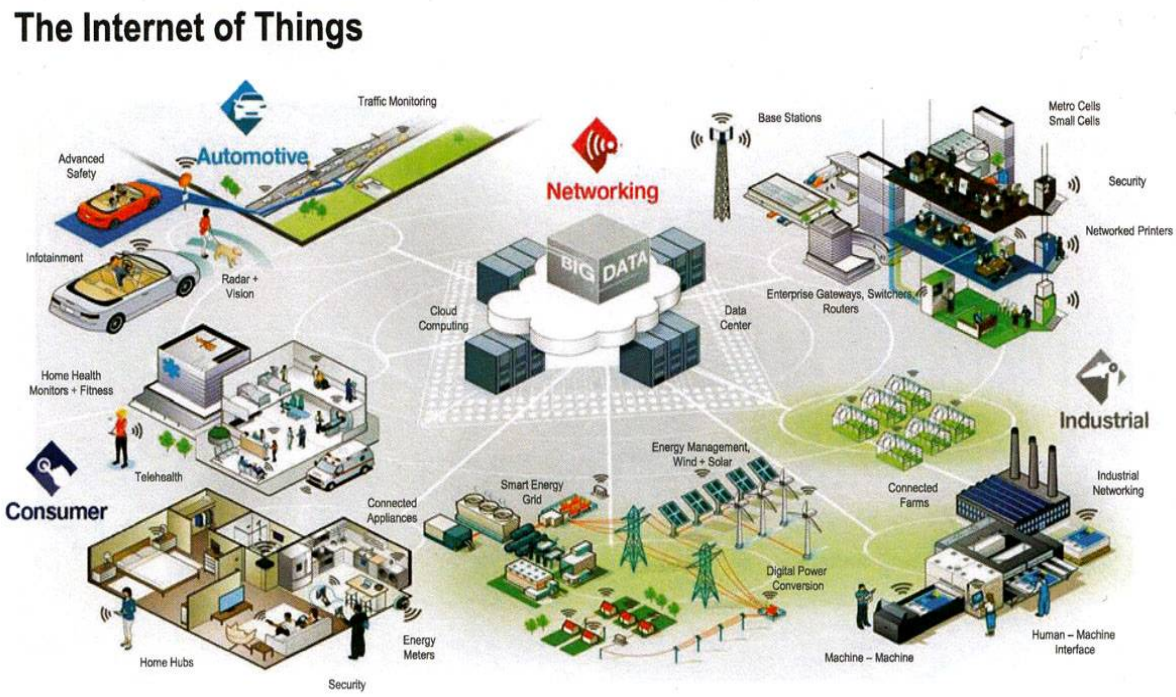

Fig.2. Applications of IoT [20]

B. **Improving SCM operational efficiency by IoT**

Through advancement of internet connectivity provided by IoT it has been easy to share information across the supply chain. As complexity in supply chain rise, high visibility of products along the supply chain will reduce operational pressures and reduce costs in logistics. As of 2017, the number of devices connected through IoT was estimated at almost 7 billion and estimated to extend to 26 billion by the year 2020 [21]. The rapid growth has been influenced by improvement in cloud-based visibility and Radio frequency identification which form IoT Backbone. However, despite this huge potentiality by IoT in connecting products and different members of the supply chain management such as suppliers, clients, manufacturers and logistics, majority of the companies have not benefited from its broad competitive advantages. This has been largely due to lack of frameworks that illustrate how business can integrate IoT with various supply chain processes to promote efficient and effective SCM systems and increase revenue. Devices such as RFID have made it possible to track and manage inventories more easily [22], hence reducing the required resources and saving time. As technology advances, supply chains are becoming more flexible, and faster as a result of available real time information that is useful in making critical decisions [23].

C. **Improving information sharing through IoT**

As the modern IoT technology replaces the paper-based information exchange, companies are putting more emphasizes on the value of information to gain a competitive advantage in the market. Therefore, different entities such as suppliers can gather important information from other entities of the supply chain such as manufacturers and clients the increase their operational efficiency. This exchange of information between the different supply chain entities brought by the modern technology such as IoT increases productivity, reducing the rate of error and promotes improved billing, all which contribute to an efficient and effective supply chain [24].

D. **IoT in improving customer satisfaction on SCM**

IoT has played a major role in promoting supplier-customer relationships in the supply chain through improved logistics across the supply chain systems. The data collected using IOT systems can be used to prevent unplanned

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downtimes among other logistical operations, saving both time and money [25]. The current innovation in the IoT has given these systems the capability to collect, analyse and present information for to product supply and demand [26]. This has led to more optimized, flexible and responsive logistics systems as well as enabling both the customers and the suppliers to track and share real time information on the movement of their products along the supply chain [27].

E. IoT in inventory management

This has been one of the most challenging aspects of the supply chain management. However, IoT innovation has significantly improved how companies handle their inventory by providing real time information on restocking and reordering inventories [28]. It has also enhanced low operation cost and updating of inventories.

III. PROPOSED FRAMEWORK

The basic architecture of the IoT is illustrated in Figure 3. It consists of four layers, namely the cloud, network and data service layers. Layer for the object/sensor consists of devices for gathering information such as sensors, machines among others. It provides the interaction between IoT and the environment. The application layer consists of the software for storing the gathered data in user friendly mode. It is also the interface for human and IoT interaction. The network layer is made up of the internet network and other wireless technologies and is responsible for the transmission of the collected information. The last layer is the data service layer for storing that is processed according to the user's request. According to [29], these four layers include cloud services that can either be public or private.

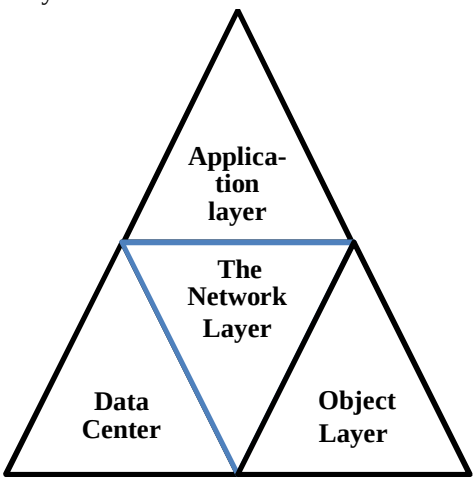

Fig.3. Basic architecture of IoT

The proposed framework connects suppliers of different levels to the manufacturer and the end user of the product. The model is illustrated in Figure 4. All the suppliers share their information with the centralized cloud-based technology.

A. How the Platform works

Sensors placed on the products with web enabled devices collect data on the surrounding environment and send to the connected cloud-based storage system. The information can include temperature, quality of the goods, and security of the products among several other attributes relevant to the condition of the goods. This information can be shared through a network, shown as connectivity, through Wi-Fi, cellular, internet or a WAN depending on the bandwidth and the specifications of an IoT application being used. Once the data is shared to the cloud, it is processed using the software. The software checks the data provided against the appropriate requirement. For instance, if the temperature information sent by the IoT device is not within the acceptable temperature for the product, the system raises and

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alarm. This information is made accessible to the end user in a user-friendly way, through an interface where the user interacts with the system. The information is processed in real time; therefore, manufacturers can determine the location of their goods along the supply chain beyond their immediate supplier whom they have a relationship. In addition, this information can also be shared with the product's end user.

This framework uniquely proposes a deeply intelligent supply chain, especially between manufacturers and suppliers on various areas of their business including financial, operations, sales, and customer support among several others. The big data analysis strategies examine large varying data sets to identify hidden patterns such as market trends, correlation, preferences from different clients, hence enabling members of the supply chain to make more informed decisions. The framework can be perceived as three levels with each level carrying out a different function as shown in the Figure 4.

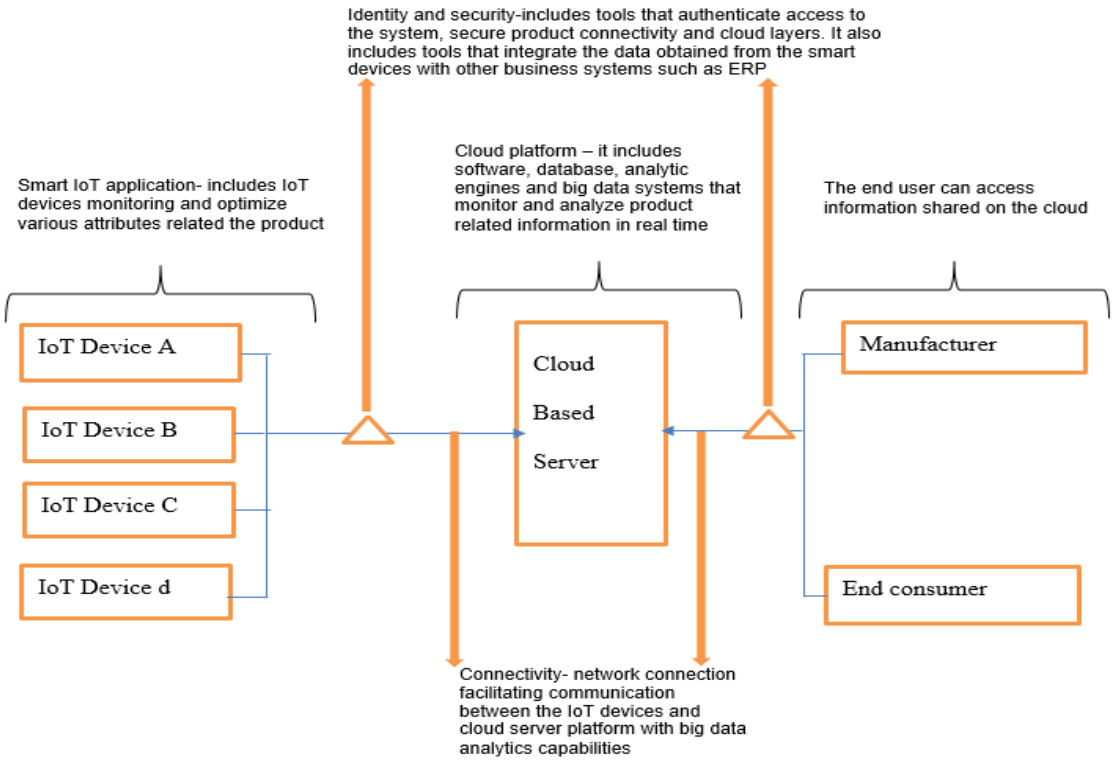

Fig.4. General model of the proposed framework

This level analysis presents all the information transmitted to the system in which the users interact with the system and access the useful information used in decision making. The centralized cloud-based information management system is the major part of the proposed framework as shown below.

B. **Supply chain process**

The information from different supply chain aspects such as the warehouse, supplier, logistics and client is collected through IoT devices such as sensors and others to the system. The internet network transmits the information generated by the supply chain processes to the supply chain management level, where the information is analysed, processed and accessible by the user in a meaningful form.

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C. **Application of IoT on the proposed framework**

Currently, GPS signals are used for tracking or fleet management in the logistics aspects of the supply chain. However, the rapid growth of dense urban areas and underground tunnels is creating a challenge to GPS for accurately track the location of vehicles [30]. Therefore, with the current development of the IoT technology, it is possible to utilize radio-frequency indication (RFID) for short range communication and mobile communication GSM enabled devices for accurate tracking of products along the supply line where GPS is inapplicable, resolving the challenge of high cost and regions where GPS signals are non-existent.

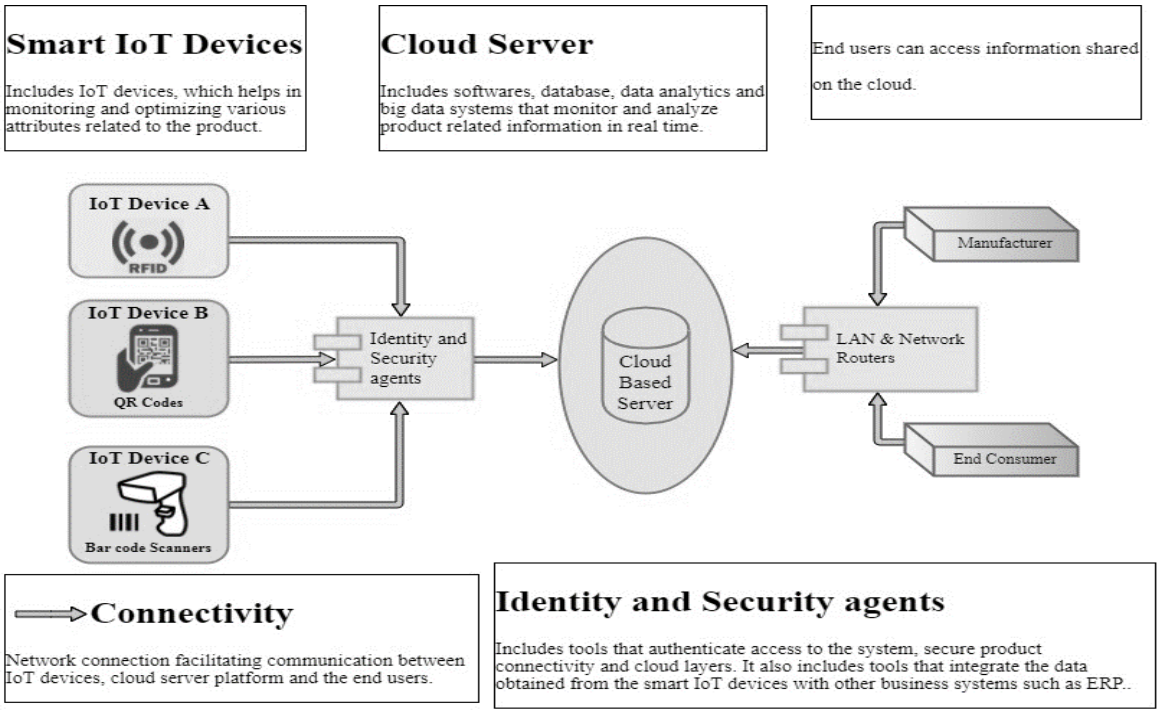

Fig.5. Specific model proposed framework

GSM communication technology is capable of sending high data quantity and is therefore the most applicable tool for IoT applications over the GPS because it is ideal sensor with low bandwidth [30].

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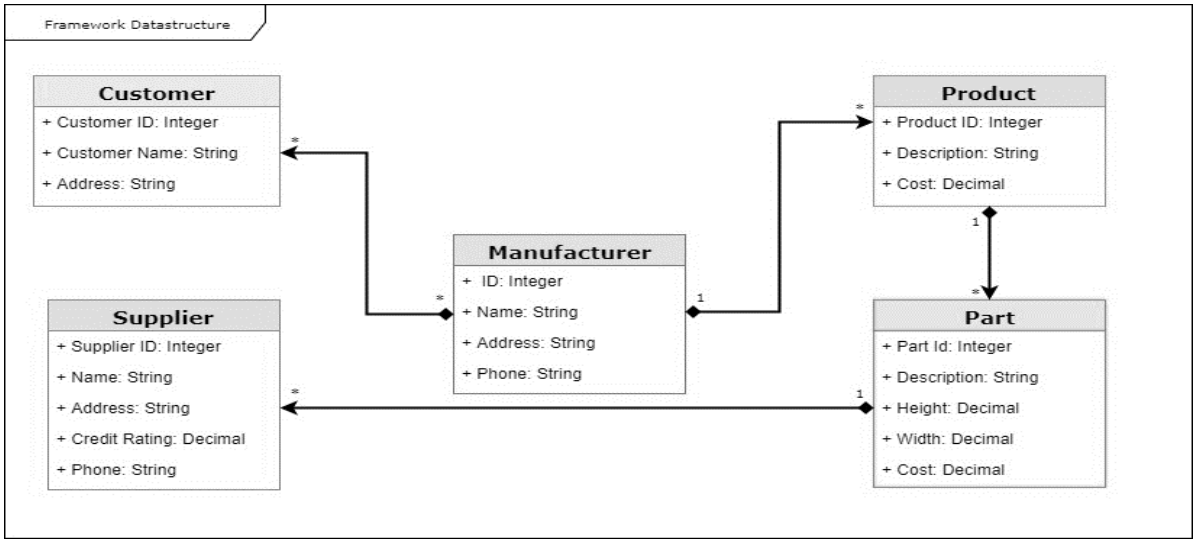

Fig.6. UML data structure

IV. A CASE STUDY OF DOOR & WINDOW MANUFACTURING INDUSTRY

A case study was carried out in one of the leading manufacturers and supplier of window and door across Northern America. The company had a problem with delivery route in building its products it had to block the needed trucks causing delay in delivery. Additionally, the company needed to allocate more buffer space for finished products since there was no flow in the visibility of product. More time were spent by the shipment department to identify the finished products that were loaded because there was lack of visibility among production employees with some products missing from production. The problem was later solved when the shipment department notified the production department which then acted and produced demanded products in a rush leading to quality issues and delay in waiting time; problems that are related to cost and the management. Later is estimated that $1 million/year would have been saved if products could have been built and delivered on time. To over overcome this issue, logistic department optimized truck routes using Google API tool that records addresses, then order is batched sequentially on trucks with the first products loaded to be delivered last. Rout optimizer is shown in the diagram below.

The recommendations that was made was that production employees had to scan the items for configurations of the product through visibility tool 'Production Live Status' for the product flow that was displayed in a big monitor for the entire production as shown below. The tool identifies orders that are not in sequence and each order is tagged with the address (cart number and bin number) for identification of the right products. The major demerit of the application is that it depends on manual scanning that can lead to repeat of items or passing without being scanned and further leading to rejection of products. Even though, currently research is being carried out to implement RFIDs to help in automatic detection of product flow as shown below.

V. CONCLUSION

Themost evident potential benefit of IoT innovation is the area of supply chain management through the application of sensor devices, intelligent analysis, data storage, and tools for decision making that have enhanced efficient resource use, supply system, and sharing of information to the end users. Hence the research has come up with a framework creating a system of the four main aspects making the SC such as manufacturers, suppliers, logistics and clients to track the product movement. Even though, there is insufficient sharing of information that has limited the innovation growth in supply chain systems leading to underutilization of the scarce resources and the proposed framework therefore aims to address this challenge.

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