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Using IoT in Supply Chain Management

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ABSTRACT:

Supply chain management has been in existence and has developed over past hundred years. This report takes a detail account of development history of the supply chain management. A review of the literature reveals that over the years the conventional supply chain management, which relied on manual and laborious gathering of information and tracking of goods, has evolved in to Smart supply chain management. Starting from simple RFID based tagging for identification of goods, the development of sensor based technologies and communicating devices has played a big role in the overall development of the smart supply chains. It is understood that a whole lot of IoT infrastructure layer operates by gathering, communicating the information to track the position, quality and timely delivery of goods. The application of IoT today not only tracks the goods but intelligently predicts the situations and helps in protecting and reducing losses. Complex algorithms are in place today which drive the IoT application in different supply chains.

Keywords — **SCM – Supply chain management, IoT – Internet of things, SN – Sensor nodes, RFID – Radio frequency identification, WSN – Wireless sensor network, M2M – Machine to machine, APS – Advanced planning and scheduling, ERP – Enterprise resource planning**

I. INTRODUCTION:

In today's world supply chains are operating under ever changing environment and hence are vulnerable to a variety of risks. Several risk factors affect this ever changing environment. Companies are challenged with finding ways to meet ever rising customer expectations at a manageable cost. The expanse over wide geographies exposes supply chains to risks on global scale (Butner 2010) [1]. The global spread of supply chains, is further being challenged with significant increase in customer awareness. Customer today not only desire timely delivery, they also demand and are highly sensitive w.r.t. product quality, price and service (Christopher 2016) [2].With involvement of diverse and dispersed players, managing uncertainty in the supply chain process poses a big challenge. Despite big scientific developments on several aspects of supply chains, a number of unpredictable and difficult to control factors can affect timely fulfillment of orders. Typical common factors causing late deliveries are traffic and shortage of stocks. Rapid developments in technology has led to equally rapid obliviousness / change of products which has further increased the complexity of supply chains (Simchi-Levi, Kaminsky and Levi 2003) [3]. Hence, Supply chain management (SCM) has become essential and important aspect of many industries.

To survive in such competitive and challenging environment, companies have to build a robust but structurally flexible, risk free and highly responsive supply chain (Christopher & Holweg 2011) [4].

A lot is being written about the Internet of Things (IoT) and how it will affect nearly every global industry—from retail to connected vehicles. One of the most exciting areas of impact is the global supply chain. (Ross 2016) [5]. This has been achieved through improving communication, acquiring and transmitting data which enables quick decision making and enhancing supply chain performance. Implementation of

IoThas significantly improved typical challenges of SCM like visibility of the chain and at the same time has enhanced agility and adaptability of SCM (Ellis, Morris and Santagate 2015) [6].

This report deals with various elements of supply chain and its management. The importance and challenges of supply chain management. The report provides a comprehensive review of literature on supply chain management, brief historical perspective on the development of IoT and its integration in to supply chain management. Further the report provides a detail account of IoT infrastructure and the application systems. The IoT technologies used today in various supply chains management are described in detail. An effort is made to provide some case studies on application of IoT in SCM. What we conclude based on this study is described in brief. A bibliography of the references used for the study are given at the end of this report.

II. REVIEW OF LITERATURE

In today's highly competitive market place, management of supply chain is not just important, it requires serious development through research and innovate to meet the dynamic and ever rising expectations of customers at manageable cost (Jinesh Jain et.al. 2010) [7].According to Ganeshan and Harrison (1995) [8]SCMis an integrated network which operates in a coordinated manner from procurement stage of materials till delivery of the finished goods to end user. A similar definition of SCM is proposed by Lee & Corey (1995) [9].It states that, SCM is comprised ofa complex network of activities that converts raw materials to intermediates and finished goods which are delivered to end user through a chain of distribution system. Christopher (1998) [10] defines SCM as a value creation interlinked system for both for the supply chain and the end user in the form of products and services.

During the course of this review, it revealed that the topic is still under considerable development and debate. Richard Lamming (1996) [11] has given a general review on lean supply chain in which Lean supply has been characterized as "beyond partnership". Balakrishnan and Cheng (2005) [12] have proposed spreadsheet based methodology to handle multi product environment which often faces multiple bottlenecks. Manydefinitions of IoT are available in literature. According toAtzori, Iera and Morabito (2010) [13], the main reason for this is that IoT is composed of two words: "Internet" and "Things" and so we have two visions.

As in Xu, He, and Li (2014) [14], a typical IoT network includes four main essential layers:

(1) A sensing layer that integrates different types of 'things' like RFID tags, sensors, actuators;

(2) A networking layer that supports information transfer through wired or wireless network;

(3) A service layer that integrates services and applications through a middleware technology; and

(4) An interface layer to display information to the user and that allows interaction with the system.

Radio-frequency identification (RFID): It allows identifying, tracking and transmitting information. There are five main classes of RFID tags (López et al. 2011) [15].

Wireless sensor networks (WSN): It is a network composed of a set of sensors to monitor and track the status of different devices like their location, movements or temperature. Sensors can be used for a multitude of purposes such as temperature, pressure, flow, level, imaging, noise, air pollution, proximity and displacement, infrared, moisture and humidity and speed (Rayes and Salam 2016) [16]. There are several literature reviews on the subject of IoT and supply chain. In this section, we summarize those that are most relevant to our review and explain how our review is different. Musa and Dabo (2016) [17]focus on RFID uses in supply chain management in the period 2000–2015. Strozzi et al.(2017) [18] review the literature on smart factories and thus focus only on the manufacturing sector. In addition, the authors restrict their review to only those papers that are listed on Web of Science between 2007 and 2016.

III. SUPPLY CHAIN MANAGEMENT

Supply chain management (**SCM**) is managing the flow of goods and services. Management of supply chain includes movement and storage of raw materials, inventory, and finished goods from point of origin to point of destination. A supply chain is managed by designing, planning, execution, control and monitoring. It serves the purpose of creating net value, building competitive infrastructure leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally.

A. Importance of Supply chain management:

- Customer Service
- Reduction of Operating Costs
- Decrease Production Cost
- Decrease Total Supply Chain Cost
- Improve Financial Position
- Reduce inventory costs
- Improves handling of goods
- Improves process integration

B. Weak links in supply chain:

1. **Adaptability:**Managing sudden changes in demand.
2. **Visibility:**Difficult to gain proper visibility of the market requirements.
3. **Agility:**Responsiveness to customer requirements.
4. **Analytics:**Not efficient enough to be deployed to the entire supply chain.

C. Smart Supply chain Management:

A supply is smart if it is: **Instrumented, Interconnected &Intelligent**

Smart supply chain overcomes the weak links in the system by use of **Internet of things (IoT)**. IoT provides rapid solutions to the challenges of a traditional supply chain like:

1. Product tracking
2. Improve Transactional Efficiency

This gives end-to-end visibility of the entire supply chain.

IV. INTERNET OF THINGS

Internet of things is a network of varied physical devices which connects physical devices and allows / facilitates exchange of data. The physical devices with built in electronics and software connect through a whole lot of actuators, sensors. Each device can be identified by its embedded computing system. This makes devices to inter-operate within the established infrastructure.

A. Advantages of IoT:

Communication: IoT provides a transparent system with better ways of communication thus increasing the quality of service.

Automation and Control: Faster and timely output.

Monitor: Monitoring the supplies helps keep track of availability in warehouses as well as their locations in transport or warehouses.

Time: Helps reducing the time by accelerating the supply chain process.

Money: Alerts can be provided in case of breakdowns, and damages to the system. Hence, save money by using this technology.

Efficient and Saves Time: The machine-to-machine (M2M) interaction provides better efficiency.

B. IoT Architecture:

IoT is an umbrella term that involves various categories:

1. Wireless sensor/actuator networks
2. Internet-connected wearables
3. Low power embedded systems
4. RFID tracking
5. Use of mobile phones to interact with the real world
6. Devices that connect via Bluetooth-enabled mobile phones to the Internet
7. Connected cars And many more

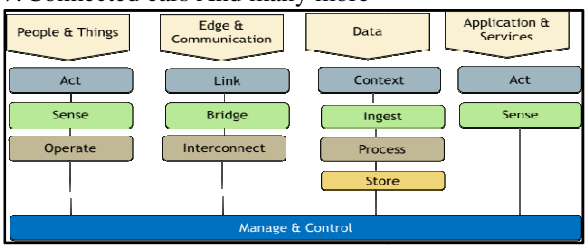

Fig No. 1

Some specific requirements for IoTdevices and the environments that support them as shown in Fig No. 1 are:

1. People and Things:
2. Edge and Communication.
3. Data collection, analysis, and actuation
4. Scalability
5. Security
6. Application and Services

V. IoT AND SUPPLY CHAIN

A. Supply chain challenges:

Globalization Challenge: Having suppliers in different geographic locations complicates the supply chain.

Fast changing markets: Constant innovation due to fast-changing markets means enterprises constantly have to anticipate demand for new products.

Quality and compliance: Pressure to create high-quality products.Enterprises need to abide by the compliance or the rules of the regulatory standards in manufacturing, packaging, handling, and shipping of their products.

Managing Inventory: Keeping enough inventory on hand so that all customer and client expectations are met.

Managing Suppliers: Finding suppliers with consistent and reliable service at a price that doesn't hurt your bottom line.

Managing safety and quality: The globalization of supply chain brings concerns about the quality of products that are made in other countries.
Risk Mitigation: Companies that rely on one or less numbers of suppliers are vulnerable if that supplier doesn't meet demands.

B. Integrating IoT and Supply chain:
Integration: A traditional SCM will have supply chain managed by business process using planning the shipment or transport of the goods from manufacturing to the end user. But when IoT is used the system architecture changes as shown in Fig No. 2 the new architecture is-

The supply chain:
1. **Manufacturing:**Manufacturing companies can support other manufacturers, distributors or consumers with fabricated or assembled products. Manufacturers can have extensive supply chain issues within their own facilities, depending on the number of products produced and the manufacturing processes they are engaged in.

2. **Loading:**While loading the goods from the manufacturer's premises or warehouse it has to be confirmed that all goods meet all requirements. Protection measures for goods have to be taken in consideration.

3. **Shipment:**Transportation modes include trucking, rail and air. These modes are the link between manufacturers, suppliers, retail stores and consumers.

4. **Supplier:**Suppliers come in many forms and are a crucial link from manufacturers to other businesses and consumers. Suppliers may also perform assembly operations, carry inventory or operate the transaction as coordinators between Suppliers and other businesses or consumers.
5. **Consumer:**They buy and use the product, give feedback for the products and their demand changes the market demand.

Business process:
1. **Shipment planning:**Shipment planning includes the strategic planning of supply, manufacturing, distribution, production scheduling, demand forecasting, and supply chain network design.
2. **Transport planning:**It deals with the flow of goods while they are taken from one SCM component to other. It plans the route that will be taken, which mode of transportation depending on the demand.
3. **Shipment Tracking:**Shipments are tracked by the use of IoT where the products, vehicles transporting the products are considered and their locations are tracked. Shipments can be tracked to know the location, route taken for transportation.
4. **Product Tracking:**Product tracking is important so to avoid frauds and losses, know their exact location whether they are in transport vehicle, in warehouse or with suppliers.

IoT service:
1. **Tracking:** The tracking process involves various IoT devices. They sense conditions, calculate distance or give the location of the products or vehicles in SCM.
2. **Server:** Servers are used for communication between cloud controllers and the tracking devices as well as end users. Servers take action predefined by the business process if need arises for instance if a container having perishable raw material being kept below a certain temperature if the temperature rises beyond the threshold data is sent to server which updates on cloud and sends alert of the same to the person in charge.
3. **Cloud:** Cloud is where everything is present like product information, customer information, routes to be taken, algorithms for alert situations, vehicle information, real time data etc.

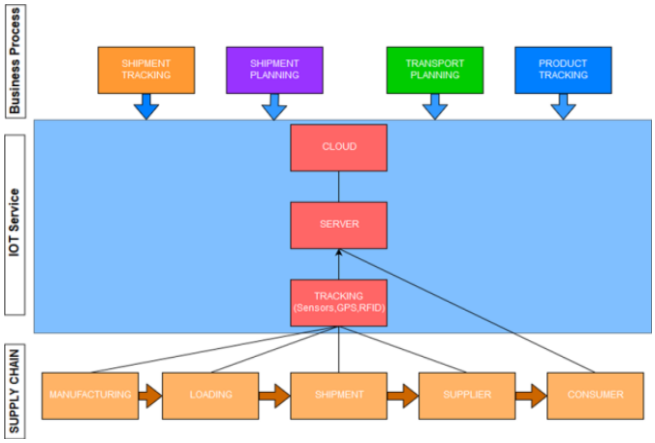

Fig No. 2

VI. IoT TECHNOLOGIES AND ALGORITHM

Technologies used for smart supply chain are divided in 2 layers:

A. Infrastructure layer:
It consists of all the physical entities of the management system.

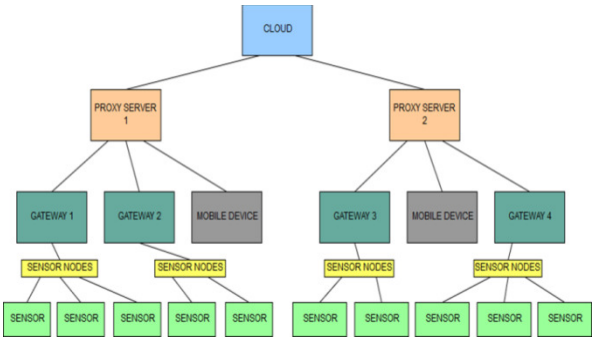

Fig No. 3

1. **Sensors:** Sensor is a device which serves the purpose of detecting events or changes in its surrounding environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronic devices. In simple words Sensors are the eyes and ears of the system as they detect occurrence of events, surrounding conditions and transmit the collected information. Different types of sensors used in proposed system are:
   i. Temperature Sensor
   ii. Humidity Sensor
   iii. PH Sensor
   iv. Chemical Sensor
   v. Tilt Sensor
   vi. Location Sensor
   vii. RFID Tag
   viii. Vehicle Speed Sensor (VSS)
   ix. Pressure Sensor
   x. Real Time Clock (RTC)
   xi. Moisture Sensor

2. **Sensor Nodes (SN):** It is the transportation vehicle that carries various kinds of goods. Each sensor node is provided an IP address which helps in its unique identification. Every sensor node communicates all of its sensor data to its subsequent gateway.A sensor node is composed of:

i. **Controller:** The controller performs the tasks of processing the data and controlling the functioning of other components in the sensor node.
ii. **Transceiver:** The functionality of both transmitter and receiver are combined into a single device known as a transceiver. Transceivers often lack unique identifiers. The operational states are transmit, receive, idle, and sleep.
iii. **External memory:** Memory requirements are very much application dependent. Program memory also contains identification data of the device if present.
iv. **Power source:** The sensor node consumes power for sensing, communicating and data processing. Power is stored either in batteries or capacitors.

3. **Gateways:** All the information that has been sensed and collected by the sensors is transmitted to the gateways. Gateways act as a common point of contact wherein diverse kinds of information coming from heterogeneous types of sensors gets collected. It is the gateway which is responsible for the global addressing of Sensor Nodes (SN) by making use of IPv4 addresses. Every gateway is allocated more than one area so as to enhance the granularity of SN identification. Gateway transmits all forms of unstructured information to its subsequent proxy servers.

4. **Mobile Device:** It acts as a representative for a supplier or a customer. It is the mobile device which allows the end user to monitor, track and manage the entire supply chain on a real time basis. Any alert that is triggered from a sensor node is directly communicated to the mobile device in wait of an appropriate response.

5. **Proxy Server:** It acts as an intermediary node for requests coming from a supplier or a customer. Proxy server provides a communication link between Cloud and the rest of the system and also offers local processing and storage capabilities in order to boost the efficiency of the system.

6. **Cloud:** Cloud controls the entire system. It is used for storage of real time data, algorithms, customer information, and product information.

B. Application layer:

This layer consists the working and the information flow of the entire system.

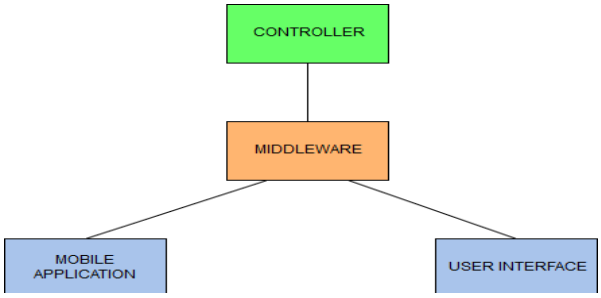

Fig No. 4

1. **Mobile application:**It resides on the mobile device of a supplier or a customer and allows them to interact, monitor and manage the rest of the entities of the system. The mobile application receives alert notifications from the middleware and responds to

them in form of suitable actions which are then conveyed to the pilot through the user interface.

2. **User Interface:** It resides on the vehicle that is responsible for the transportation of goods. It informs the pilot of the vehicle about the route to be taken, sensor node status, supplier information, sensor alert notifications and end user requests.
3. **Middleware:** The purpose of the middleware is to receive orders from the controller and communicate them to the respective entities involved in the system. The middleware resides at the proxy server and regularly updates the controller regarding the status and working of all other entities. It communicates this information to the controller in response of a suitable order.
4. **Controller:** Controller orchestrates the functionalities of other application modules and entities within the system. The controller resides at the Cloud end and has detailed information regarding every product, customer, supplier, source, destination, sensor node, actuator, and gateway and proxy server. It is the controller which generates detailed product supply chain reports on the basis of supply chain performance, quality control and alters triggered by the sensors.

Algorithm:

1. Start()
2. Controller()
3. Middleware()
4. Product_Info()
5. (product_Source, product_destination) ⟶ Controller ()
6. Controller() ⟶ Middleware()
7. SensorNode(sensor_data) ⟶ Gateway
8. Gateway(time, sensor_data, location_sensor, route) ⟶ ProxyServer
9. ProxyServer (product_Source, product_destination, time, sensor_data, location_sensor, route) ⟶ {UserInterface, Mobileapplication, Cloud}
10. SensorNode(Sensor, Alert_type) ⟶ Gateway
11. Gateway(Sensor, Alert_type, location_sensor, time, route) ⟶ ProxyServer
12. ProxyServer(Sensor, Alert_type, location_sensor) ⟶ {UserInterface, Mobileapplication, Cloud}
13. CloudAlert_⟶ Action()
14. Alert_Action(Alert_type) ⟶ ProxyServer
15. ProxyServer(Alert_type, Sensor, location_sensor, time, route) ⟶ {UserInterface}
16. UserInterface(Action_taken) ⟶ProxyServer
17. ProxyServer (Action_taken) ⟶ {Cloud,Mobileapplication}
18. Mobileapplication(Customer_Authentication) ⟶ProxyServer
19. ProxyServer(Customer_Authentication) ⟶Cloud
20. Distribution_Pattern ⟶Cloud
21. End()

Detailed Algorithm:

1. Start.
2. Controller is activated which sends request to middleware at proxy sever to send information.
3. Controller first gets information from command center of source i.e. suppliers end and destination i.e. customers end.
4. Controller sends this information to middleware.
5. Sensors sense the data which is collected at sensor node, sensor node sends data to a particular gateway.
6. The gateway then sends the sensor data, time at which it is taken, location of sensor and route to proxy server.
7. Proxy server then updates the sensor data, time at which it is taken, location of sensor, route, and source, destination on user interface, mobile application and cloud.
8. Step 5 to step 7 takes place continuously in a loop till alert is generated.
9. If a sensor detects alert the sensor node sends the sensor data along with alert to the gateway.
10. Gateway then sends the sensor data, alert and location of sensor to proxy server.
11. Proxy server sends sensor data, alert, time, location of sensor and route to user interface, mobile application and cloud.
12. Cloud call for alert action and sends alert action with alert type to proxy server.
13. Proxy server the alert action, sensor data, sensor location, time and route to user interface.
14. User interface sends action taken to proxy server.
15. Proxy server updates action taken on cloudand mobile application.
16. Once the product reaches the customer the customer is authenticated by mobile application.
17. Mobile application sends data to proxy server.
18. Proxy server sends data to cloud.
19. The distribution pattern is updated on cloud for future use.
20. End.

VII. CONCLUSION

It is concluded that management of the supply chains in various industries has developed significantly from earlier manual, laborious and risk prone operations to real time, automatic and risk free operations to a large

extent. The advent of IoT and its applications in to supply chain management has developed to an extent which has not only helped tracking and of goods in transit but has impacted the efficient management of inventories and reducing losses of supply chains. This has resulted in large scale economic benefits to the companies and has helped in expanding supply chain operations over large geographies. Beginning from simple goods identification devices to complex network of physical devices operating in a coordinated manner, the application of IoT has granted greater visibility in manufacturing of goods as well as the supply chains to deliver the finished goods till end user.

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