

The Internet of Things (IoT) for Supply Chain Management

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ABSTRACT

The Internet of Things (IoT), also called Internet of Everything or the Industrial Internet, is a revolutionizing the ways we conduct our business operations, interact with customers and partners, and innovate our business models. The IoT is recognized as one of the most important areas of the future technology and is gaining a lot of attention from a wide range of industries. This paper presents IoT technology architecture essential for successful IoT-based supply chain management and discusses how the IoT can support supply chain management.

Keywords: Internet of Things, Supply Chain Management, Business Model, Monitoring, Data Analytics

INTRODUCTION

The Internet of Things (IoT) is a megatrend in which a global network of interacting machines and devices is mainstreamed into the economy and society through the Internet. Since the term, the Internet of Things, was coined in 1999 by Kevin Ashton, significant IoT investments have taken place in smart homes, cars, and smart cities. Recently, the IoT was also recognized as an essential disruptive technology for the supply chain management. The IoT will enable supply chain partners to improve collaboration by connecting internal and external business processes through devices, machines, RFID tags, and sensors.

Gartner, Inc. [3] forecasts that the IoT will reach 26 billion units by 2020, up from 0.9 billion in 2009, and will impact how the supply chain operates and how the partners collaborate with each other. From production floor and warehousing to the distribution and store shelving, the IoT provides real-time data and business intelligence for all partners in the supply chain. Firms will invest in the IoT to increase visibility of materials flow, reduce loss of materials, and lower distribution costs.

As the IoT is penetrated into core business processes and more and more firms support green supply chain, finding ways to leverage the IoT for supply chain management will become a subject of great interest for managers. The IoT for supply chain will generate values in inventory management, preventive maintenance, and transportation areas. The supply chain will provide new ways of communication among the partners and customers with rich data and timely situational responses. However, the true value of the IoT can be realized when managers fully understand what data the IoT devices generates, and how the data should be processed to make the right decisions.

This study discusses IoT architecture essential for effective supply chain management and identifies three types of IoT applications for supply chain partners. This paper also discusses how the three types of the IoT applications support the supply chain partners using data from the 2014 Fortune 100 companies.

Basic IOT Architecture

For successful IoT-based supply chain management, basic IoT architecture needs to be established and updated continuously to commission and decommission the IoT assets. Domingo [2] suggests three layers of IoT architecture including perception, network, and application. For supply chain management we expand the architectural layers. The basic architecture includes four layers: (1) object layer, (2) communication layer, (3) application layer, and (4) data service layer. Each layer has core components and essential functionalities described below.

Object layer: it consists of physical objects such as devices, machines, sensors, RFID tags, and readers. The object layer is responsible for sensing the environment, identifying objects, and collecting data. This object layer strives to be miniaturized to become energy-efficient, location-independent, and cost-effective. RFID tags and sensors are often embedded in the machines and devices.

Application layer: it consists of a set of problem-specific software tools that interact with users, solve problems, store data, and share data with other applications and users. The application layer is responsible for presenting data and images to the user in a user-friendly format.

Network layer: it consists of a network of wired/wireless networks, the Internet, and protocols. Its main function is to handle transmission of data obtained from the object layer to other devices or datacenters. The IoT is driving the rapid diffusion of the wireless network due to its flexibility and low cost compared to the wired network.

Data service layer: it consists of private/public cloud and related data management systems. Its main function is to store data generated by sensors, devices, and machines and provide the object layer with access to stored data. At the request of the users, data are processed into a form useful for decision makings. Data mining often is conducted to discover knowledge hidden in the sea of data at the data service layer. Unlike the above three layers which are mostly owned and managed by an individual company, the data service layer may be owned and managed by public cloud service providers.

IOT APPLICATIONS TO SUPPORT SUPPLY CHAIN MANAGEMENT

Supply chain management is a central theme in today's global industries [6]. Since an individual firm alone is not able to coordinate the complex web of supply chain activities, firms move towards more integrated collaborative supply chain management [1] [4] [5]. Understanding how IoT applications can enhance the value of their organization is a prerequisite to successful IoT adoption. This section discusses how the IoT applications support the supply chain management of the 2014 Fortune 100 companies. Three types of the IoT applications are identified: monitoring and control, collaboration and information sharing, and data analytics.

In a typical supply chain, monitoring and control applications use sensors, RFID tags, and sensor networks to minimize theft in warehouse, transportation, and store shelves. Sensors are also used to maintain goods at the correct temperature and protect them from chemical spills to spoilage. Sensor networks monitor traffic conditions, and navigation devices track the location of transportation vehicles to make routing more efficient. Information sharing and collaboration applications enhance the decision-making of the channel partners through better visibility of materials flow in the supply chain pipeline. Inter-organizational data sharing becomes real-time via wireless online communications. Data generated from the multiple partners' machines and devices are fed into a cloud datacenter and merged into a supply chain-wide database for simulation, data analytics, and optimization. Data analytics applications enhance the predictive maintenance of the fleet, demand forecast, delivery lead time, and customer services.

Table 1 shows the conceptual model of IoT applications for supply chain management. Supply chain partners are divided into manufacturing, distribution, and retailing. By combining these supply chain partners and the three IoT application types (i.e., monitoring and control, collaboration and information sharing, and data analytics), the IoT applications for supply chain management can be divided into nine cells. Each interaction cell represents the specific supply chain partners and IoT applications developed/adopted by the Fortune 100 companies. The last column shows the benefits/values derived from the IoT applications. The mapping of the IoT applications to supply chain partners will help other enterprises understand the nature and effects of the IoT, reduce the trials and errors in the implementation process, and maximize the value of investment. We excluded Fortune 100 IT companies such as IBM, Intel, and Cisco to focus on non-IT companies' use of the IoT applications for supply chain management.

A total of 15 applications adopted by the Fortune 100 companies indicate that the IoT is not hype and has become a reality for enterprises. Our analysis shows that the IoT is widely used in the area of retailing (10), followed by distribution (3) and manufacturing (2). Monitoring and control is the most widely used IoT application area (7), followed by data analytics (6), and information sharing and collaboration (2).

Table 1. A Conceptual Model of IoT Applications for Supply Chain Management

Supply Chain Partners	Monitoring and Control	Information Sharing and Collaboration	Data Analytics	Value Creation
Manufacturing	Ford: Connected Car Dashboards, a collaborative project with Splunk Enterprise and Cisco that analyze data collected from vehicles improve vehicle performance		General Electric: Predictive maintenance in its jet engines, turbines, and wind farms. By analyzing data in real time, GE saves time and costs.	Improved information quality, Decreased cost, Increased productivity, Enhanced knowledge management
Distribution	John Deere: WorkSight technology for monitoring an entire fleet of vehicles are at any time UPS: Fleet tracking devices to cut costs and improve driver efficiency Fedex: SenseAware to keeps tabs on the temperature, location and other vital signs of a package, including when it's opened and whether it was tampered with along the way			Lower inventory, Partner relationship management, Enhanced business intelligence,
Retailing	Kroger: Retail Site Intelligence for store security and	Macy: Bluetooth-based location system providing customers	Walmart: Inventory system to optimize its warehouse and	Consumer loyalty, Open innovation, Increased consumer

	<p>surveillance</p> <p>Home Depot: Wink (a spinoff from crowd-investment firm Quirky) app which coordinates some 60 Home Depot products, making houses into “smart homes</p> <p>Lowe's: Smart kit app called Iris which lets customers manage their devices such as a smart garage door controller, a window blind controller, and a hose faucet water timer that help the home owner manage this home anytime, anywhere</p>	<p>with product information and special discounts</p> <p>American Express: Partnering with several retailers to offer real time promotions based on a customer’s location and credit card activity</p>	<p>supply chain operations with vendors</p> <p>Macy: Smart technology that sends special offers and recommendations to the customers’ smartphones based on vicinity</p> <p>Proctor & Gamble: Interactive Electric Toothbrush links with a smartphone and records brushing habits, while an app gives mouth-care tips alongside news headlines</p> <p>Coca-Cola: Smart vending machines collecting real-time data about customer behavior and equipment</p> <p>Mondelēz International Inc. (maker of Cadbury chocolates, Trident gum and other items): “Smart shelves,” new display units located in the checkout aisle and near snacks, employing sensors and to get a basic demographic information about the shopper and analytics to analyze their purchase patterns.</p>	<p>satisfaction, Increase revenue, Targeted marketing, Custom-tailored experiences, Enhanced brand image</p>
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CONCLUSION

Because the IoT is such a recent development, there is still a paucity of studies on the supply chain aspects of the IoT. This makes it very challenging for companies to make informed decisions in regard to IoT adoption/implementation in the area of supply chain management. We identified three categories of IoT applications: monitoring and control, data analytics, and information sharing and collaboration, data analytics. We discussed how supply chain partners can use these IoT applications for better management of their supply chain. Since the IoT became a reality beyond hype, supply chain partners need to understand the benefits and related investment costs and conduct a thorough cost-benefit analysis for the investment justification.

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