INTERNET OF THINGS IN LOGISTICS: TOWARDS AUTONOMOUS LOGISTICS & SMART LOGISTICS ENTITIES

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ABSTRACT

`In today's society, internet has become a given due to its ubiquitous presence. It is affecting our lives in every possible way. Due to the rapid development of the internet and the advancement of communication technology, the internet of things (IOT) revolution has evolved. Amid the hype of IOT, logistics industry is a key player that is expected to benefit from the IOT revolution. In this paper we start by explaining the IOT concept, components and best practices. We then move to its application in the logistics industry. In doing so we shed the light on its impact on logistics. Turning logistics entities into smart entities, IOT can be an enabler for autonomous logistics. We demonstrate the concept by showing a use case for using IOT in logistics. Finally, we conclude with the success factors for IOT in logistics.

Keywords: Internet of Things (IOT), Internet of Everything (IOE), autonomous logistics, smart logistics, cloud computing, RFID

INTRODUCTION

Technology advancements are evolving rapidly. As a result, the borders between the physical world and the cyber world are becoming increasingly blurred. Internet has been previously concerned with connecting computing devices. Nowadays, it's connecting objects or "things" more than people. As reported by Cisco, it's expected by 2020 to connect over 50 billion devices. However, it's the use of technology and the value harnessed by economy due to this use that deems the technology useful. When it comes to IOT, the future is very promising. Many industries are now finding their ways and best practices to benefit from IOT. The logistics sector is one of the key players expected to benefit from IOT. Actually, IOT technologies are not completely new to logistics. Some of the technologies used in IOT have been used before in logistics and supply chain management, for example the use of RFID. However, this is only the tip of the iceberg. There is still a vast scope for applying IOT in logistics and supply chain management waiting to be unleashed.

To study the expected impact of IOT on logistics, this paper goes through some academic research as well as industry reports. The following sections of the paper are organized as follows. The next section will go through the definitions of IOT in both academic research and industry reports. Following that, the paper will show the technologies that IOT has built on and a generic architecture for IOT. Next, IOT applications and best practices in some industries are visited. The next section focuses on the utilization of IOT in logistics and supply chain management. Finally a use case is demonstrated for using IOT in collaborated supply chain management to track pallets and containers.

IOT CONCEPT AND VISION

It's often said that we are witnessing the next major step in the evolution of the ICT industry. Internet as we used to know it is changing. Internet that has been before connecting computing devices is now connecting also everyday devices[1]. IOT is linking the physical world to the cyber world.

The term "Internet of Things" has first been coined in 1992 by Kevin Ashton the cofounder of Auto-ID center MIT[2]. However, the term was officially used in 2005 by International Telecommunication Union (ITU) in their first report on the subject. ITU explained their vision as an intelligent infrastructure linking objects, information and people through the computer networks, and where the RFID technology found the basis for its realization[3]. Over the past decade, IOT has gone through many definitions. IOT definitions vary according to the perspective of the organization or entity defining it. In general, there are three major perspectives for viewing IOT. The first perspective is the thing oriented perspective. In the thing oriented perspective, the definitions are mostly interested in IOT ability to connect more objects. The second perspective is the internet oriented perspective. This perspective is concerned mostly with the connection protocols and networking technologies. The third perspective is the semantic perspective. This perspective is mostly related to the vast amount of information exchanged due to the interconnection. The convergence of these three perspectives fully defines IOT[4].

One of the most interesting definitions of IOT is the 6A vision presented by the Cluster of European Research Projects on the Internet of Things (CERT-IoT) in 2001 [5]. Before this definition IOT has been about connecting the 4 As (Anything, Anyone, Anytime and Anywhere). The 6A vision adds 2 more As. It introduces "Any path/network" and "Any service".

Many terms and fundamentals are now becoming more familiar. Smart objects, M2M (machine to machine) and pervasive computing, to name some of them, are coming into light. None of these terms is a synonym for IOT. They are rather fundamental components of it.

Revising industry reports regarding IOT, DHL presented a very interesting expression in their definition of IOT "When we connect the unconnected - when we light up "dark assets" - vast amounts of information emerge, along with potential new insights and business value"[6]. By 2020, Cisco estimates there will be more than 50 billion devices connected to the Internet [7].

INTERNET OF EVERYTHING (IOE)

IoT brings together the physical world and the cyber world. It is a vital enabler of certain types of connections that together make up what Cisco refers to as the "Internet of Everything" (IoE). IoE connections can be machine-to-machine (M2M); machine-to-person (M2P) or person-to-person (P2P). IOE links not only physical objects. It links also people, processes and Data (figure 1).

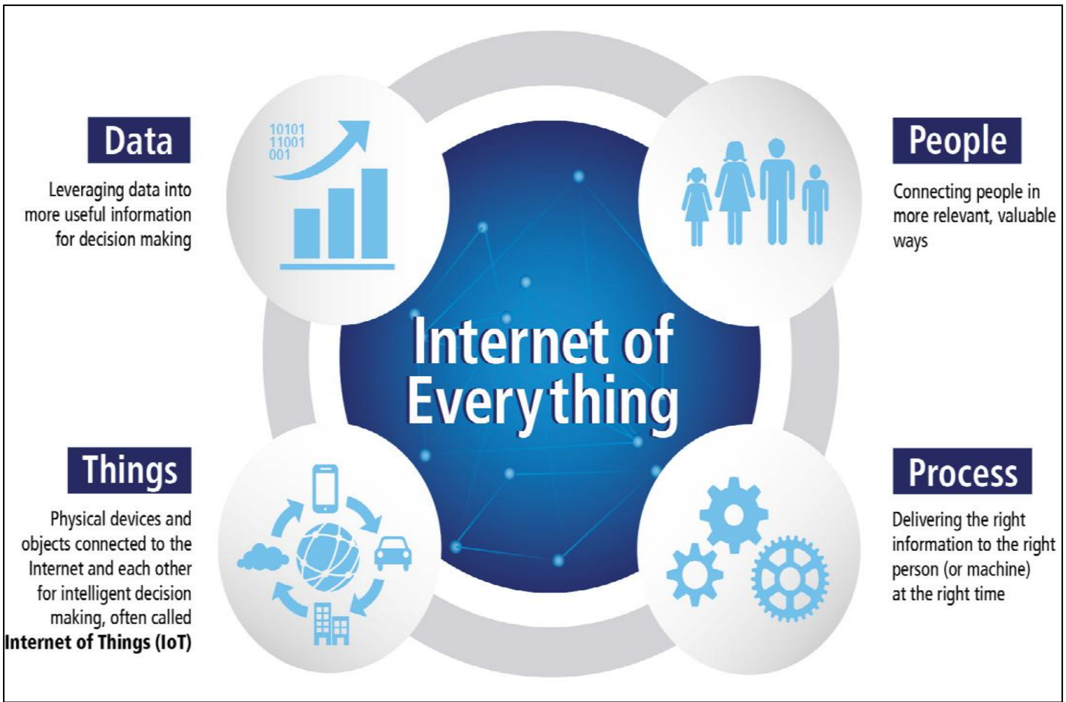

Figure 1. IoE, the Networked Connection of People, Process, Data, and Things[6]

IOE creates new opportunities for innovation and business transformation. IOT is one of the technology enablers of IOE. Many technological advancements are coming together to form the IOE paradigm that paves the road for huge innovations and business opportunities. Some of these technology enablers are also cloud computing, big data, P2P video/social collaboration, mobility (including location based services) and security[6].

IOT ARCHITECTURE AND TECHNOLOGY

Evolutions in networks and infrastructure has paved the way for the IOT vision described above. To understand IOT and how we can benefit from it in various industrial and services and activities we need to get a better understanding of its architecture and enabling technologies and components.

IOT Application Architecture

The vertical approach used by some current systems is replaced by a more flexible and horizontal approach[2]. Figure 2 shows the horizontal representation for IoT applications and technologies.

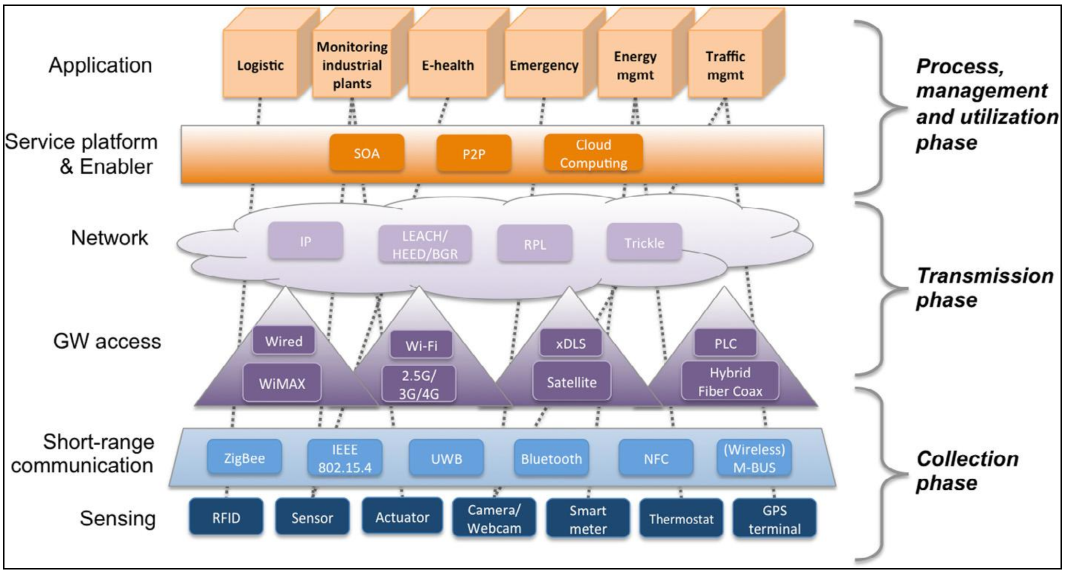

Figure 2 Horizontal representation for IoT applications. A non-exhaustive list of technologies and protocols is shown[2]

According to the recommendations of the International Telecommunication Union[8], the network architecture of IoT consists of five layers: the sensing layer, the access layer, the network layer, the middleware layer and application layers. According to Borgia[2] these layers can also be arranged in three phases. Figure 2 above shows a representation of these layers with the corresponding phases. Let's first discuss the functions of each layer to get a better understanding of the architecture.

Sensing layer: the main function of this layer is to capture information from various sensors linking objects smartly to the network. It links objects to the network through sensors and actuators.

The access layer: this layer's main function is to transfer information from the sensing layer to the network layer through existing mobile networks, wireless networks, wireless LANs, satellite networks and other infrastructure.

Network layer: this layer's main function is to integrate the information resources of the network into a large intelligence network with the Internet platform, and establish an efficient and reliable infrastructure platform for upper-class service management and large-scale industry applications.

The middleware layer: this layer's main function is to manage and control network information real-time, as well as provide a good user interface for upper layer application. It includes various business support platform, management platforms, information processing platform, and intelligent computing platform.

Application layer: this layer's main function is to integrate the function of the bottom system, and build the practical application of various industries, such as smart grids, smart logistics, intelligent transportation, precision agriculture, disaster monitoring and distance medical care.

IOT Key Technologies

As highlighted before, it’s through the evolution of several technologies that we could now have what we call Internet of Things. The convergence of these technologies is giving us the new era of ICT utilization in our daily lives. The continuous advancements of such technologies will continue to give us new innovative business models to use. Some of the major technologies contributing to IOT are:

Wireless sensor networking technologies: The development of appropriate means for identifying smart objects and enabling interactions with the environment paved the way to lighting up dark assets as denoted by DHL[6]. The ability of sensing the environment and to self-organize into ad hoc networks represent important features from an IoT perspective[10].

Radio frequency identification devices (RFID): RFID is nowadays considered a mainstream communication technology. It’s used widely in many industrial systems especially logistics. RFID is expected to play a key role as enabling identification technology in IoT. At the same time, its integration with sensing technologies brings alongside a number of challenges and issues.

Near Field Communication (NFC): NFC is a communication technology that enables devices to share information wirelessly by touching them together or bringing them into proximity. It can be useful for sharing personal data, making transactions, accessing information from smart posters or providing credentials for access control systems with a simple touch. NFC can be considered as an evolution of RFID as it is built upon RFID systems, but, differently from it, NFC allows bidirectional communications. Specifically, when two NFC devices are located at a distance lesser than 4 cm, a peer-to-peer communication between them is created, and both devices are allowed to send and receive data.

Ambient Intelligence (AmI): Ambient intelligence builds upon the ubiquitous computing concept, loosely defined as the embedding of computational devices into the environment. Aml is growing fast as a multi-disciplinary topic of interest which can allow many areas of research to have a significant beneficial influence into our society. The basic idea behind AmI is that by enriching an environment with technology (mainly sensors and devices interconnected through a network), a system can be built to take decisions to benefit the users of that environment based on real-time information gathered and historical data accumulated. AmI inherits aspects of many cognate areas of Computer Science.

Service oriented computing (SOC): Service-Oriented Computing (SOC) is a computing paradigm that utilizes services as fundamental elements to support rapid, low-cost development of distributed applications in heterogeneous environments. The promise of Service-Oriented Computing is a world of cooperating services that are being loosely coupled to flexibly create dynamic business processes and agile applications that may span organizations and computing platforms, and can adapt quickly and autonomously to changing mission requirements.

Cloud Computing: The evolution of the cloud computing paradigm has been a key component for collaborative operations. It unleashed computing & storage capacities thus enabling analysis and storage of the huge amount of information collected by IOT and providing a collaborative platform for management and utilization.

IOT APPLICATION AND BEST PRACTICES

As IOT represents a transition in the way of doing business promising a new scope of unleashed value, many industries are now adopting it. In this section we will shed the light on the application of IOT in various industries. By revising the best practices of the major players now seeking to benefit from IOT, we can get the big picture and realize the new paradigm that IOT brings around. Figures 3 shows IOT application domains and related applications[2].

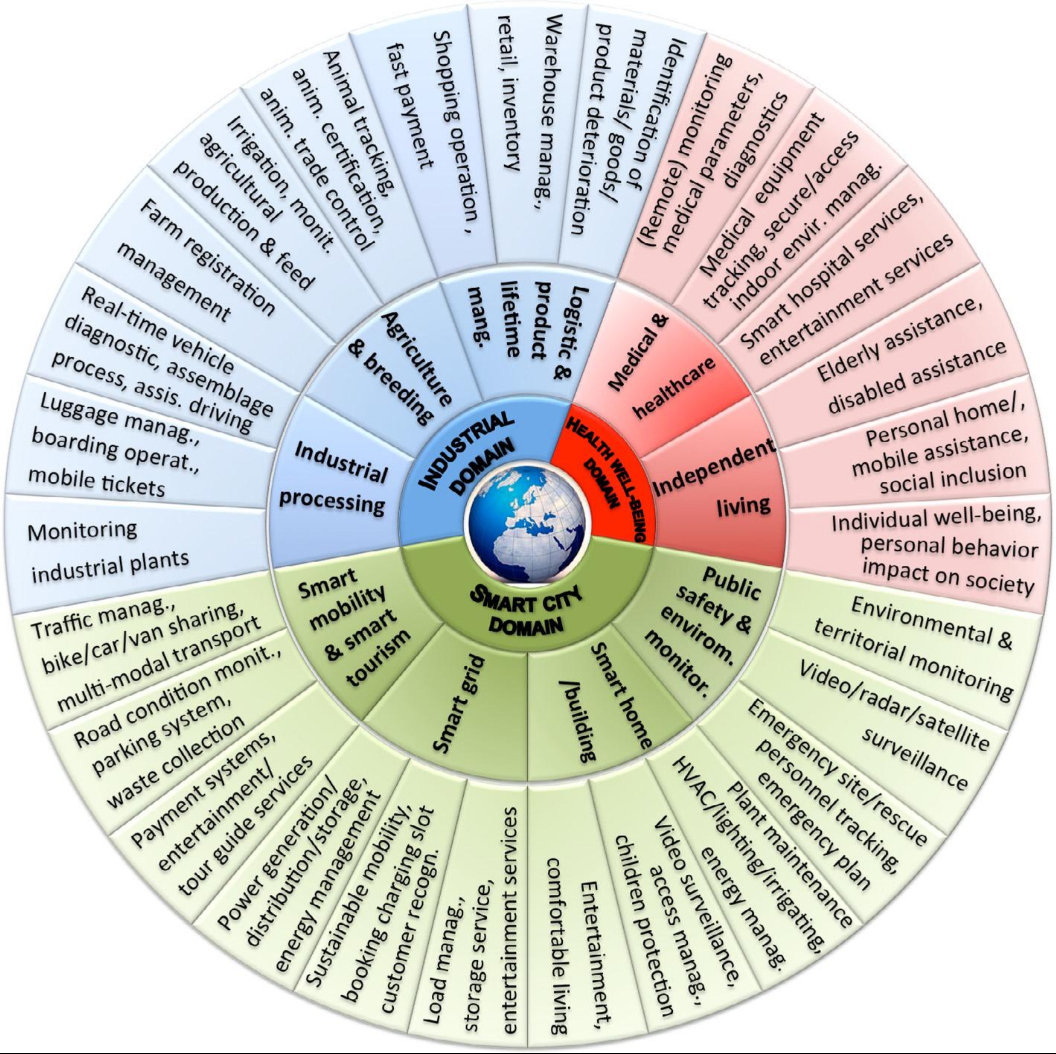

Figure 3 IoT application domains and related applications[2]

In this section we will shed the light some of the best practices through which several industries are seeking more value through IOT. The most promising areas are operational efficiency, safety and security, customer experience and new business models.

Operational Efficiency

Operational efficiency has always been a major concern for most industries. Optimzing assets utilization is one of the most areas tended to by businesses. It’s considered as means of providing value. This puts operational efficiency at the heart of IOT value. We need to make sure that resources are fully utilized with minimum idle time. Efficient utilization of energy is another important issue. Preventive maintenance can be as well another perspective for operational efficiency. The following are examples of such practices within different industries.

Traffic and fleet management: Fleet management can be crucial at ports and logistics centers. By coordinating all operational aspects impacting vessels, rail and trucks ports can have less waiting time and higher efficiency. It also minimizes the impact of port congestion on urban traffic. IOT is also applied in traffic control programs to provide efficient public transportations. Whether applied for traffic and public transportation or applied for managing fleet in industrial transportation, hubs and ports the concept is the same. Sensors are used to collect timely data. Data is analyzed and used to provide better services. An example for transportation and traffic utilization is the application of IOT in Seoul City Transportation Information Center (TOPIS). TOPIS center gathers data from streets, buses, taxis and citizens using GPS devices, loop detectors, road sensors, videos and citizen reports. Thus they can approach transportation policy in a more scientific way. Citizens can thus gain access to a wider range of information regarding public transportation (for example bus arriving time) 24/7. Another example is the Port of Hamburg where an IOT-based approach is used to coordinate all aspects of harbor operations. The initiative’s target is to improve the operational efficiency and economic development. Hamburg Port Authority has installed more than 300 roadway sensors to monitor traffic in the port and track bridges wear. Sensors are also used in waterways and in assigning parking locations and directions for truck drivers. IOT collected data is also utilized to minimize the impact of port congestion on roadway traffic and help manage traffic disruptions.

Resource and energy monitoring: IOT can provide means for monitoring resources and minimizing waste in water, oil, gas and energy. In fact IOT can be a critical component of the smart energy grid of the future. Labor-intensive work models can be replaced with smart-technology solutions to detect leakages. Several technologies can integrate together like sensor produced data, SCADA systems, GPRS, GIS and ERP to general potential cost savings through minimizing waste.

Connected production floor: Automating industrial plants have been one of the areas receiving major interest by many major industry players. While the automated manufacturing has been previously a closed system, IOT is giving it the chance of wide connectivity. Through open IP standards it can result in increased scalability, interoperability, uptime, manageability and security. Preventive maintenance for example a key use case for applying IOT to manufacturing.

Nevertheless, energy consumption and monitoring status of inventory are other manufacturing areas of improvement through IOT.

Safety and Security

Monitoring of equipment and people to increase safety is another value proposition of IOT. Data can be collected to predict failure of equipment or public transportation facilities than can raise a safety hazard. Mining is one of the areas receiving major safety benefits through the application of IOT.

Another area of application is health monitoring. Thanks to IOT devices the lives of many heart and diabetic patients can now be saved.

Physical security is another area where IOT can provide a good help. Examples can be IOT-enabled locking mechanisms and intrusion detection systems.

Customer Experience

IOT is promising a new form of customer experience in retail industry. There are so many use cases in this area such as smart shelves, inventory merchandise optimization, mobile payments and smart home replenishment applications.

There are also some applications for customer recognition that can determine the customer’s interests and provide offers based on that. This can contribute to better shopping experience and higher customer satisfaction.

New Business Models

There is a relatively wide body of research regarding new business models inferred by IOT. When using cloud computing with IOT the concept of “x as a service” is increasingly coming to light. Many new services can be offered. Information itself might become a service and a product of its own. Companies adopting IOT might find themselves on top of lots of information than can be then served for their customers as consultation services. Also usage-based service models can now be adopted more widely. Thanks to IOT, the exact usage pattern can be detected.

IOT APPLICATION IN LOGISTICS AND SUPPLY CHAIN

One of the key industries expected to leverage from IOT is logistics. Logistics is a very fragmented industry by nature. The Logistics chain includes a lot of players and encompasses several industries. This puts a greater pressure on synchronization deeming it harder to optimize. Real-time integration among such players is harder to achieve. However, real-time integration is a mandatory prerequisite to build a robust collaborative supply chain.

A lot of academic research has focused on the benefits of IOT applications in logistics and supply chains. IoT could provide various advantages in supply chain management operations, such as improved inventory management, increased logistics transparency, business process optimization, and resource saving [11]. It can also be utilized to reduce inventory inaccuracies[12] and provide item level information visibility[13] leading to better inventory replenishment decisions[14]. Another added value provided by IOT will be better processes tracking[15].

Industry reports also show increasing interest in IOT applications in logistics. As highlighted by DHL, IOT paves the way to many logistics applications that haven't been available before. IOT-driven smart inventory management enables optimal asset utilization, real-time visibility, damage detection and smart warehouse energy management to name some. As related to freight transportation, location and condition management through IoT will provide a new level of transport visibility and security. Also, safety and security hazards are better tackled through IOT-enabled applications[6].

Some research even goes to the extent of delegating some of the decision making processes to smart object within the logistics change. In autonomous logistics, smart items are expected to do more than collecting data. They have some computational power and expected to handle unexpected situations[16].

THE CASE OF COLLABORATIVE SUPPLY CHAIN FOR TRACKING PALLETS AND CONTAINERS:

A good application of IOT in logistics is the tracking of pallets and containers in a collaborative supply chain. The identification, traceability and real-time tracking of goods in supply chains have always been difficult, because of the heterogeneity of platforms and technologies used by various actors of the chain. The recent innovations in IOT and cloud computing when used together can provide new models for approaching this problem. The problem addressed here is the enhancement of the collaboration between supply chain actors to make easier the flow of goods management in the overall supply chain, including 4PL operators. A model have been proposed in a research recently to target this issue[17]: Figure 4 shows a global presentation of the model.

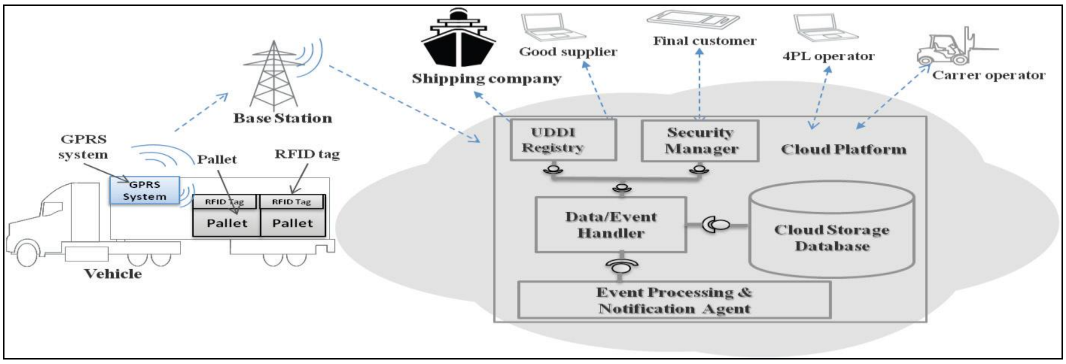

Figure 4. Global architecture of the model[17]

The model builds on several technologies: It uses RFID for sharing information about the goods with all involved parties along the supply chain. The pallets are equipped with RFID chips containing all the required data related to the goods. RFID readers sense the status of the goods and send it through GPRS/GSM network to a cloud platform. The cloud platform is event driven. It is responsible for the collaboration and mediation between the physical network of devices and sensors and the users of the platform. It has five main functions. First function is the data/event handling to handle the messages sent by the heterogeneous end devices. The second function is cloud storage of information received by the physical network (RFID tags for example). The third function is event processing to act as a mediation platform. The forth function is the directory service to store platform external consumer services to be notified. The final function is the security management.

A good use case scenario for this model: In a process to stuff and ship a container, a 4PL operator has a container to stuff with a list of goods. After stuffing the container, it is galvanized and transferred to the port. Then it is transported by ship and delivered to the distribution hub. When the container arrives at the distribution hub, the goods are stripped and shipped to end customers via terrestrial transport operator. In this example the goods come from different suppliers. Also operators who transport are as different as end customers and are not in the same geographic area. This example shows the complexity in coordinating logistic flows and supply chain. The cloud-oriented service platform architecture illustrated above is applied to manage and share information between all involved actors. The platform will handle all events emitted by the flow of goods and the actors in real time. Furthermore, the bus is responsible for automatic notification to all actors. This leads to facilitate the coordination and monitoring of the flow of goods. The 4PL operator could ensure the various

phases of the process: filling the container, shipping, distribution of goods to the final client.
This example is just one of many that can be applied in the logistics industry and that can have tremendous impact on it.

CONCLUSIONS

Based on the current research there are some conclusions that can be applied to the logistics industry:
1. The use of IOT can lead to better efficiency and more collaboration and trust among actors.
2. IOT can be used hand in hand with cloud computing to build new models of information technology and communications.
3. IOT application in supply chains and logistics is a very promising means of collaboration and also monitoring and tracking.
4. IOT can help in many security problems.
5. Investing in communications infrastructure is vital.

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