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A Fog Computing Framework for Blackberry Supply Chain Management

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Abstract

With the rapid proliferation of RFID systems in global supply chain management, tracking every object at the individual item level has led to the generation of enormous amount of data that will have to be stored and accessed quickly to make real time decisions. This is especially critical for perishable produce supply chain such as fruits and pharmaceuticals which have enormous value tied up in assets and may become worthless if they are not kept in precisely controlled and cool environments. While Cloud-based RFID solutions are deployed to monitor and track the products from manufacturer to retailer, we argue that Fog Computing is needed to bring efficiency and reduce the wastage experienced in the perishable produce supply chain. This paper investigates in-depth: (i) the application of fog computing in perishable produce supply chain management using blackberry fruit as a case study; and (ii) the data, compute and storage requirements for the fog nodes at each stage of the supply chain. In the process, we discuss the benefits of the proposed fog nodes with respect to monitoring and actuation in the blackberry supply chain.

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Keywords: Radio Frequency Identification (RFID); Blackberry Supply Chain Management; Internet of things (IoT); Fog Computing

1. Introduction

The Internet of Things (IoT) is based on the idea that the physical environment will be seamlessly merged with the virtual environment. One key technology used to realize this is the Radio Frequency Identification (RFID) devices [1]. The most data rich and intensive RFID application is the supply chain management system in which a tagged product is tracked from manufacture to final purchase. Supply chain represents the sequence of organizations involved in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customers. Supply chain management consists of planning, implementing and controlling the operations of the supply

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chain as efficiently as possible.

RFID differentiates itself from the traditional barcode through its possibilities for bulk registration, identification without line of sight, unambiguous identification of each individual object, data storage on the object, and robustness toward environmental influences and destruction[2]. Potential benefits of implementing RFID for the supply chain stakeholders include: obsolescence prevention; counterfeit prevention; decreased inventory; reduced stock-outs; reduced shrinkage by theft; improved asset visibility; and real-time decision making.

Global supply chain scenarios are typically characterized with use cases in which massive amounts of data are collected for processing from myriad geographically dense endpoints. In such cases, storing and analyzing all the data in a centralized, remote data center may be less than optimal for the following reasons. Firstly, the data volume generated by the sensors may exceed the network bandwidth thus introducing delays. Secondly, for latency-sensitive applications, data transmission to a remote cloud would introduce unacceptable delay, especially when the data analysis is designed to trigger a local, real-time response (e.g., automatically alerting the shipping manager when the temperature of perishable produce in transit goes above the optimal temperature). Thirdly, to survive in today's competitive market, retailers need to make it easy for consumers to buy anywhere, receive anywhere, and return anywhere. The key to this cross-channel order promising is the ability, in real-time, to locate and allocate available inventory from any location, whether in the store, in distribution centres, in transit, or on order from the manufacturer. The solution is to do more computing locally, thus reducing the amount of data which needs to be sent to central servers in the cloud. In addition, network and compute resources may need to be configured in a more suitable architecture in which compute resources are split between local sites (where data is temporarily stored as it undergoes preliminary filtering or analytics) and the cloud (where it is further analyzed and stored).

Perishable produce are sensitive to temperature conditions in which they are handled and require special storage conditions in order to preserve their freshness. The variation of temperature arises when items move through supply chain actors (manufacturing, transportation, distribution stages). The freshness of perishable products is tracked by their "lifetime" (also known as Shelf Life). Once an item surpasses its lifetime, it is no longer safe for use. Sensor-enabled RFID tags are deployed to monitor and track the produce from manufacturer to retailer in large-scale applications. We consider the blackberries supply chain. The dynamics of berries supply chain are different compared to other perishable supply chains due to the following reasons: (i) the high respiration rate of the fruit; (ii) the ability to quickly lose water and weight from the lack of a protective peel or rind; and (iii) the need for the fruit to be rapidly cooled and kept cold during the harvest and distribution process since they are highly susceptible to mold and decay[3]. These characteristics make the fruit extremely perishable and therefore strictly regulated climate-controlled environments are needed to maintain the freshness of the fruit. Once harvested, shelf life begins to deteriorate based on the prevailing environmental conditions. For blackberries, the amount of heat produced as a natural consequence of respiration depends on the storage temperature. Therefore, tracking and monitoring the environmental conditions of blackberries from the field to retailer is critical. This can help the grower, distribution manager and retailer calculate the remaining shelf life, identify any potential quality issues and help route produce effectively. For this reason, Fog Computing is proposed.

Fog Computing was first introduced by Cisco in 2012, to describe a compute, storage and network framework for supporting Internet of Things applications. The metaphorical term highlights that compute resources are close to the ground (that is, proximate to the data sources), in contrast to cloud computing, in which compute resources are centralized and remote [4]. The main feature of fog computing is its ability to support applications that require low latency, location awareness and mobility. This ability is made possible by the fact that the fog computing systems are deployed very close to the end users in a widely distributed manner, making it suitable for global supply management. By orchestrating and managing compute and storage resources placed at the edge of the network, fog computing can deal with the ever increasing demand for real time analytics in perishable produce global supply chain management.

We adopt the following approach: