Smart Inventory Management System For Warehouse Industry Using IoT Sensors & Machine Learned Data Analytics

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ABSTRACT
Current Warehouse management Systems are slow, inefficient with respective to managing and tracking the huge demand of large inventory traffic and hence make a poor customer experience while managing large, urgent and/or important inventories. The proposed system focuses on the delighted customer experience which intend to provide safe, secure and fast inventory tracking and management. The proposed system utilizes the radio frequency based communication along with the cloud based IoT sensor device ecosystems to establish an efficient, fast and smart inventory management system to provide an enhanced customer experience. This system works on the philosophy of goods-ids and location-ids. These goods-ids are the movable sensor nodes attached to the inventory’s which broadcast their identity to the Centralized inventory Manager. Centralized inventory Manager further share this to the relevant customer for whom this inventory is meant for. For universal access, the Centralized inventory Manager can manage its database on cloud for connected geographically independent privileged access. Location-ids are the static sensors which receive the broadcast from the goods-ids. Both Location-ids and goods-ids communicate with each other through the radio frequency wireless communication. The intra location-ids communication is done through node-to-node messaging hopping with shortest path algorithm. This solution aims to reduce the goods queue waiting time considerably and improve inventory management efficiency multi-folds. This solution strengthens warehouse operations & inventory management smartly, safely and efficiently.

KEYWORDS
Inventory manager, IOT sensors, customer experience

INTRODUCTION
Transportation is the basic need of companies, agencies and government. And inventories are main help during transits while transporting. But inventory travel time is the main concern for each and every customer during each and every transportation. Warehouse although offer a good space for inventory but when observed minutely, the fast, hassle-free, seamless experience is still missing today due to long transit lounge, various types of intersections, multi-floor environment etc. The current paper propose an analysis of the present available inventory management system and propose a smart inventory management system based on micro-controllers, sensors working on radio frequency. At the backend, inventory management system keeps the customer aware about the state and location of the inventory and hence maintaining the transparency.

REQUIREMENTS OF SMART INVENTORY MANAGEMENT SYSTEM
The most important requirement of the smart inventory management system is to reduce the inventory time to minimum. Further the intended and articulated need of this system is to provide safe movement of the goods to/within/from warehouse inventory. While the good is being moved or kept in inventory, the customer must be updated about the state of the inventory and whereabouts of the inventory. System should also aim for minimum human intervention in the movement so as to automate the process to maintain safe and faster travel of goods. When good enters the warehouse terminal, it should be properly identified in terms of color, size, x-ray scanned
images and attached to the customer profile for immediate tracking till goods reach customer. The tracking facility should be available through app and website along with message notifications. In case of loss of goods, expectation is to be tracked it fast. In case of theft, wrongdoer should not be able to carry the goods for long time. The inventory management system should be able to handle the peak goods load surge. This also means that server capacity should be scalable in terms of processing power and storage capacity.

EXISTING INVENTORY MANAGEMENT SYSTEMS

Current warehouse systems doesn’t manage the customer inventory exhaustively and smartly. They lack to record few of the important goods characteristics like color, 3-D shape etc. But they doesn’t have a way to track goods within the warehouse, bogie, truck, other vehicle and premises. These kind of inventory systems lose some time during movements and hence need improvements to optimize the timings.

INVENTORY MANAGEMENT SYSTEMS IN AVIATION INDUSTRY

Air Traffic luggage inventory mgmt. system has evolved in a collaborative way over many year. Constraints from international laws forced companies to agree on basic inventory management and improve continuously in coming years. In this way companies and governments agreed on common standard to follow. This helped aviation inventory management to standardize. And hence improved the customer travel experience. There the two common standards followed in aviation inventory managements systems – IATA & ICAO.

IATA [3] is major leading trade association of most of the Aviation. It is also known as International Air Transport Association. It has list of resolutions as mandatory practices for IATA Member Aviation. It also has a list of best practices in form of recommended which can be implemented at the discretion of the Aviation. E.g. Resolution 739 - inventory Security Control.

ICAO [5] is The International Civil Aviation Organization, a UN specialized agency, established in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO works with the Convention’s 191 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. E.g. ICAO Annex 17, discuss about standards dealing with reconciliation of inventory with customers, controls over items left behind on the aircraft by disembarking customers.

INVENTORY MANAGEMENT LESSONS FROM COURIER COMPANIES

These courier management system could provide us some insight of how inventory could be managed. World best courier companies like FedEx [1], UPS etc. are using the barcode scanning as the coded signature along with the barcode scanners to scan the codes. Further it uses Wireless LAN to transfer the details to Server. This is the primitive kind of passive identification units doesn’t transmit their location. They further require a scanner to read them and in a particular way. This require mandatory human intervention and hence limit the efficiency and speed of transportation. The more the courier stay in inventory house, the more space needed for coming courier. Hence becomes costly as compared to fully mechanized operations.

DRAWBACKS OF AVIATION INDUSTRY INVENTORY MGMT. SYSTEMS

The current luggage inventory management system is not adapted to latest needs of the customers. Aviation inventory systems add extra luggage drop time and luggage pickup time. Some airport also add extra delay due to long exit corridors. Aviation inventory systems aren’t smart to keep customer updated about the current inventory state and location. Customer has to wait at destination to see and check the state of the inventory. All other inventory systems besides aviation industry are very primitive and lack even the basic standardization of inventory safety. Hence there is a huge scope for improvement in warehouse inventory management.

DRAWBACKS OF TRADITIONAL TRACKING SYSTEMS
CCTV is the most traditional way to track a good in inventory. But there are major drawbacks related to it viz. it require continuous monitoring. Also it has no built in alert mechanism. Although cctv video recording allows post-mortem analysis but it is a time consuming exercise and has costly human efforts. This doesn’t work effectively in low visibility conditions like fog, night etc. GPS Based Tracking doesn't provide accurate and effective tracking movements in case of multi-floor building, basement area in warehouse. Turnstile installation for inventory tracking is also time consuming and hence not suitable for real-time tracking. Smartcard based solutions required human intervention at each step and hence are discouraged.

LEARNINGS FROM AVIATION INDUSTRY

Aviation industry has incorporated inventory management system since long time. The major learnings received from this industry is that luggage drop time should be small to enhance customer experience. On similar lines, luggage collection time should be kept low. The location of luggage collection area should be strategically near to the exit so that customer doesn’t have to carry inventory for long time. Also better & flexible standards should be proposed and implemented for travel-restricted items. Goods management charges should not be too high to be seen as a burden on customer pocket.

COMPONENTS OF SMART INVENTORY MANAGEMENT SYSTEM

The main components of the smart inventory management system are:

1) Customer Profile Server (CPS)
2) Goods Identification Server (GIS)
3) Location Identification Server (LIS)
4) Customer Notification Server (CNS)
5) Customer Interface Server (CIS)
6) Warehouse Data Analytics Server (WDAS)

CPS

The CPS is a system of dedicated array of high capacity fast processing server to manage the profile management of the customers. These server could be managed in centralized or decentralized way depending on the policy selected by the management. These could be based completely on the vendor managed clouds or a private warehouse cloud. These server are first server which gets updated as soon as new customers good enters into the system. And the profile is further maintained and managed. The Data Analytics Centre called WDAS also provide crucial updates (machine-learned analysis) from time to time to this server depending on the analytics being performed.

GIS

The GIS Server manages the Radio Frequency based transceiver modules called goods-ids. The aim of this server is to manage the inventory i.e. Allocation, deallocation and live tracking of all goods.

LIS

The LIS Server manages the maps, route of the warehouse, tracks and its networks through location-ids. This effectively will be a map server of all warehouse. It should have the latest update of the real situation of all warehouse, tracks, and inventory rooms. Every route’s live status should be managed and controlled here. The LIS are based on RF based transceiver modules called location-ids. Examples of GIS unitary goods-ids and LIS location-ids are: STM32F446RE MCU + Sub-Ghz RF SPIRIT module. Depending on the topology/usage/design it can act as a transmitter/receiver/transceiver.
CNS
CNS server manages the notifications to all the customer about all their inventory. This interact with GIS, LIS Servers and update the status in CPS and further notify the inventory state, location. The latest state is being maintained in CPS. CNS also keep in touch with WDAS and provide updates to the customer via website, app, mobile message and phone call.

CIS
The customer interface server manages all the customer interactions. These interactions could be chat via messages, website. These interactions could be service requests via websites, app, phone, messages. A pool of dedicated human resource when needed interact directly as they sit behind it. The aim of this server to handles all the customer queries via website, mobile. This would act as a frontend server which intelligently decide the actions depending on the query. These actions could be upgrading the request priority if not solved in service level agreement period.

WDAS
The WDAS server manages the data analytics over the warehouse data stored for the customer profiles. And hence it build result summary of data collected and analyzed from customer activities over a period of time. WDAS server also get profile updates from attached social/professional/networking profiles in secure and safe way. Data Analytics has been proposed in this paper as an important tool to fetch useful summary out of the customer data stored on the go. The aim is to make target marketing learnings and service market learning from the data being analyzed. This process could act as continuous improvement for more efficiency. Data Analytics service could be done through in-house research as development activity or can be availed as a vendor service. And would help warehouse to get answers for some of basic questions. E.g. how many goods does a customer transport in particular day? Or what is the typical size of the goods carried by corporate customers?

Figure 1: STM32 based GIS, LIS [6] Data Communication Flow

PROPOSED SMART WAREHOUSE INFRASTRUCTURE
Warehouse needs to be upgraded to provide a better inventory management system for enhanced customer experience. For this, infrastructure requirement for the smart inventory management is to have a smart warehouse campus. The Smart warehouse Campus must have

1) Smart Goods Entry Facility
2) Smart Goods Exit Facility
3) Goods Management Facility
4) Goods Transportation System
SMART GOODS ENTRY FACILITY
This facility receives the inventory through manual intervention or via interactive user interface to generate smart inventory tokens. The GIS are allocated in the system and attached physically to the goods through mechanical facility. And CPS is updated with the information and data about these inventory. And CNS inform the customer via mobile message or app alert.

SMART GOODS EXIT FACILITY
It is based on an array of smart user interface machine based on touch and sense technology to fetch the desired inventory. The GIS are detached from the system using mechanical facility. CPS is updated about the removal of GIS entries and inventory is received by the customer. CNS inform the customer about the inventory state and location.

GOODS MANAGEMENT FACILITY
Goods management facility is established by the CPS, CNS and CIS servers. These servers act in conjunction with each other with dedicated share of responsibilities as specified in the requirements above.

GOODS TRANSPORTATION SYSTEM
This is the backend of the smart warehouse campus meant for transporting the inventory from the goods entry facility till the goods exit facility. This require an infrastructure of LIS being established at specific intervals. These connected LIS in specific topologies (e.g. star) act as the communication backbone for the information to flow. LIS is well connected to all the components of the smart warehouse management wirelessly. The main aim of the LIS is to maintain the location and health status through the means of the message updates shared by GIS. The messages are transported to the CPS and CPS further take care of providing the command to the CNS and CIS for further action. CPS interacts with WDAS to send data at specific intervals.

FUTURE SCOPE
It is important to highlight that the future scope of this inventory management system is immense in terms of technological advancement. We are highlighting few of them

1) Human Intervention-less smart inventory management system: It is observed that human intervention from executives add delay in terms of time spend by goods in the warehouse. This could be largely reduced if goods entry is made robotic. This means goods entered in inventory through a 3-D scanner which should update
the customer profile with all the parameters like weight, color and scanned image and attach the GIS. Here goods has to spend very less time.

CONCLUSION

Understanding the state of existing inventory management system, the next generation smart warehouse inventory management system is proposed. The uniqueness about this system is that it is more advanced than the best inventory management available even in existing inventory (and aviation industry). Hence this would also support to tap the commercial opportunity of this major gap in the customer expectations and experience. Hopefully this will also guide the main stakeholders to formulate& formalize the standards of next level inventory management. This paper leverage on the current technology and propose a technologically advanced solution to the customer. The inventory system proposed is a unified system for end-to-end inventory mgmt.

This paper leverage on the current technology and propose a technologically advanced solution to the customer. The inventory system proposed is a unified system for end-to-end inventory mgmt. which is future ready with cloud support and real time tracking of the inventory. The system may further be customized for different topology of decentralized or centralized servers. The minute detailing of the inventory charges, restrictions and waivers are left to the conscience of the skilled brainstorming panels along with the warehouse authorities and concerned corporates. This would help to enhance the commercially viability of the smart inventory management to make a pleasant customer experience.

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