Adaptive Wireless Sensor Network Technology for Ubiquitous Container Logistics Development

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ABSTRACT

At the present day, the use of containers crisscrossing seven seas and intercontinental transport has significantly increased and bringing the change on the shape of the world economy which we cannot be neglected. Additionally, with the recent technological advances in wireless sensor network (WSN) technologies, has providing an economically feasible monitoring solution to diverse application that allow us to envision the intelligent containers represent the next evolutionary development step in order to increase the efficiency, productivity, utilities, security and safe of containerized cargo shipping. This paper we present a comprehensive containerized cargo monitoring system which has adaptively embedded WSN technology into cargo logistic technology. We share the basic requirement for an autonomous logistic network that could provide optimum performance and a suite of algorithms for self-organization and bi-directional communication of a scalable large number of sensor node apply on container regardless inland and maritime transportation.

키워드

Wireless Sensor Network; Sensor Node; Multi-hop; Container; Monitoring;

Ⅰ. INTRODUCTION

Nowadays the world trade mostly is accomplished by the assistant of container using different channel of transportation including railway, airway, maritime, truck and others, these have an extraordinarily large impact on global economy. Containerized shipping made the world smaller and the world economy bigger [1]. By taking the advantage of container shipping, it's bringing on a new world economic geography. There had estimated in year 2008 more than 500 million Twenty-foot Equivalent Unit (TEU) of container turnover in the world-wide most important container ports and compared with ten years ago only around 200 million TEU of container which is a dramatically increment [2].

The new challenging era of the port industry has been forced to drive by the global completion process [3]. Security is one of the essential elements in containerized cargo shipping. At the present day, the port security has become a key factor in determining the value of a port brand. Numerous of international security laws, such as International Ship and Port Facility Security Code (ISPS), Container Inspection Program (CIP), Container Security Initiative (CSI), Customs-Trade Partnership Against Terrorism (CTPAT) and so forth have provided a comprehensive set of measures that in response to the perceived threat to ships and port facilities [4][5][6].

Innovation on container is needed, in order to maximize the security and safe of the containerized cargo and able fulfill the international standard security laws simultaneously. The development of information technology in containerized cargo trade can bring significant effect. In this paper, we

applied Wireless Sensor Network technology (WSN) in the containerized shipping and providing an autonomous cargo monitoring system. We share the basic requirement for an autonomous logistic network that could provide optimum performance and a suite of algorithms for self-organization and bi-directional communication of a scalable large number of sensor nodes apply on container regardless inland and maritime transportation.

In this paper is organized as follow. Section II gives an overview and basic requirement of containerized cargo shipping network. Section III, IV and V are the proposed solution of the system and finally, this paper is concluded in section VI.

II. OVERVIEW

In logistics industry, generally there are two types of containerized cargo transportation, which are inland and maritime transportation. Maritime transport always is the best choice for long distance shipping because of is it provides a comparative cost advantage compare with others cargo transport. A container laden vessel able carry more than 10,000 containerized cargos simultaneously crisscrossing the seven seas to its destination. When vessel reaches the seaport, port operators and longshoremen will do the transshipment of containers to different modes of transportation. Inland transportation such as domestic rail and truck transportation play an importance role in domestic and short distance transportation. Inland and maritime transportation collaborated freight containerized cargo from different parties in a supply chain involves manufacturers producing goods for global use to the other parties. The whole process of shipping might take few weeks or months reach its final destination.

Nowadays logistics industry rising to challenges from the rapidly changing markets. Safe and secure packing of cargo transport units is the main concerns to increase the productivity and efficiency on cargo transportation. An autonomous cargo monitoring system is essential. In performing optimality autonomous logistic network, basic requirement below is needed [7]:

- Real time risk monitoring, intrusion detection and theft reporting mechanism
- Robustness and reliability hardware operating in a harsh environment
- Sensor network longevity allow long-term container monitoring without maintenance
- Low power consumption schemes and techniques
- Minimum human intervention but able track more than 10,000 containerized cargo
- Network self-organization capabilities for high mobility containerized cargos.
- Ease and flexibility installation to add and remove sensors with as-needed basis
- Small monitoring device avoid become any obstruction for normal cargo
- Availability of container information to all the stake holders of shipment

On the other hand, Wireless Sensor Network (WSN), a wireless network formed by a group of small and cheap sensor deployed in same region, which can be used to measure the temperature, motion, humidity and forth then transmit signals via radio signal, By taking the advantages of wireless sensor network, we uses diverse sensor to detect and monitor the environment changes in container and wireless surveillance sensor networks for providing security of the containerized cargo.

III. CONTAINER COMMUNICATION DEVICE

In this proposed system, the communication devices use in the autonomous cargo monitoring system is comprises by Container Network Device (N/D), Container Network Bridge (N/B), and Coordination Point (C/P). N/D is self-configuration sensor nodes are place in each container which would be used to sense, gather and communicate container data. N/B in the system used to link two adjacent networks rebroadcasted. C/P collecting N/D data and acts as an infrastructure node used to connection with the global internet sending to application for further analysis depend on the diverse needed.

A) Container Network Device

Container Network Device (N/D) is the basic unit of container communication network and placed in every single container in the system. N/D contains group of sensors: Tilt sensor, temperature sensor, humidity sensor and so on to gather data within a container. N/D capable manages information on condition inside the container and transmits to C/P or others N/D

which they may have a path towards the C/P. N/D is supporting multi-hop routing and bi-directional communication. It will be discussed in detail in next section.

B) Coordination Point

Coordination Point (C/P) has global connectivity that connects with Internet and multi-hop container network capable. C/P is collecting the information sending from N/D and then forward to data center for application usage by using its global internet connection. Generally there are two types of C/P: stationary C/P and mobile C/P. Stationary C/P used in the cargo terminal seaport, and vessel, where C/P will stationary place on a lamp pole or on a tall pillar and listening to immense number of containers. On the other hand, mobile C/P is used by land carriage. When truck is carrying a container with N/D, this N/D will able to function accordingly and send related data to this mobile C/P. In mobile C/P, which equipped with CDMA modem, the acquired data will send to the main server through CDMA network for further processing anytime anywhere during inland transportation.

C) Container Network Bridge

Container Network Bridge (N/B) used in the system is responsible on connecting adjacent network segments accordingly especially during a large number of container movement like when a container laden vessel reached the seaport and huge numbers of containers on transshipment moving. N/B only be allocated in place where numerous of container in a same region such as in container terminal seaport and vessel. N/B also playing an importance role which is clustering the N/D, since N/B will be located at some places stationary with power supplied easily, which can permanently become a cluster head in the multi-hop configuration, which can minimize energy expenditure of N/D.

Ⅳ. MULTI-HOP CONFIGURATION

In this operation, N/D is a self-organizing, adaptive clustering wireless sensor device. The N/D will automatically form a multi-hop cluster tree network among N/Ds. Multi-hop configuration is broken up into rounds. Each round have setup state and ready state, where each round will begins with a setup state to organize the clusters, then follow by ready state when cluster is build and data transfer to the C/P begin. The Ready state is long compared to the Setup state with the purpose of minimizing the overhead of the N/D.

I. Setup State

In multi-hop configuration, we are considering communication delays and the container load environment has the 5-hop depth design. Initially, C/P is sending the advertise message to nearby N/D and received N/D will responded and building the cluster. However, for N/D not able to contact any C/P, it will run the select parent algorithm to get parent node and the current N/D will go depth from the parent node and authenticate does it within 5-hop standard to reach the C/P, if not it will jump for another parent node. If a non-parent node found out all the nearby parent node is unreachable or more than 5-hop standard, the node can request its neighbor node which has path to C/P be a new parent node, send its related data to this parent-node.

II. Ready State

Once the clusters are built, containers' condition data transmission begins. The cluster-head node will received the data from the nodes in its cluster and performs some compression and collaboration to compress the data into a single signal and transmit to C/P or to its parent node N/D which they have a path towards the C/P according the neighbor table built during setup state.

Every N/D node has three timers: round timer, tilt timer and status timer to identify currently which state they are belong to. Round timer will start on C/P only. This timer determined a priori, when the new round begins. It will set itself to new round and send the re-build topology route packet with topology sends flag 'ON' to its member of cluster nodes. Tilt timer for periodically detect does the N/D has any motion. If tilt sensor detected motion, in other word, the container has been moved it set itself to new round and set Tilt ID on route packet and sends the route packet with topology sends flag 'ON' to the nodes in the same cluster. As a result, all the nodes within 1-hop of the leaving N/D will immediately broadcast the leave message to its neighbor, without wait for the next priori round timer.

On the other hand, status timer periodically broadcast the advertise message to its neighbor nodes and listens the status from others nodes then update node's table. If notices neighbor node dead or leave, set topology sends flag 'ON'. If the current node currently no round allocated and is not a C/P, it will run the select parent algorithm to get parent node. After that, current node broadcast advertise message to 1-hop level of neighbor nodes. If node have parent node and is a cluster head and topology send flag is 'ON', its send the topology packet out for rebuild the new topology. In others words, either priori time of round timer reach or tilt/motion of container had detected or neighbor node status change, it will set the topology send flag to 'ON' and broadcast to its neighbor nodes, neighbor nodes will back to setup state rebuild the topology.

Ⅴ. BI-DIRECTIONAL COMMUNICATION

This topology is building a bi-directional communication. At the start, the sensor node broadcasts advertise message to its neighbors and formed a neighborhood table. Subsequently, when a N/D sink node send the message to C/P and which sink node does not have directly connectivity with C/P, it will send to its parent node and then parent of the parent node and continues till reach the C/P within 5-hop standard. The trail has been passing by from sink node to C/P is marked and C/P can follow the marked trail to send any unicast communication message to particular N/D.

For every data packet received by the sensor node, if that packet is not from C/P, it will check does the sender Node ID exist in its neighbor table or not, if not found in its neighbor table, it will add new sender Node ID into the neighbor table. Next, if the current data packet message (from C/P or forward from N/D) is for this current node indicate that the packet destination is here, it will process the message command or acknowledgment else if this packet is a broadcast message it will continue forward the packet to its member node in the cluster.

Ⅵ. CONCLUSION

This paper describes the design of Wireless Sensor Network in transport and logistics industry. We identified and discussed the basic requirements that are needed to form an autonomous cargo monitoring system with WSN and the container communication devices in used and how it is working. We envision future where large numbers of N/D and C/P are densely embedded in the containerized cargo. We are aware this prototype entails many business processes and suspension by a lot of technical and non-technical challenges. Thus, we are currently model its behavior in large-scale deployment through simulation and the performance will be evaluated thoroughly towards the realization of the concepts.

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