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Wireless Sensor Networks as an Enabler for Cooperating Logistic Processes

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ABSTRACT

In this paper a promising application for wireless sensor networks (WSN) in future logistics is described. We present a hardware infrastructure for the *intelligent container* that enables real-time transport supervision and dynamic quality forecasts for sensitive and/or perishable goods. This is achieved by employing a WSN system in conjunction with a combined embedded agent system/communication gateway. The generated quality information may be further used for adaptively changing transportation media or the transport destination and thereby enabling the vision of autonomous cooperating logistic processes.

Categories and Subject Descriptors

C.2.1 **[Network Architecture and Design]**: *Wireless communication*

General Terms

Design, Measurement, Experimentation

Keywords

Autonomous Cooperating Logistics, Wireless Sensor Networks

1. INTRODUCTION

Ever increasing complexity of supply chains and cost pressure on logistic carriers demand for automated and highly optimized logistic processes. A new approach to the modeling of these complex logistic processes is carried out using cooperating software agents (as shown in e.g. [1]). These agents form virtual representations of all items in the supply chains. The resulting concept of autonomous cooperating logistic processes allows freight items to autonomously choose their optimum transport route and carrier and the marketplace where the optimum price is achieved. This concept is evaluated within the Collaborative Research Center 637 [2].

Cooperating logistic processes need information about their environment to enable decision-making. This information can be divided into an outer view (e.g. traffic information, market prices) and an inner view to explore the transportation environment that affect the quality of the transported goods. This inner view is supplied by sensor nodes that may be fixed to the freight items or deployed separately during the loading process.

These sensor nodes autonomously form wireless sensor networks. The acquired sensor readings are collected, aggregated and pre-processed in the sensor network and forwarded to a gateway system at transportation system level (e.g. a container). In this gateway the sensor readings are transformed into dynamic quality information by an inherent assessing system. This quality information is used to determine the quality leverage during the transportation process under given conditions. The gateway may communicate with distant logistic servers and networks via UMTS, GPRS or WLAN, depending on availability. An imminent quality loss (e.g. due to failure of a cooling aggregate) may trigger route re-planning to the next available warehouse. This poster features the system architecture and the implementation of an autonomous logistic freight carrier at the example of the intelligent container.

2. SYSTEM ARCHITECTURE

The basic elements of the intelligent container are the central gateway system at transport system level and the sensor network, as shown in Figure 1. These two will be described in the following.

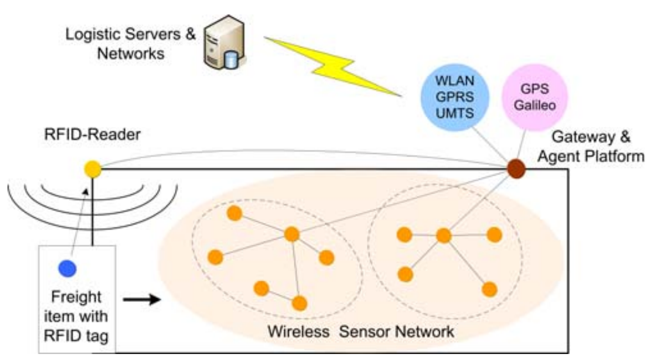

Figure 1. System architecture of the intelligent container.

2.1 Gateway System

The gateway system basically consists of a RFID reader, a communication front-end and an embedded host platform. The RFID reader is needed to identify the freight items that are being loaded or unloaded from the transportation system and is directly connected to the embedded platform. Using RFID technology additional supporting information (e.g. current server where representing agent is running) can be provided. The communication front-end provides a link from the transportation media to the outside world. Using this link, global data (e.g. positioning, traffic, market information) can be collected. This communication link is also used by the agent system within the gateway. As shown in [3] the agent platform requires a sufficiently powerful embedded CPU.

2.2 Wireless Sensor Network

The WSN monitors the freight compartment. The nodes of the network are added separately during the loading process and adaptively form energy-efficient topologies. The hardware consists of a custom-designed platform based on the TmoteSky system from Moteiv [4] and features attachable sensor boards that enable sensor self-testing. Both systems are shown in Figure 2.

The key features of a WSN system for an application in logistics are:

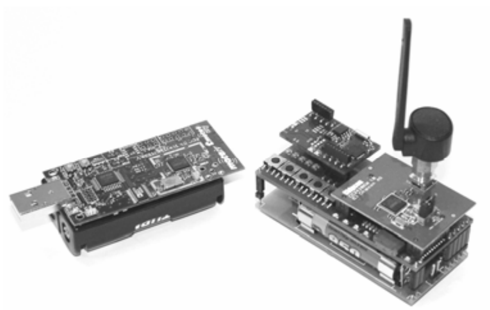

Figure 2. Motes from Moteiv (left) and custom-designed mote hardware platform prototype (right).

Security – Sensor readings may not be spoofed by attackers in order to prevent sabotage and/or theft.

Energy-Efficiency – Conservation of energy is imminent to increase battery and system lifetime and minimize maintenance effort.

Robustness –Identification of wrong sensor readings, failure of sensors or even whole nodes and adaptive and reliable reorganization of the network are absolutely necessary.

3. IMPLEMENTATION

This chapter features the functionality of the system. It covers the loading process, the transportation and the unloading. Before a freight item is loaded into the container, its RFID tag is read by a cargo attendant (CA) system within the warehouse. The CA deploys a software agent that supervises the item, stores the necessary prescriptive environment parameters and inhibits a model indicating the quality leverage during the transportation process. As soon as the cargo item is loaded into the intelligent container, its RFID tag is read. This tag contains the address of the originating CA and is associated with the previously deployed CA agent and the loaded freight. The CA agent can now be downloaded into the intelligent container's agent platform and the intelligent container is now able to configure the WSN according to the parameters required by the freight. This is done for all loaded items. If a sensor type is missing, the loading personnel are ordered to deploy this sensor type into the container before starting. Newly deployed sensor nodes are automatically added to the network. Authentication in the WSN can be guaranteed by a hybrid RFID/ECC mechanism [5]. Energy-efficient topology control is required to ensure a long system lifetime. Therefore, the system will use a multi-tier cluster-tree topology (as demonstrated in e.g. [6]). In order to ensure robust operation, self-testing of each sensor as well as cluster-wide cross-checking of sensor readings will be performed to increase the reliability of the sensor readings.

As soon the freight is loaded, the CA agent will start dynamic quality supervision based on the sensor readings acquired by the WSN. If any event is detected (e.g. quality leverage reading out of nominal region) that may cause severe cargo damage, the CA agent will trigger an alarm which is signaled to distributed planning instances using the best available mobile communication channel. These agents assess the situation and may trigger route re-planning to the next available warehouse or marketplace. Route re-planning may also be triggered due to price drop at the planned destination and better prices elsewhere. When arriving at the destination, the originating CA will be notified that the cargo was successfully delivered and current quality state is also transmitted.

4. CONCLUSION

The usage of state-of-the-art information technologies enable autonomous cooperating logistic processes. Wireless sensor networks mark one of the key elements of this emerging concept and give a promising industrial application for WSN systems in general. The intelligent container was successfully demonstrated during a DFG review meeting in mid-January 2006 in Bremen.

5. ACKNOWLEDGMENTS

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