CONTROLLING THE COLD CHAIN USING TRAILER TELEMATICS AND INTERCONNECTED REFRIGERATION UNIT

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***Abstract*:** Within the project *Intelligent Container*, Cargobull Telematics GmbH developed a telematics unit and an online communication service. This system is used for tracking and monitoring of goods during land-based transports. In this paper we give an overview of the contributions and results within the project. The experiences gained during the project have led to improvements that are already available to customers using Cargobull's commercially available telematics unit: New means to remote-control and monitor the settings for refrigeration units provide a better control of the cold chain. Recently, Cargobull has released its own refrigeration unit which is closely connected to the telematics unit. It provides detailed online information about parameters like temperatures, maintenance intervals, alarms and fuel level. This allows to optimize the environmental parameters of the carried goods and avoids spoilage caused by misconfiguration or outage of the refrigeration unit. Transports that do not allow human interaction, like train-based transports, do no longer prevent the full control over the carried goods. Furthermore a prototype has been developed that demonstrates the usage of wireless sensors directly at Cargobull's telematics unit. The technical demands for wireless nodes within the trailer environment are further analyzed with the goal to design a new flexible and robust way to control the trailer and its goods.

Keywords: *trailer telematics, refrigeration unit, cold chain, intelligent container, wireless sensor networks*

I. INTRODUCTION

As the freight transport volume is further increasing[1], exact quality control and improved monitoring of the freight become indispensable. At the same time environmental concerns need to be faced. To meet these challenges, Schmitz Cargobull AG [2] and its subsidiary Cargobull Telematics GmbH [3] have developed both telematics units and refrigeration units. A telematics unit offers online monitoring of the environmental status of the freight and the trailer. This comprises parameters like temperature and humidity, GPS based information and detailed reports from devices like temperature loggers or the electronic brake system. It further enables the remote control and monitoring of the refrigeration unit. Figure 1 gives an overview of the devices and sensors comprising such a system. To further contribute to an improved control of the cold chain, Cargobull takes part in the project *Intelligent Container* [4], [5]. Here, Cargobull's telematics unit is combined with a system called Freight Supervision Unit (FSU) and a wireless sensor network. The systems main advantage is to provide an estimation of the remaining shelf-life of perishable goods based on parameters like humidity, temperature and ethylene concentration. The goal is to allow suppliers to apply the *dynamic FEFO (first expire first out) paradigm*: Goods that are close to decay should be transported and sold with preference to prevent spoilage and reduce costs.

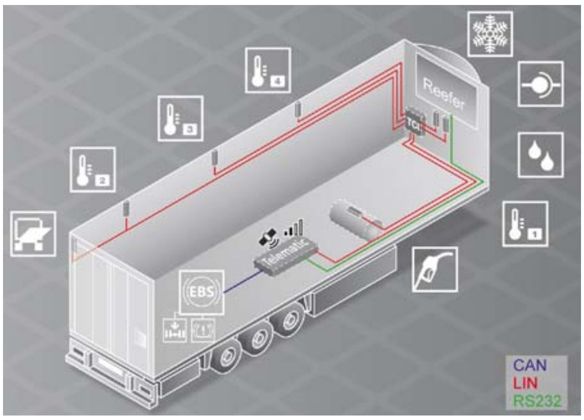

Figure 1: Location of sensors and devices connected to Cargobull's telematics unit

[1] The freight transport volume on Germany's roads and rails increased by about 8% in 2011, with a total volume of about 4000 million tons [1].

The remainder of the paper is organized as follows: The contributions and results of the project *Intelligent Container* are presented in II. Several advances that originated from the project lay the basis for developments within Cargobull's commercially available telematics system. These are pointed out in III. An outlook towards trends and current developments is given in IV. The paper closes with concluding remarks in V.

II. THE PROJECT INTELLIGENT CONTAINER

A. Overview

The communication system architecture of the Intelligent Container is shown in Figure 2. The system offers 3 communication methods: Iridium based tracking and monitoring for sea-based transports, GSM based communication for land-based transports and so-called offline monitoring. Cargobull Telematics implemented the land-based transport architecture (Figure 2). A new telematics unit was developed, which is significantly reduced in size (13 x 3.5 x 11.5 cm) compared to its predecessor (18 x 5 x 14 cm). This unit is able to interface the FSU which provides the mathematical

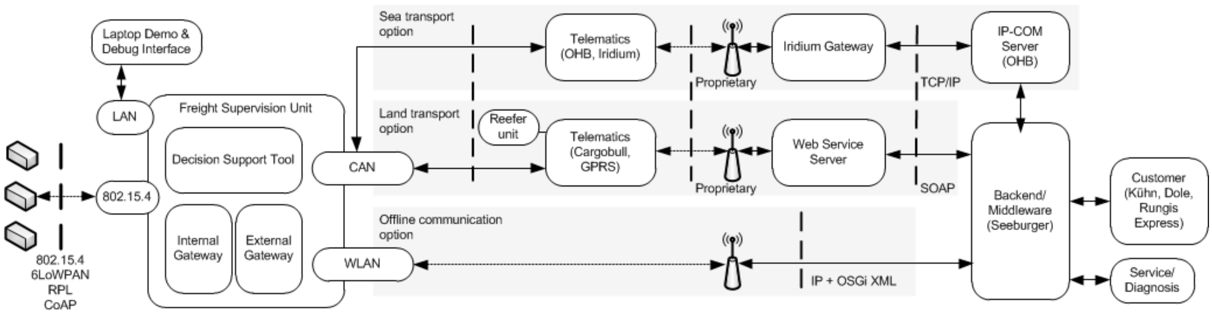

Figure 2: Communication system architecture of the project *Intelligent Container*

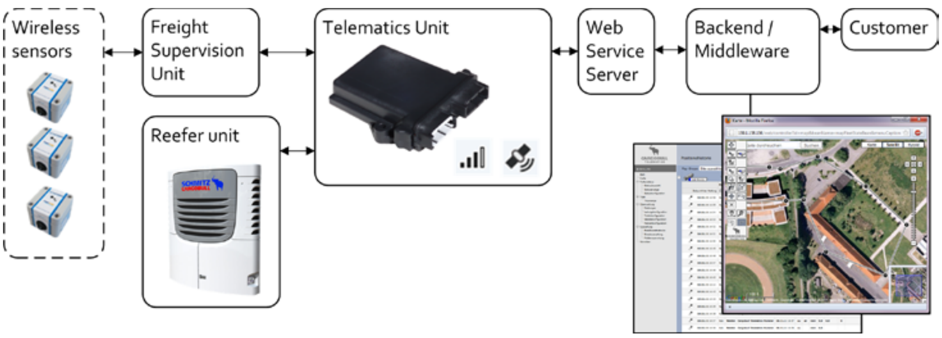

Figure 3: Communication system architecture for land-based transports within the project *Intelligent Container*

models for shelf-life estimation. It adds GPS-based time, location, heading and preprocessed sensor data like readings from a refrigeration unit. It further handles the GSM based (GPRS/SMS) delivery of information from the FSU towards Cargobull's web service server. Here, it can be accessed through a SOAP-interface by various backend systems. Within the project, a user-interface at the backend was developed by project partner Seeburger AG [6]. At the same time Cargobull's telematics portal could be used to visualize the tracking.

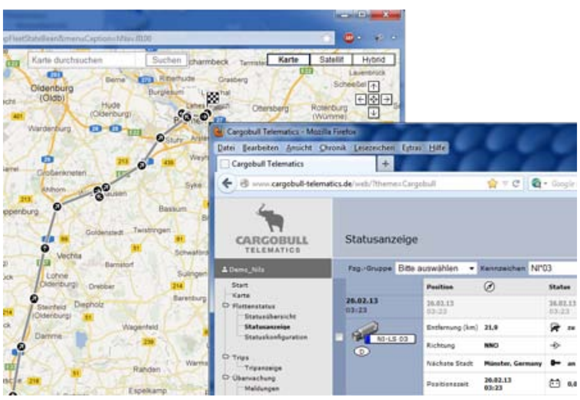

Figure 4: Position history and status information shown during a field-test within the project *Intelligent Container*

B. Field tests

Field tests of the land-based transport system were conducted for suppliers taking part in the project ([7], [8]). The online position and status information were tracked and shown in a web-frontend (Figure 4). Furthermore, the remaining shelf-life of the carried goods was estimated based on temperature and humidity readings from a wireless sensor network. The algorithms for the estimation were adapted specific to the type of the carried goods, in this case fresh meat. The remaining shelf-life was indicated by a traffic light, with a green light meaning that it has not expired (Figure 5).

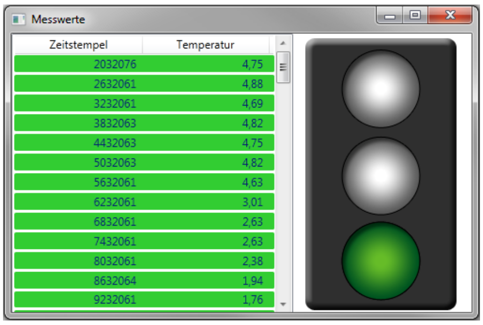

Figure 5: Signalling based on estimated shelf-life

III. IMPROVING THE CONTROL OF THE COLD CHAIN

A. 2-way communication with refrigeration units

For the project *Intelligent Container*, Cargobull extended its protocols that enable reading and changing the states and settings that are provided by refrigeration units of various vendors. It was extended to read diagnostic information and service intervals from the refrigeration unit, which may help to optimize the resource planning of the trailer. Real-time information about the settings of a refrigeration unit is shown, so that they can be optimized to keep the constraints of the cold chain. The visualization of these parameters within the Cargobull's web-portal is shown in Figure 6. For the information that is read from the telematics unit and refrigeration unit, thresholds can be configured. As soon as these thresholds are exceeded, the customer is automatically notified via e-Mail or SMS to provide a real-time status of the unit and the goods.

Figure 6: Status information from the trailer and from the refrigeration unit as shown within the web portal of Cargobull Telematics

Beyond this, the protocols were extended to offer remote control of the unit's setpoints and presets, as can be seen in Figure 7. A preset itself contains the settings optimized for the specific type of the carried goods. A configuration may be corrected or adjusted online to improve the performance or to reduce the fuel consumption. In certain scenarios like transport via train or a temporarily inaccessible parking position, this may provide the only means to operate the system.

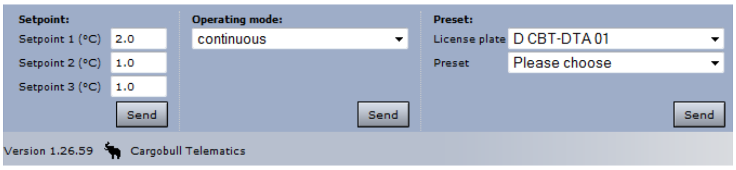

Figure 7: Possibilities for the remote control of a refrigeration unit from the web portal of Cargobull Telematics

B. Incorporating wireless sensor networks

Within the project *Intelligent Container* a wireless sensor network [9] is used to measure temperature, humidity and ethylene concentration. The possibility to measure these parameters directly at the goods enable a more accurate measurement and a more flexible setup in comparison with a wired solution. To reduce the hardware-related costs further improvements are currently done. The usage of this wireless network directly connected to the telematics unit, without the need of the FSU, was successfully demonstrated. Further challenges when applying the network were analyzed in [10]. To ensure a reliable radio propagation, the sensors forward the information in a multi-hop fashion towards the gateway. I.e. sensors with a good radio link propagate data from sensors with a bad link. However, an additional challenge arises when considering the location of Cargobull's telematics unit, which is typically placed below the floor of the trailer. A communication link would be attenuated by both the goods and the trailerfloor. A new approach is currently developed which avoids this problem and reduces the energy consumption of the wireless sensors: The sensors forward the information along the top of the trailer towards a gateway node placed at the bulk head corner. The gateway then forwards the data to the telematics unit using a LIN network which is available at that position in Cargobull standard solutions.

IV. FUTURE DIRECTIONS

In the following, further means are given to improve the control of the cold chain and to reduce costs for the system.

A. Hardware and software consolidation

To reduce costs of the hardware-system used for the project *Intelligent Container* efforts were done to integrate the FSU into the telematics unit. The first step was done by directly connecting the wireless sensor network with the telematics unit. The next step is to integrate further parts, mainly the algorithms for shelf-life estimation into the telematics unit.

Another current focus is to harmonize the software system by reducing the usage of proprietary protocols. A common Internet Protocol (IP) based system enables more flexible compositions of system components and backend systems and more rapid deployments of new services. Therefore the usage of the IP-based Constrained Application Protocol (CoAP) is investigated. It already implements the communication between the wireless sensor network and the FSU. Its usage over GPRS/SMS, needed for telematics applications, is described in [11]. Furthermore, a comparison on application-level was performed between CoAP and proprietary telematics-protocols. The results are presented in [12].

B. Telematics-aware refrigeration units

In the previous sections it was outlined how the customer benefits from the information gathered through a telematics-based system. On the other hand, the information may also be used to improve the functionality of a refrigeration unit. Current refrigeration units mainly use a single temperature sensor as a basis to control the refrigeration circuit. This sensor is typically located close to the refrigeration unit, measuring the temperature of the air stream returned from the trailer leading towards the unit. However, this does not take into account the temperature situation at the other far end of the trailer. Incorporating the temperature readings from a telematics unit, originating from multiple places within the trailer, a more exact control becomes possible. Further applications arise considering telematics-aware refrigeration units: The units display can be used to visualize the information from the telematics unit like sensor readings from the carried goods or status information about the trailer and connected devices. Another improvement may be a location-aware control of the refrigeration cycle: GPS information may lay the basis to reduce noise disturbance within urban areas through a decreased usage or reduced speed of the units' diesel engine.

V. CONCLUSION

The project *Intelligent Container* lay the basis for new developments to enhance the control of the cold chain. The main advances related to a land-based transport scenario and the results gathered during field -tests were presented. Furthermore an overview over advancements gained from the interconnection between telematics and refrigeration unit were given. Scenarios were shown, were a "telematics-aware" refrigeration unit may profit from the information about its environment.

VI. ACKNOWLEDGMENT

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