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Special Issue on
‘AN RFID-ENABLED INFORMATION SYSTEM FOR MONITORING PERISHABLE PRODUCTS’

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The transport sector is essential for continuous economic development. Advanced business models [1] and methodologies utilizing state of the art technologies [2] tend to integrate the transport sector in the overall supply chain through advanced logistics applications that aim at providing end-to-end high quality services to the final customer. In this context transport services may be viewed as a part of an inter-enterprise integration process that involves among others suppliers, manufacturers, third party logistics and wholesalers.

Safety presents a major challenge for transport. With reference to freight mobility, safety is defined as the probability that a given shipment is damaged or destroyed during its transport and the total value of damaged or destroyed goods [3].

Given that safety is essential for the overall transport of goods, it is a sine-qua-non for perishable freight transport. In the latter case, special vehicles are used ranging from simple insulated and ventilated vans, used for the transport of e.g. fruits, to refrigerated trucks.

The present work describes, in brief, an integrated real-time system for perishable freight transport management. The system integrates data stemming from different subsystems that are installed on the truck, which are transmitted to a central point, stored and processed, so that real time information related to the location and status of transported perishable goods may be obtained. Thus, such a system can provide the needed information to support an end-to-end safety and quality management system for the transport of perishable freight.

This review presents the operational requirements, the overall architecture of the proposed integrated system and analyses its subsystems. Work presented in this review was partially implemented in the framework of the METATRO project [4].

A freight transport management system is based on a fleet management system enhanced by appropriate safety requirements determined by the nature of the freight. The basic operational requirements of such a system comprise:

- Freight satellite tracking and map positioning: satellite GPS tracking is utilized and the vehicle / freight position is shown on a map. Thus the exact position of a vehicle and of the goods that it transports is well known on a real-time basis.

- Bidirectional communication: communication between the vehicle and the fleet manager is supported. In this context, various events associated with the safety of the vehicle and the freight may be communicated to the fleet manager on a real-time basis, while the vehicle driver may be updated on such transport parameters as route changes, cancellations, etc.

- Freight transport safety condition monitoring: with reference to the freight transport safety requirements it is possible to monitor different transport parameters. Such parameters comprise for instance freight transport conditions like temperature, humidity and door openings.

- Freight management: the freight transported by each vehicle should be well known by the fleet manager. Appropriate technological solutions should be employed so that the goods that exist in a truck are monitored.
- System Dynamic Parameterization: the different parameters of the system should be dynamically defined both in terms of the functionalities that utilize them as well as in terms of the individual limits set for them.

The above operational requirements represent the minimum set that a freight transport management systems should respect. Such a system could provide the needed background for a more effective execution of transport process workflows, being either the business scope of transport companies or part of more extensive process workflows of integrated supply chains.

The freight transport management system is built utilizing a distributed architecture, comprising a central system capable of communicating with mobile system units that are installed in vehicles. The central system (Figure 1) comprises two subsystems:
- The GSM/GPRS communication subsystem
- The central information subsystem.

It is responsible for the gathering, storage and processing of data stemming from the different mobile system units, as well as presentation of the relevant information. The mobile system (Figure 2) is responsible for the integration of five different subsystems that are installed in the vehicles / trucks:
- The mobile communication subsystem,
- The sensing subsystem,
- The RF tag management subsystem,
- The GPS subsystem and
- The mobile information subsystem.

The data acquired by the different subsystems are stored and processed by the mobile information subsystem and the ensuing information is appropriately utilized. Thus, a real time and continuous monitoring of the vehicle conditions, freight conditions and vehicle location, is possible. The relevant information will be possible to be shown to both the truck driver and communicated to the central system.

**HIGH-LEVEL ARCHITECTURE**

The functionalities expected by the central information subsystem may be grouped as following:

- User Management, comprising User Registration, User Data Update, User Deletion, User Information Printout.
- Client Management, comprising Client Registration, Client Data Update, Client Deletion, Client Printout.
- Warehouse Management, comprising Warehouse Registration, Warehouse Data Update, Warehouse Deletion, Warehouse Printout.
- Product Management, comprising Product Registration, Product Data Update, Product Deletion, Product Printout.
- Freight Management, comprising Freight Registration, Freight Data Update, Freight Deletion, Freight Printout.
- Route Management, comprising Route Registration, Route Data Update, Route Deletion, Route Printout.
- Driver Management, comprising Driver Registration, Driver Data Update, Driver Deletion, Driver Printout.
- Transport Management, comprising Transport Registration, Transport Data Update, Transport Deletion, Transport Printout.
- Transport State Monitoring
- Transport Condition Monitoring
- Parameterization
- Message Exchange with the Drivers
- Statistics
- Data Publishing
- User Authentication

Mobile Information Subsystem
The mobile information subsystem comprises the following functionalities:
- Transport State Update
- Transport State Monitoring
- Transport Condition Monitoring
- Message Transfer
- Freight Update

The associated diagram is shown in Figure 3.

Figure 3. Mobile Subsystem

RFID Subsystem
Radio Frequency Identification technology comprises the following components:
- RFID tags being the elements where data is stored, comprising at least an identifier,
- RFID readers presenting a medium for RFID tag reading and
- The medium used for the exchange of data between readers and tags, which is radiowaves, which frequency and maximum distance is specified by the actual application needs and the tags and reader specification.

The standard followed by the RFID subsystem with reference to tags is the “EPC™ Radio-Frequency Identity Protocols/Class-1 Generation-2 UHF RFID/Protocol for Communications at 860 MHz – 960 MHz Generation 2”, recently approved as standard ISO/IEC 18000 entitled “RFID for Item Management” [5]. In the context of the presented application case, class 0-3 tags with reference to the aforementioned standard have been utilised. An indicative type of tag is Squiggle type Printronix RFID Smart Labels [6].

RFID readers selected follow EPCglobal standards such as Reader Protocol Standards (RP) [7], Reader Management Standard (RM), and Application Level Events (ALE). An indicative reader type used for the pilot system application is Alien ALR-8800 with three antennas [8].

The RFID subsystem provides the capability to monitor the truck freight content, provided that it is RFID tagged.

There are three possibilities, to tag the palettes, to tag both boxes and palettes. The third choice is more appropriate for the pilot application presented, since boxes are the unit of transport which may be transported independently or as a group of boxes in a palette. When a large number of boxes having their own tags is transported in a palette, it is possible for the RFID readers to fail to read some of them due to technology immaturities. In this worse case, the tagging of a palette and the association of this tag with the tags of all carried boxes, makes sure that a correct monitoring of freight movement takes place.

RFID readers are installed in appropriately selected points in the interior of the truck storage compartment. Whenever something is loaded to or unloaded from the truck, RFID readers register the relevant information and send it to the mobile information system. The installation of the readers and their antennas is related to the space available in the storage department of the truck. Readers and antennas may be installed at different points. The exact number and position of readers and antennas required may differ between different trucks and has to be studied in order to have the more efficient solution. The antennas may be installed at the entrance of the storage compartment or be distributed inside it. In the former case three antennas are required installed on the ceiling and the sides of the
entrance. In the latter case the appropriate installation of the antennas plays a critical role in avoiding errors.

The exchange of information between the RFID subsystem and the mobile information system is based on EPCglobal mechanisms standardized by the Object Naming Service STANDARD (ONS) [9]. The ONS is based on the DNS and is utilised in accordance with this standard.

**Sensing Subsystem**

The sensing subsystem is implemented utilizing a logic controller so that modularity and extensibility is ensured. The PLC presents a local control unit for the data acquisition from the sensing equipment installed in the truck storage compartment.

The sensing equipment selected for the pilot application implementation performs measurements of both temperature and humidity, required for perishable freight transport safety. Digital contact switches are used in order to sense door openings and closings, while the time that the door remains open is measured at the controller level. The appropriate installation of the sensing equipment is critical, due to air currents in the interior of the storage compartment of the truck.

The communication interface of the sensing subsystem and the mobile information subsystem utilizes the TCP/IP protocols over Ethernet.

**CONCLUDING REMARKS**

The aforementioned integrated real-time system for perishable freight transport management presents several advantages. With reference to the public good and overall economic development, the major advantages are:

- the end-to-end quality assurance of transported goods,
- freight tracking and traceability whenever spoiling takes place,
- transport safety is enhanced through the registration of vehicles and freights

From an entrepreneurial point of view the advantages are:

- transport cost reduction through the optimization of freight transport and the subsequent reduction of fuel consumption and erroneous routings,
- dynamic change of routing when there is a change in the routing conditions (e.g. transport canceling, road obstacles),
- optimal control over drivers / vehicles,
- increase in competitiveness.

From the operational point of view the presented system relies on open standards and is thus modular and extensible.

**REFERENCES**


