

THE POTENTIAL OF WIRELESS COMMUNICATION, POSITIONING AND NAVIGATION SYSTEMS FOR IMPROVING THE MANAGEMENT OF COMMERCIAL VEHICLE OPERATIONS

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Abstract: *The Paper gives an overview about advanced wireless communication, positioning and navigation services for telematic applications in particular those ones connected with freight transportation processes and management of commercial vehicle operations. The challenges and restrictions of different radio technologies are discussed. A tele-matic solution for freight wagon tracking is presented and its impacts for the involved partners in the transport and logistics chain are introduced.*

Key words: *wireless communication, satellite positioning and navigation, fleet management, tracking & tracing*

1 INTRODUCTION

The growing challenges for freight logistics with regard to just-in-time and just-in sequence philosophy, competition between the different shipment companies (motor carriers, railway carriers, courier service provider, air cargo companies etc.) and exceptions of timeliness, flexibility, reliability, and cost efficiency have increased significantly over the last years and will continue to increase even more in future.

Progress of wireless mobile communication and information technologies allow to use advanced transport and fleet telematic systems resolving a major obstacle for computer-based real time decision support: the lack of timely and reliable information on such questions like: where is my item, box, container, truck, ship, train and when will it arrive in what condition? Vehicle's localisation and control, tracking & tracing services and dynamic planning transport systems help to reduce the uncertainties of the forwarding activities between the different stages of the entire supply chain from the suppliers to the final customers. Arrival and pick up times as well as forwarding time can be predicted and planned exactly. Thus,

firms can easily co-ordinate their business and manufacturing process to these transportation activities enabling them to reduce the time between the customer's order and the delivery and to minimize the inventory of parts, components or finished goods in their distributing warehouses. Security, time or temperature critical shipments can be monitored continuously and in case of irregularities counteractive measures can be taken.

2 WIRELESS ENABLING TECHNOLOGIES FOR COMMERCIAL VEHICLES OPERATION

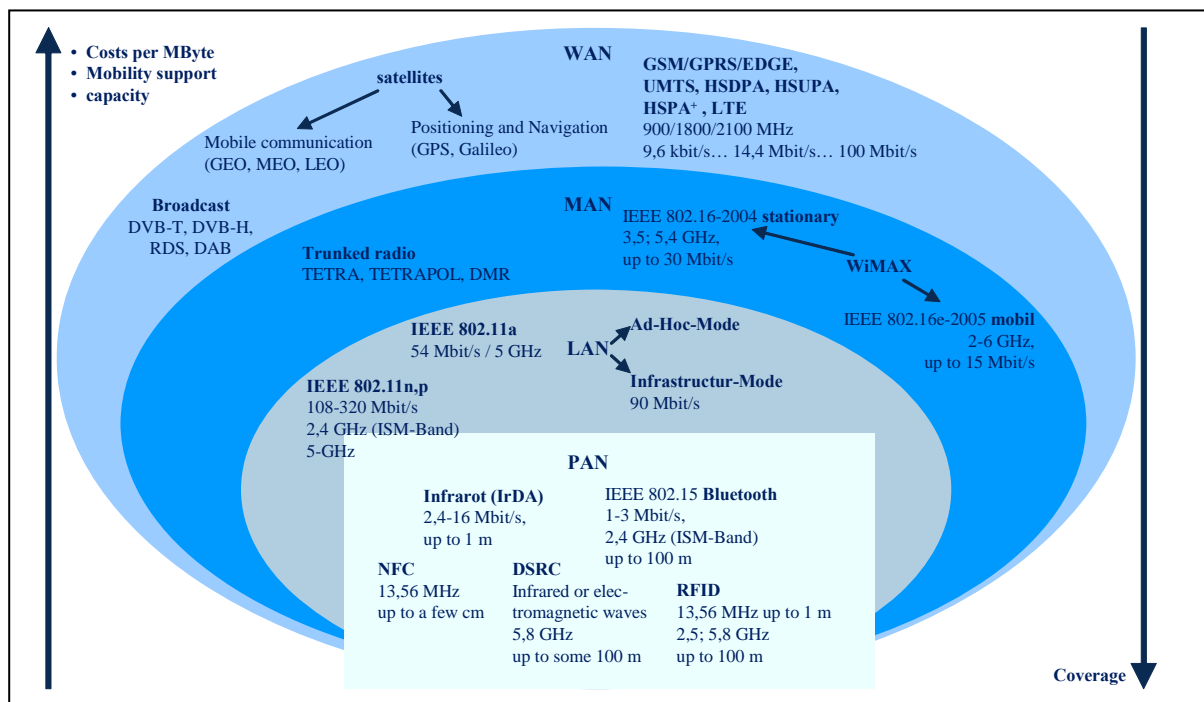


Fig. 1 Features of wireless technologies by comparison

Wireless communication technologies, positioning systems and geographical information systems are essential preconditions and make an important contribution to improve the efficiency of commercial vehicle operations. Figure 1 gives an overview about the most important radio technologies. They differ from

- ♦ data rates
- ♦ service performance
- ♦ coverage
- ♦ capacity
- ♦ ability for mobility support
- ♦ costs per MByte.

Wireless communication is a prerequisite for information and data exchange between vehicles or drivers and stationary systems. It is mainly realised by using electromagnetic waves (radio waves, microwaves and infrared). With regard to the bridged distances and the coverage the wireless technologies can be classified in Wide Area, Metropolitan, Local and Personal Area Networks (see figure 1). Only by interaction of the different wireless technologies supported by standardisation, common interfaces and open network philosophy telematic based fleet management solutions or intermodal and company wide tracking & tracing services can be offered. Local data capturing as-

sisted by RFID-systems, data processing and middleware as well as wireless data transmission by GSM or UMTS networks in combination with different positioning technologies make possible continuous tracking & tracing of goods or loading units.

Both, satellites and wireless communication networks like GSM, GPRS/EDGE and UMTS can be used for communication purposes as well as for positioning and navigation services. A very well known example for this is the wireless satellite communication system EutelTRACS using GPS or Qualcomm-owned satellites for positioning and navigation. The services are operated from the Eutelsat-Uplink station in Rambouillet near Paris offering the following functions:

- ♦ real-time data transmission, captured and supported by the EutelTRACS Fleet Management System
- ♦ roaming-free communication in whole Europe, data integration possibilities
- ♦ assignment of loading, status reports, shipments details, route restrictions, drivers working hours, monitoring and control of refrigerated trucks, hazardous goods, analysis of drivers behaviour etc.

The processing of the signals and data is realised in a so called “black box” with the extension of a home satellite receiver (see figure 2)

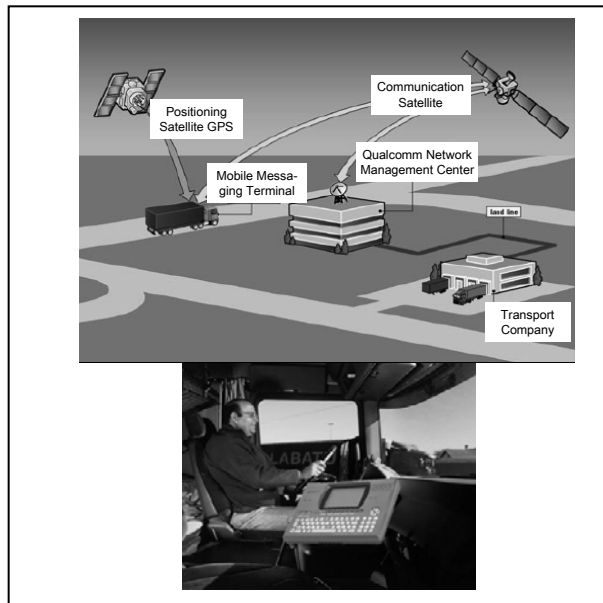


Fig. 2 Components of EutelTRACS system

Voice, data transmission, SMS, MMS, mobile TV, mobile internet access, mobile access to company owned servers or virtual private networks are most popular services in cellular communications networks and widely used for Order & Fleet Telematics Management Systems to support dispatchers in monitoring, control, and planning transportation chains and order processes.

3 SATELLITE BASED SERVICES TO MANAGE COMMERCIAL VEHICLE OPERATIONS

Voice and data communication can be realised by communication satellites and classified accordingly whether satellites are positioned in a Geostationary Orbit (GEO), Medium-Earth (MEO) or Low-Earth Orbit (LEO). It is shown in figure 3.

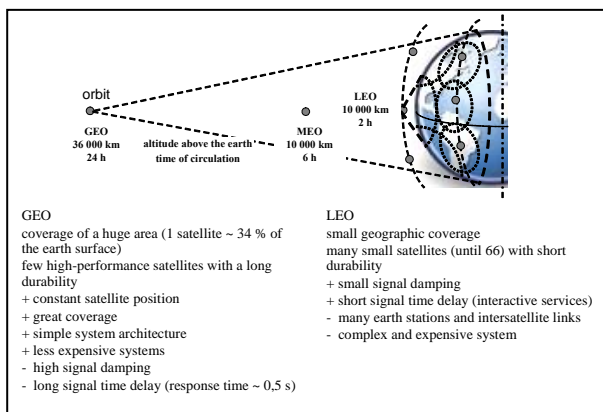


Fig. 3 Satellite Communication Systems

Geostationary satellite communication services are provided by Inmarsat or Qualcomm. The main users are the navy, air transportation carriers and international forwarders with vehicle fleets and supply chain partners in different countries and continents. Leo satellite systems are offered by private satellite system operators like Orbcomm, Iridium or Globalstar. The link to the satellite is realised either by means of small antenna (30 cm) or a normal rod antenna. The prices for data or voice transmission per minute are quite expensive (up to 2 Euro per minute). Vehicles’ positioning is a fundamental task in transportation. The knowledge of vehicles location is important for autonomous navigation systems or tracking commercial fleets. Positioning systems base on different approaches and technologies (see figure 4).

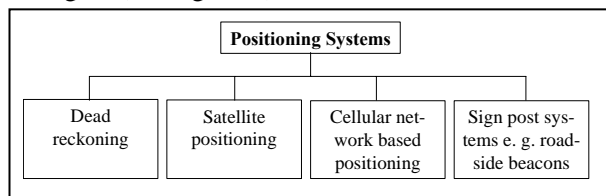


Fig. 4 Positioning technologies in freight transport

A so called Global Navigation Satellite System (GNSS) e. g. allows a mobile receiver to define the exact position by calculations using information of several satellites. There are 3 GNSS:

- ♦ Global Positioning System (United States)
- ♦ GLONASS (Russian federation)
- ♦ Galileo (European Union)

For the moment only the first one is fully operational.

In 2003 The EU and ESA agreed to develop and to establish an independent European civil and highly reliable satellite positioning and navigation system for world wide application. It will be a key element for interlinking the different transport modes and creating an integrated transport system at national and European level.

The Galileo constellation will consist of a total of 30 satellites, each of which will be fitted with two atomic clocks for the accurate measurement of time. Each satellite will transmit not only a time signal but also its current coordinates. If a receiver on earth receives the signals from a satellite, the distance between the receiver and the satellite will be calculated. From a knowledge of the coordinates of the satellites and the distance from them, the position of the receiver and, if necessary, the time at which the satellite signals

reach the receiver will be calculated and displayed. Precise positioning will require signals to be received from at least three satellites. The satellites will be monitored by the required number of ground stations. [1]

The development phase is due to be completed in 2009/10 and causes costs of 1.6 bn Euro financed 50 % by EU budgets and 50 % by ESA. The installation phase building the satellites and putting them up into orbit runs from 2007 - 2013. The installation cost are calculated with 3.4 bn Euro funded by EU budget. The objective is to get substantial private sector involvement for the following years of operation. The high availability, reliability and accuracy in the range up to 1 m due to additional local positioning components will be used in aviations approach for landing, in railways for the European Train Control system, in shipping for save navigation and docking manoeuvres in port entrances, in road transport for road guidance and in intermodal deployments to monitor the movements of dangerous good and for cargo tracking. A great advantage is the localisation of mobile objects also in tunnel buildings and even in high rise cities where buildings obscure signals from satellites low on the horizon. Despite of these advantages has to be critically noted that a comprehensive development of true innovative Galileo based services and application in transport does not yet exist till now.

The European Geostationary Navigation Overlay service EGNOS a forerunner system from Galileo has already started operation. The first experimental Galileo satellites Giove-A and B were launched for testing on-board equipment and ground station equipment functionalities in 2005 and 2008.

4 CELLULAR NETWORK BASED TELEMATIC SERVICES FOR FREIGHT TRANSPORT

Telematics applications in freight transport like Messaging & Fleet Monitoring Systems, Dynamic Vehicle Routing, Dynamic Transportation Planning Systems, Container Tracking etc. base on the transmission of information by cellular based networks like GSM, GPRS and UMTS networks or trunked radio networks combined with computerised processing of information. Navigation satellites e. g. give information of an exact spot and wireless cellular networks transmit these data from

the vehicles on-board-unit to different transport companies' operation centres or to other partners in the supply chain in order to provide automatic vehicle location and tracking services.

The bandwidth and data transmission capabilities are quite different. It ranges from 144 kbit/s for full outdoor mobility applications in all environments via 384 kbit/s for limited-mobility outdoor applications in urban and suburban areas up to 2 Mbit/s for low-mobility in urban areas and hotspots. The further development of the 3. generation networks towards Long Term Evolution allows down link data rates up to 14.4 Mbit/s and in the up-link up to 5.8 Mbit/s (theoretical performance) by using High Speed Packet Access. Nevertheless for transportation telematics the bandwidth is not so important but the availability of the network and the coverage in remote areas too.

In cellular communication networks base stations are distributed throughout the covered areas and can be used for localisation and cell tracking of mobile objects. The most important techniques for positioning in cellular communication networks are cell of origin, time difference of arrival and triangulation (enhanced observed time difference). The simplest but also the most inaccurate way is to approximate vehicle's position by cells coordinates locating the mobile object. The accuracy can be less than 100 metres in urban and up to 35 km in rural areas. That's why the advanced methods involve measuring the round trip time of a signal transmitted between the base station and the mobile device. The latter is able to listen to signals transmitted simultaneously by several base stations and measures the time difference between each pair of arrivals. Two or three time difference measurements are required for unambiguous positioning when the time relationship is known between the receiver clocks. [2]

In addition to GSM/UMTS networks WiMax (Worldwide Interoperability for Microwave Access) telecommunications technology will be interesting for freight telematic purposes. The WiMax standard 802.16e-2005 provides full mobile cellular-type access and supports high data rates up to 15 – 20 Mbit/s by a vehicles speed up to 120 km/h.

5 TELEMATIC SOLUTIONS FOR FREIGHT WAGON TRACKING IN RAILWAY

In railway freight transportation business it is essential for involved railway companies or owners of freight wagon fleets to achieve robust information about actual localisation of the wagon, the wagon-inside and freight conditions, the time of arrival or leaving a certain station or handling point, the mileage and technical performance of the wagons, the door status etc. For automatic capturing, transmission and processing of such important data the German Railion Company as a part of the business segment Railway Freight Services within the Transport & Logistics department of Deutsche Bahn AG equipped 15 000 wagons with telematic devices, so called NavMaster for GPS navigation and GSM/SMS communications functionalities (see figure 5)

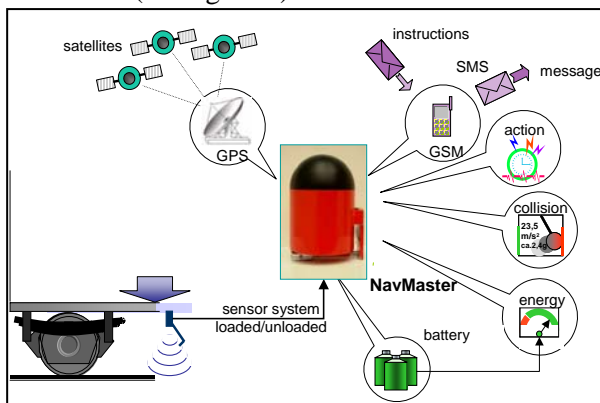


Fig 5 Freight wagon equipment for vehicle attendant localisation and communication [3]

The NavMaster comprises a cinometer that gives the information to the dispatching centre in Duisburg if the wagon has left a defined station at time, is moving or standing. This information is reconciled with the schedule and in case of differences the dispatching staff can react immediately. The collision sensor is measuring the power of a shunting collision. It activates direct measures if the shunting collision has been too hard or the wagons tailgated. Another sensor determines the loading status of a wagon as an important information for vehicles dispatching. Furthermore sensors will be mounted for determining the exact wagons mileage, for monitoring the wagons axle boxes and for indicating hot boxes. High-Tech sensors and electronic seals for wagons with theft susceptible goods are able to distinguish whether irregularities are only caused by vibration during train operation or whether there was an unauthorized doors opening.

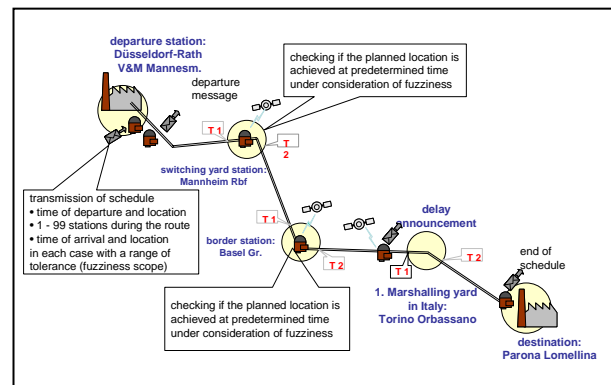


Fig 6 Networking tracking & tracing of wagons according to the reference transportation plan [3]

As shown in figure 6 the whole transportation process can be managed and monitored by interaction of data capturing by sensor technology, radio-based data transmission and communications and satellite positioning.

When Railion Customer Service Center gains orders from freight forwarders or consignors the transportation plan will be prepared describing the trace and the wagon's estimated time of arrival in a defined switching yard station, handling point, border station etc.

At the departure station GPS NavMaster receives the transportation plan from the Service center. When the wagon starts on schedule a departure message is sent and recorded. In case the monitored wagon does not start on schedule a non-event message is sent to the railroaders and they can initiate needed steps. This procedure also happens in case of delayed wagons border crossing or other late arrivals which are out of the defined fuzziness scope. The transport dispatchers now are able to change marshalling, to shorten crossing times at the next switching yard, border station etc. Parallel to this a modified transportation plan is calculated in the transport management and transmitted via GSM to the NavMaster of the concerned wagons. This approach is repeated till the arrival of the wagon at the destination station where an acknowledgement is sent by SMS.

All this happens in a complete automated manner by the wagon itself and changes an ordinary freight wagon in an "intelligent" high-tech product. There is no need anymore for the dispatchers to identify manually any discrepancies between the actual and the planned data in the logistics system. The tracking and tracing information is made available as written messages at the Rail-

ion company's Dispo-portal "eCargoService" and in geographical layout via web GIS-portal for shipping companies, freight forwarders, consignors and other customers. But also national and foreign partner railway companies and wagon fleet owners are provided with needed data by a multi-client-information system. The higher accuracy and availability of Galileo navigation signals will meet the challenges of track accurate positioning of vehicles in railway operations much more better than GPS system today.

Finally the challenge for the Railion company is not only to capture, to transmit and to distribute data about the distances covered by a wagon but also the efficient control of all operational processes within a complex network solution. In the backend data processing center of the Railions company the data gained from the telematic equipment of the wagons are integrated in a wide spread workflow system to distribute the workload between the different employees and departments. In addition the relevant information is given to the involved partners in time via intranet or the "eCargoService" internet portal. That means networking amongst all the partners is the real comprehensive issue of the wagons' tracking & tracing system. The most important impact of the described telematic system are:

- ♦ quickly detect significant delays and other irregularities
- ♦ reduce operational costs, e. g. when vehicles are standing unnecessarily
- ♦ determine actual arrival and departure times
- ♦ monitor the communication within the transport and logistics chain.

Conclusions

Freight transport logistics is characterized by time sensitive processes which are very susceptible to troubles, delays, breakdowns etc. The objective of advanced radio based positioning and navigation services is to achieve more information during the supply chain process including shipments in connection with mobile business. A consignor wants to know the exact situation and position of goods transported or stored. This paper discussed the different approaches and application scenarios of cellular network and satellite based mobile communication and navigation technologies. For real time management and planning of commercial vehicle operations the advanced Galileo system in combination with GSM/UMTS or WiMax cellular

communication technologies on the one hand and radio communication technologies like RFID or DSRC on the other hand offer advanced possibilities to identify discrepancies between actual and planned data to revise the logistic systems database automatically and to react immediately to disturbances in transportation processes. At least the vehicles and the goods transported become more and more "intelligent" and will be able to route themselves between consignors and consignees on an optimized trace.

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Abbreviations

| | |
|-------|---|
| DAB | Digital Audio Broadcasting |
| DMR | Digital Mobile Radio |
| DSRC | Dedicated Short Range Communication |
| DVB | Digital Video Broadcasting |
| DVB-S | Digital Video Broadcasting Satellite |
| DVB-T | Digital Video Broadcasting Terrestrial |
| EDGE | Enhanced Data Rates for GSM Evolution |
| ESA | European Space Agency |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| GSM | Global System for Mobile Communications |
| HSDPA | High Speed Downlink Packet Access |
| HSPA | High Speed Packet Access |
| HSUPA | High Speed Uplink Packet Access |
| IEEE | Institute of Electrical and Electronics Engineers |
| LTE | Long Term Evolution |
| MMS | Multimedia Messaging Service |
| NFC | Near Field Communication |
| RDS | Radio Data System |
| RFID | Radio Frequency Identification |
| SMS | Short Message Service |
| TETRA | Terrestrial Trunked Radio |
| UMTS | Universal Mobile Telecommunications System |
| WIMAX | Worldwide Interoperability for Microwave Access |

ПОТЕНЦИАЛЪТ НА БЕЗЖИЧНАТА КОМУНИКАЦИЯ, ПОЗИЦИОНИРАЩИТЕ И НАВИГАЦИОННИ СИСТЕМИ ЗА ПОДОБРЯВАНЕ НА МЕНИДЖМЪНТА НА ТЪРГОВСКАТА ЕКСПЛОАТАЦИЯ НА ПРЕВОЗНИ СРЕДСТВА

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ГЕРМАНИЯ

Резюме: Докладът представя преглед на модерните безжични комуникации, позициониращи и навигационни услуги за телематични услуги, в частност тези, които са свързани с товарните транспортни процеси и мениджмънта на търговските оператори на превозни средства. Обсъждат се предизвикателствата и ограниченията на различните радио технологии. Разгледано е телематично решение за следене на товарен вагон и са представени неговите въздействия върху партньорите, включени в транспортната и логистична верига.

Ключови думи: безжична комуникация, сателитно позициониране и навигация, управление на парка превозни средства, следене и проследяване.