Stratix

Wireless applications in Transport and Logistics

Observations, trends, and potential vulnerabilities

REPORT

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Stratix

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1 Introduction

Since its invention, the importance of wireless communication for logistic processes has been clear. Starting around 1900 with the use of radio telegraphy for ships using Morse code, wireless voice and data connections have grown to be a vital aid to transport by road, rail, water and air.

In the last decades miniaturisation and advances in data processing and radio technology led to a fast development of wireless technologies and growth of use of radio connections, and modern wireless technologies are applied in almost every aspect of transport and logistics, to optimise and speed up logistic processes, to increase safety and to improve traffic flows. As a result those processes are ever more depending on the availability of those wireless communication channels [1] and the reliability and availability of sufficiently dimensioned wireless communication becomes more and more vital for society because it is interlinked with economy, safety, employment, emission reduction and flexibility with regard to emergency situations [2]. For some applications dedicated, international standardised radio channels are available, while other applications use license exempt spectrum and generic data networks. Apart from the use for data and voice connections, spectrum is used for applications like radar and navigational aids and positioning systems varying from park assist technology in cars to landing systems on airports.

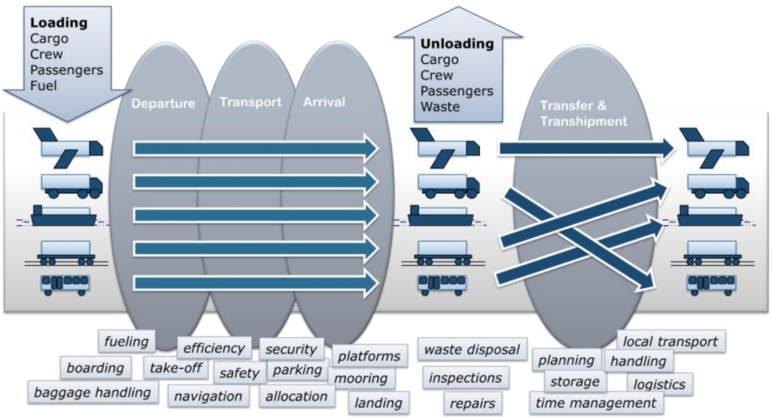

Figure 1: Transport & Logistics: many processes with interrelations and dependencies, and facilitated by a variety of applications that use radio spectrum

This report gives an overview of the developments of the use of radio frequency in the transport and logistics sector and the challenges this sector faces: which applications are used, how are these related to primary transport processes, what trends can be distinguished and what are possible vulnerabilities of such applications and radio frequency use. This report was commissioned by the Dutch Radiocommunications Agency of the Ministry of Economic Affairs in the Netherlands.

For four areas that together cover the most important aspects of transport and logistics in the Netherlands, ('Metropolitan', 'International airports', 'Seaports', and 'ITS and the highway of the future') used applications are given, with observations regarding used radio spectrum, vulnerabilities and focus areas, and organisation of use.

1.1 Research Questions

The main focus of the research was about open or shared ('license exempt') spectrum usage. Highly standardised or regulated spectrum for specialised applications, and specific issues arising from the use of such dedicated spectrum were out of scope. The following research questions were the starting point for the investigation:

1. Which wireless applications are used for different functions in the Transport & Logistics sector?
2. What are the most important trends in this sector regarding wireless applications?
3. Which vulnerabilities can be identified?
4. What are the developments of ITS and which risks are involved?
5. What is the approach of different actors and stakeholders with regard to risk factors related to the use of wireless applications?
6. What are possible countermeasures for risks that pose a large impact on society?

1.2 Method

In order to answer the questions the following steps have been taken:

- *Selection of application areas*

Four 'sub'-sectors have been selected within the broad application spectrum of transport and logistics in such a way that a large part of wireless applications in the transport & logistics area are covered in general in the research, allowing for the description of specific cases and their context as examples.

- *Desk research followed by interviews on a select number of example-cases;*

Based on the general available information and on specific, topic-related interviews an overview is created of the applications that use wireless communication, and challenges that are seen in the use of those applications, now and in the future.

- *Analysis of the example cases*

Based on this (case-specific) information, observations are made, where present vulnerabilities or unwanted dependencies are highlighted, and an overview of the stakeholders active in those kind of cases are identified.

- *Determination of generic trends for the transport and logistic sector*

From the analysis of the cases ('Metropolitan traffic', 'International airport Schiphol', 'Seaports', and 'ITS and the highway of the future') more generic trends for the transport and logistics sector are determined. This includes additional desk research and verification with stakeholders.

- *Conclusions and recommendations*

Where possible, the generic trends lead to identification of ‘common’ challenges and vulnerabilities faced by the transport sector (or even more widely). From this possible common countermeasures and conclusions and recommendations are made.

2 Transport in Metropolitan Areas

In the large cities of the Netherlands and elsewhere elaborate traffic management systems are used to monitor and control the city's road traffic and in some cases to monitor and control public transport systems (tram, bus and metro). A variety of systems is used to monitor and control road traffic to optimise traffic flow, use of scarce parking resources and efficiency of public transportation systems. Other applications include measurements of air quality due to traffic and control of zones in city centres where polluting vehicles are prohibited.

Historically there are separate municipal departments each with their own control rooms monitoring and controlling the city's traffic and logistic processes. This has led to diversity in technological solutions for the same problems.

The first paragraph in this chapter describes the applications and management systems that use wireless communication in the metropolitan area of Amsterdam, based on interviews and other (public) information. The second paragraph describes more general use of wireless communication in several metropolitan traffic management applications. In the third paragraph technology and spectrum use of such applications is described and in the fourth paragraph concludes with related risks, vulnerabilities and areas of concern.

2.1 Case: Amsterdam traffic management

Amsterdam is the largest city of the Netherlands, hosting a variety of high density transport, transfer and transhipment services. It is one of the Dutch cities with a (partly) underground 'metro' train-system. The city has the second busiest railway station in the country and features a complex combination of major and secondary roads, waterways, railroads and several train stations, narrow city streets with limited parking space, an extensive tram system, bridges, a number of tunnels for road and rail transport, and a large airport very near to the city.

Some of the major transport management functions that the municipality of Amsterdam performs are traffic flow management, parking management and the metro system.

2.1.1 Applications

Traffic flow management in Amsterdam

There are around 400 traffic light management systems operating in the city of Amsterdam. The city distinguishes three levels of traffic management systems for traffic lights: the simplest (category 3) are stand-alone systems that manage the traffic lights of one particular crossing. More elaborate systems (category 2) communicate with a central office (approximately once per minute) to relay traffic information. The most sophisticated (category 1) systems combine a number of traffic lights nearby to create 'green waves' and/or allow on demand priority for police, fire brigade or VIP transport. Approximately 50 of the 400 systems in Amsterdam fall in this category. The majority of the traffic management systems use wired connections, but in various cases public wireless gprs connections are used, for instance for temporary traffic lights that require remote management or monitoring and cannot easily be connected by wire.

Another form of traffic flow management is provided by *Traffic Guidance systems* directing traffic to certain destinations. The most advanced Traffic Guidance systems in Amsterdam incorporate regional traffic information and manage and optimise the entire traffic flows using 40 electronic road signs, ('Dynamic Route Information Panels or 'DRIP's) to (re)direct traffic and point out alternative routes to reduce travel times and probably optimise for other parameters (like environmental impact).

Traffic flow management in Amsterdam interworks with several other public organisations such as Rijkswaterstaat[1], and the province of Noord-Holland, using DVM 2.0[2] to improve this interworking by defining a standardised interface between traffic management systems.

A specific component of traffic management is traffic detection and monitoring, using inductive-loop traffic detectors and/or using image recognition of roadside cameras. For enforcement of low emission zones and traffic separation (using bus and taxi lanes) number plate recognition is used. In some areas boom barriers or retractable and rising bollards are used to restrict access to area's that are only open for specific traffic.

Another form of traffic management that is in use in Amsterdam since many years is prioritisation of public transport (busses and trams) and emergency vehicles (like ambulances) using local communication in the form of short range radio messages sent from transponders on the vehicle and detected using 'radio detection loops' in the road (based on the VETAG/VECOM system, Vehicle Tagging /Vehicle Communication). Now local ad-hoc radio communication between vehicle and traffic light based on 'KAR' (Dutch 'korte afstands radio', or 'short range radio') is being introduced, removing the need for the vehicle to approach the traffic lights up close since KAR operators up to tens of meters, and operates at a frequency 429.85 MHz.

Parking management in Amsterdam

Parking management is another important aspect of transport in Amsterdam (and in other urban areas) and is directly related to congestion since efficient (re)direction of vehicles to their designated destination and associated parking spot can significantly reduce road occupation near city centres (estimates range from 15% up to as much as 40% of inner city traffic to be parking-related in extreme cases, part of which can be reduced[3]).

Multiple applications are used to optimise the use of scarce parking space in the city. Wired connections are used for the parking lots to communicate the availability of parking space to the *Traffic Guidance* and *parking guidance systems* that direct traffic to parking lots, bays and garages with available capacity. This is done using 200 electronic signs (connected using fixed or public GPRS networks) indicating availability of spaces (full or number of available

[1] Management of country wide public infrastructure such as highways and large waterways

[2] http://www.dvm-exchange.nl/

[3] https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/road-solutions/urban/case-studies-for-traffic-solutions-en.pdf , http://www.beterbenutten.nl/pagina/301/

spaces), in combination with the above mentioned 40 *Dynamic Routing and Information Panels,* connected using public GPRS networks.

In the vicinity of the large soccer stadium Amsterdam Arena and large concert halls (Heineken Music Hall and Ziggo Dome) the municipality of Amsterdam uses electronic signs that dynamically direct traffic to the available parking spaces (over 20.000) in parking lots and parking garages, or back to main motorways, optimising traffic streams. Similar systems are used in the vicinity of the VU Academic Hospital. GPRS is used because it offers a great amount of flexibility, but it also poses a challenge: although the average network availability of the mobile networks is high, there are occasions when the network gets congested. Unfortunately these occasions tend to occur prior to - and after - large events, when the public mobile networks are extensively used by the people moving to - and from - these events. So when the electronic parking and traffic direction signs are needed the most, they tend to be the least reliable.

Pay and display machines on the streets for *parking fee collection and parking enforcement* support PIN transactions using a secure data connection using public mobile networks. Battery charging machines for *electric cars* use mobile network connections to transport data related to status, support and payments.

Amsterdam Metro and other public transport

The Amsterdam metro system uses wireless local network communication systems for the driver and automated systems to communicate with the control centre for increased safety, security, control and monitoring of metro trains. This network system around the rail tracks uses shared 5 GHz spectrum. But this was not the preferred choice for Metro Amsterdam as shared spectrum posed some long term risks. The need for dedicated spectrum has been discussed with Radio-communications Agency Netherlands but initially European regulation did not allow for specific spectrum allocation. Metro Amsterdam indicated in 2011 that they preferred the use of dedicated local spectrum for communication along the rails, with a desired licence period of at least 10-15 years ([1],[3]). This case illustrates the need felt for specialised policy for closed broadband networks related to specific non-commercial use. Examples of such special case policies have been implemented in Germany, France and Spain.

For speech communication with tram drivers a private trunking solution[4] (MPT1327, to be replaced with Tetra in the near future) is used in 410-430 MHz range for the tram, busses and metro trains in Amsterdam. GPRS (migrating to UMTS and LTE) is used for (less essential) data communication regarding departure times and traffic information for passengers between central systems and trams, busses and platforms. This means in practice that (real-time) departure-times might not be available if the connection is lost, but that availability of the public transport system itself is not (or at least should not be) affected.

[4] One system is used in Amsterdam for communication with tram, busses and metro trains.

2.1.2 Organisation and awareness

Many data communication systems related to transport in Amsterdam are historically evolved from very specific use, managed by different departments. Application management including management of the related underlying networks is in many cases outsourced or organised as a package: without functional separation between network layers, transport and signalling layers and application layers. That leads to the use of separate networks for separate applications, and optimisation of cost efficiency and robustness for each separate case. Some of the (legacy) communication systems do not use IP (yet). An example is the street light control system: a system of about 700 switching cabinets interconnected by a dedicated copper wire network is not owned by the city anymore.

This leads to several issues: the municipality has no clear overview of the underlying network structure it is using for several applications, and possible interdependencies, applications that are introduced as 'nice to have' evolve into essential applications, reliability of public networks changes over time due to growing use of the general public, and vulnerabilities in peak hours are discovered using trial and error.

In the long term separation of functional layers, using a limited number of multipurpose (segmented) IP-based networks for all applications, is seen as preferable over the current situation, because this would optimise cost effectiveness and manageability of network capacity and could make risk assessment and creation of robust fall-back options easier.

Traffic flow management in Amsterdam interworks with several other public organisations using DVM and coordination with those partners is necessary to increase overall traffic efficiency.

The interviewed parties in Amsterdam would prefer a spectrum and telecom policy specially for 'urban area' or large cities in which (local) spectrum licences could be obtained which would give the city autonomy over part of its wireless communication by utilising a 'dedicated' network (for example private LTE in a frequency range in which clients and network equipment is available [3]). This could help solve some of the issues that cannot be solved using the public operators or using the current available spectrum.

2.1.3 Summary Amsterdam traffic management

Wireless applications

Traffic flow management, parking management and public transport in Amsterdam are supported by a wide range of applications that use wireless connections for distributing or relaying information about traffic amounts, parking space availability, travel times and schedules of public transportation, etc.

Trends

In the past decades many separate fixed and mobile networks have been built dedicated to specific applications. A long term trend can be seen towards standardisation of interfaces and more interoperability between the departments that are involved in traffic management. The use of shared general purpose networks sometimes provides a relatively cheap and flexible solution for non-essential applications.

Stakeholders

Stakeholders that can be distinguished in metropolitan areas: drivers, citizens, city government, city traffic department, telecom service providers and traffic service providers. A stakeholder analysis of metropolitan traffic management is described in paragraph 7.1.

Vulnerabilities

Applications that start as non-essential (such as parking guiding systems) become more essential in the course of time (for example because they become essential in limiting and reducing traffic jams) and general purpose networks with a relatively high available capacity at the time an application is introduced become more heavily used by other users as time goes by. This kind of 'shared use' in which business processes more and more depend on scarcer 'best effort' resources is a potential vulnerability. Especially because shared resources tend to become even scarcer in stress situations. Standardisation of interfaces and optimising interoperability is a long and difficult process. Road, rail and tunnel infrastructures and moving equipment ideally have relatively long life and maintenance cycles. This does not always match well with life cycles of general purpose communication equipment, and radio spectrum license or allocation policies.

Possible countermeasures

One way to obtain protection from interference of other users is to use (local) spectrum licenses which would give municipalities autonomy over part of its wireless communication.

Spectrum and telecom use can be aligned and optimised by organising 'telecom and spectrum management' into municipal organisations that keep an overview of all spectrum and telecom needs in that municipality and that could interact with counterparts at the side of the Radio-communication Agency (AT).

Increased awareness and interaction with the Radiocommunications Agency Netherlands could potentially avoid 'trial and error' approach regarding the use of general purpose or shared wireless networks for applications that are or will become essential. The Agency could act as an expertise centre on specific spectrum issues in urban areas. It could bundle and relay information on experiences in one municipality to other municipalities (which likely experience similar challenges) and could bring municipalities together for discussions and information sessions.

2.2 Transport applications for metropolitan areas in general

2.2.1 Traffic flow management

Several levels of traffic management systems can be distinguished: the most simple are stand-alone systems that manage the traffic lights of one particular crossing. The most advanced systems manage road networks and are able to create 'green waves' and to allow 'on demand priority' for police, fire brigade or VIP transport.

Traffic Guidance systems incorporate regional traffic information and manage and optimise entire traffic flows using electronic road signs, ('Dynamic Route Information Panels or

'DRIP's) to (re)direct traffic and point out alternative routes to reduce travel times and probably optimise for other parameters (like environmental impact).

A specific component of traffic management is traffic detection and monitoring, using inductive-loop traffic detectors and/or using image recognition of roadside cameras. For enforcement of low emission zones and traffic separation (for instance for bus and taxi lanes) number plate recognition may be used. In some cases boom barriers or retractable and rising bollards are used to restrict access to area's that are only open for specific traffic. A number of European pilots are conducted under FREILOT[5], in which (connected) trucks gain additional information about traffic lights they approach or even get priority at some traffic lights to increase traffic efficiency.

From the Amsterdam case it became clear that most of the traffic management systems use wired connections (partly predating the current area of omnipresent mobile communication), but where flexibility is needed - for instance temporary traffic lights that need remote management wireless connections are used. Also the use of wireless connections increases because of convenience and the lower cost of those connections.

2.2.2 Parking management

Parking management is another important aspect of transport in urban areas and is directly related to congestion since efficient (re)direction of vehicles to their designated destination and associated parking spot can significantly reduce road occupation near city centres (estimates range from 15% up to as much as 40% of inner city traffic to be parking-related in extreme cases, part of which can be reduced[6]).

Traffic Guidance and parking guidance systems aim to optimise the use of scarce parking space in the city by directing traffic to parking lots, bays and garages, and vary from standalone electronic signs per parking location indicating availability (full or number of available spaces) to systems connected to regional traffic flow management to dynamically directing traffic to available parking spaces. Many parking management applications use wired connections, for example to connect large parking lots, but in addition (or alternatively) wireless connections are used, for example for updating electronic parking signs and parking fee collection.

Amsterdam does not use 'per parking bay' availability information yet, but follows the developments and expects to look into this again in the future, specifically for 'special purpose parking bays' like for disabled people or van (un)loading near shops.

Pay and display machines for *parking fee collection and parking enforcement* support PIN transactions generally use a secure connection over public mobile networks. Battery charging machines for *electric cars* use mobile network connections to transport data related to status, support and payments.

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[5] Piloted in Helmond, see http://www.helmond.nl/Internet/Site-Root/Welkom-op-Helmondnl/Bewoners/Bewoners-Verkeer-en-vervoer/Verkeersprojecten/Freilot-(Intelligente-Transport-Systemen).html

[6] https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/road-solutions/urban/case-studies-for-traffic-solutions-en.pdf , http://www.beterbenutten.nl/pagina/301/

The Dutch Ministry of infrastructure is stimulating the use of dynamic parking information by drivers. The project 'Beter Benutten'[7] is progressing toward the use of both fixed and wireless solution in the four biggest cities in the Netherlands. Parking data is collected in a central database and subsequently published for anyone to use and application makers can use these data. At this moment, parking lots in the 4 largest cities in the Netherlands are connected, the project reports that other cities are soon joining. The goal is to collect all parking data information in all cities in the Netherlands. To be able to use the collected data, mobile applications are being developed for end-users that require the end-user to have a mobile data connection.

Many cities consider extending the information about available parking space to the parking bays on streets and incorporated that information in the parking management system[8]. This involves placing wireless sensor on each parking bay (see Figure 2) to connect a number of sensors together or to a gateway using a 'sensor' network technology in for example the 868 MHz band (like Nedap's 'SENSIT') or the 2.4 GHz band.

Figure 2: Sensors are placed under each parking bay, relaying information to gateways using (source: Libelium.com)

2.2.3 Public Transport

Modern busses and trams are equipped with all kinds of in-vehicle ICT systems, like systems to distribute and display travel information in buses and streetcars and touchscreens for the driver to control messages displayed in the bus. Location is determined, either via GPS or using beacons and sensors, and the information is send to the central system. For those applications a combination of Wi-Fi (when busses are at the depot) and GPRS[9] (as a backup and when on the road) is used[10].

On the roadside at bus stops real-time travel information is provided, and although those are 'fixed' stations, the use of public wireless communication is often preferred because of ease of use and relative low cost if the amount of data transmitted remains low (i.e. no camera pictures are send).

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[7] http://www.beterbenutten.nl/

[8] Winterswijk in the Netherlands http://www.nedapidentification.com/news/news/nedap-parking-sensors-prove-efficiency-in-reducing-traffic-searching-for-parking.html) and in other cities like parts of London, see http://www.bbc.com/news/technology-25727117 and see http://www.libelium.com/smart_parking/

[9] GPRS is used in trams in for example the cities of Utrecht and Rotterdam

[10] See http://www.initag.de/share/news/INITativ/Europ_INITativ/initiativ_2_2009_europ_small.pdf and public bus solution in Düsseldorf and Hamburg http://www.symeo.com/English/Info-Box-Schema-1/press_release_positioning_for_busdepots.html

Metro and tram lines use (wireless) network communication systems for the driver and automated systems to communicate with the control center for increased safety, security, monitoring and control. Wireless systems are generally introduced for information and voice exchange, but later driverless operation of metro/underground rail is considered.

Several public transport systems in Europe use the 5 GHz Wi-Fi band (5.15-5.740 GHz) or the 5.8 GHz (5.795 GHz-5.815 GHz) ISM band to provide broadband connectivity and send location information of metro vehicles from and to the base station. Bus and tram systems (in the Netherlands and in other countries) often use public mobile networks for their data and communications for in-bus traffic information.

For voice communication in public transportation (and taxi's) dedicated voice and data networks are used, using licensed Private Mobile Radio frequency bands for analogue voice communication (80, 150 and 450 MHz), Tetra for voice and data (410-430 MHz) and other forms of (digital) mobile radio and PMR/PAMR.

Ticketing and payment of travelling with public transportation in the Netherlands is currently almost entirely standardised using the OV chip card system. This system uses a contactless smart card using RFID technology in the 13.56 MHz band. For communication between transaction equipment (card charging equipment and card readers on platforms and in moving equipment) and central servers in many cases wireless network connections are used over public mobile networks.

A growing number of public transport companies offer 'free Wi-Fi' to travellers during transportation or on platforms. In (metro) trains, trams and buses this is often implemented using mobile (4G) backhaul connections. Generally availability of network connections for payment and for offering Wi-Fi to travellers can be regarded as non-essential: temporary loss of such connections should not influence the efficiency of public transportation itself. However they become more and more important for operating companies and traveller. This trend illustrates the growth, diversity and omnipresence of spectrum use for Wi-Fi and public mobile networks.

2.3 Technology and spectrum use

In metropolitan areas a variety of systems is used for all kinds of traffic related processes, from fixed fiber and DSL connections to wireless connections. There appears to be no de facto 'preferred' solution: The organisations behind metro-systems each choose and use their own solutions, and the communication-needs within one municipality are often fulfilled on an ad-hoc basis. Services like public transportation and traffic management in Amsterdam use public mobile network services (GPRS/UMTS/LTE) for communications. There is an overall increase in the number of 'wireless connected applications'. Public mobile solutions are used when mobility is important (i.e if the application can be moved around), as well as in cases where a fixed solution would be an option since it is flexible and easy to implement (and not so expensive if only small data amounts are used).

There is use of Professional Mobile Radio (PMR) applications, like the 410-430 MHz for Tetra networks for voice communications in taxi's and other public transport areas.

2.4 Risks, vulnerabilities and areas of concern

Systems that support metropolitan traffic management or public transportation, such as traffic light systems, are designed in such a way that they can function stand alone and only need connectivity for fine-tuning or (non-vital) active control.

However, often the use of convenient and relatively cheap public mobile connections is preferred over the use of fixed connections. This might be adequate for some non-time critical systems, but it is not always clear when an application is 'critical' for metropolitan traffic flows and when it is not.

A high availability of mobile networks now still does not mean that, in the future, especially in case of crowds and traffic jams, problems may not occur, and such dependencies are not always foreseeable for managing organisations.

There is a variety of (legacy) applications with specific telecommunication challenges each working on specific (and often mutual incompatible) communication platforms, using specific protocols for data transport. Although newer applications are often IP-based, some older applications still working in the field use proprietary or outdated protocols. Converging new and existing systems to IP where possible, would allow for a more uniform solution (of set of solutions). Although this is mentioned as highly desirable for the near future, this goal is often not yet formalised and many systems are only replaced after ten or more years of operation. There are efforts to standardise interfaces between systems, such as DVM. In the UK is a similar but broader initiative to move towards a more open and standardised set of systems for Urban Traffic Management and Control, UTMC[11].

Several organisations are responsible for different parts of the entire 'transport and logistics' processes in metropolitan areas. Some cities and municipalities own local public transport companies and parking areas are sometime exploited by the city, whereas sometimes the owner is a commercial entity. Every one of these organisation can make their own choices about communication technology. The preference of use of wireless technology differs between the stakeholders. Metropolitan organisations face the paradox that they start using wireless connected applications 'as an extra feature' that then gradually become more critical for optimal flow of traffic or public transportation. Since it is an 'extra', they choose an easy to use communication solution, while that radio spectrum or network (in case of GPRS) becomes more crowded with growth of other applications as the years pass by.

Public networks of the mobile operators are dimensioned for an average situation but over dimensioning for an exceptional worst case scenario is very expensive, so it is inevitable that network overload may occur in exceptional peak situations (especially when the data traffic generated by one user keeps growing).

A solution suggested by municipalities to avoid dependency on shared networks or spectrum (where interference by other users may occur) is the allocation of specific (local) radio spectrum for cities and local governments specific for 'metropolitan use'.

[11] http://www.technolution.eu/nl/over-ons/publicaties/195-urban-traffic-management-and-control.html

Allocation of specific radio spectrum for industries, (transport) organisations and municipalities that cover a certain limited area can provide local control over the (local) utilisation of the available capacity and gives local authorities a certain responsible in, and possibilities for, preventing future congestion in the spectrum they use. For example part of the spectrum in the 3.6-3.8 GHz range designated for local use can be used for this under the right conditions. See 6.1, “local licensed spectrum” for more on this.

3 International airports

Wireless technology is widely used in aviation. Particularly in and around major international airports such as Schiphol Amsterdam an extensive amount and diversity of wireless communication can be found. Next to mission critical applications like air traffic control and security, there are many other applications that make use of wireless technology at an airport. We can broadly divide the applications at major airports (for example Schiphol) into three categories, 'Flight-operational applications', 'flight related applications', and 'secondary and other processes'.

Flight applications are of primary importance for (safely) flying the aircraft, like air traffic control, air traffic management, and applications that are responsible for taking off and landing the aircrafts. Next to this, there are flight-related applications related to cargo handling as well as passengers with luggage handling trans-shipment. Finally, there are secondary, not directly flight-related, processes that none the less can be of importance for an airport and the position it takes as an (international) tourist and business 'hub'.

Many of these processes require wireless communication. Not all of these processes and related applications have the same level of risk; continuous flight applications are riskier than shopping facilities at the airport.

3.1 Case: Schiphol Airport

Schiphol Airport has an important function both as the largest airport in the Netherlands and as a major hub for international flights. KLM is the major airline active at Schiphol, but in total around a hundred airlines are active at Schiphol, flying at more than 300 destinations around the world. Each year around 52 million passengers pass through Schiphol. Around 500 companies are active on the Schiphol area with around 65000 employees.

In the next paragraph a number of application areas at Schiphol where wireless connections play an important role are described.

3.1.1 Applications

Flight specific applications at Schiphol Airport

For Air Traffic Management and to safely operate at Schiphol a number of flight-specific applications for air traffic control, air traffic management, and applications that are responsible for taking off and landing the aircrafts are used. Those applications use international standardised frequencies. Flight related applications are managed in international laws and regulation and are highly regulated. International airports are members of IATA, which is a United Nation organ responsible for arrangements to use spectrum and space for aircrafts. The IATA is just one of the international organisations that are working at this level. Aircrafts and international mainports are a high security concern, therefore governments make sure that spectrum use at that level is secured for interference.

Flight-related applications at Schiphol Airport

Apart from flying of the airplanes from and to Schiphol, numerous activities take place around each arrival and departure of a plane. The plane must be refuelled, luggage de-boarded and loaded, catering for in-flight restocked, passengers need to de-board and new passengers arrive at the terminal. Those processes take place in a short amount of time to minimise the turn-around time of airplanes. Apart from the 99 airlines that operate from Schiphol there are numerous aviation related companies, service providers and subcontractors (such as Menzies, airline catering etc…), each with their own applications at the airport that provide those services.

Baggage-handling at Schiphol is already partially automated. Barcodes have been used for years, but Schiphol is now moving to RFID-tags for part of its luggage handling[12] to identify a specific piece of baggage [4]. RFID-tags can be read-out automatically for tracking pieces of baggage to increase the speed with which large amounts of luggage can be handled. The RFID is (in Europe) operated in the spectrum 865.6 to 867.6 MHz [5]. This process is supported using wireless RFID-scanners, connect to a central system using conventional Wi-Fi in the 2.4 IMS band. At Schiphol issues with those connections are observed due to the crowded 2.4 GHz band.

Ground personnel that is involved in flight related processes often carry multiple wireless voice communication devices (a PMR-Radio device together with a mobile smart phone), using dedicated PMR FM channels[13] for specific flight related services, like refuelling or de-icing services. This usage is sometimes very location specific and dedicated to one hangar area, or related to a very specific user group, for instance crew transport and logistics or fire drills.

There are dedicated FM channels for several airport specific companies and services. A general communication platform, for voice, push to talk voice, and data communication for closed groups at Schiphol is offered and maintained by Entropia[14] and uses 423-424 MHz channels.

Some very specific communication systems for flight related data exchange with airplanes are operated by companies such as SITA and Arinc specialising in aviation related wireless services for communicating logistic and in-flight data with airplanes at the gate. For personnel working in and around the airport, Schiphol Telematics sees a trend that voice communication is more and more complemented or even replaced by data communication on non-PMR equipment, increasing the need for highly reliable data networks that can provide enough bandwidth.

Another trend is that more wireless data applications are used on tablets and laptops, coordinating work processes and work orders near the airplanes outside of the terminal. However, data communication using Wi-Fi on airport aprons, ramps and taxiways is difficult since Wi-Fi is only available inside and near the terminal, and not tens or hundreds of meters away. Public mobile networks (GSM/LTE) are therefore used by companies that are involved

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[12] See for example http://www.airport-technology.com/features/featureairport-baggage-handling-systems/
[13] http://www.scanman.nl/omschrijving/Frequenties%20Nederland%20totaal.pdf
[14] A company offering organisational trunked radio for PMR communication as a service

in those flight related processes at or around the tarmac for business related data and voice services for the companies that are active there. This creates some form of dependency of company processes on the availability of the contracted public mobile network(s). Schiphol argues that although they might not be safety related, disturbance of those services can disrupt regular services and cause delays. Schiphol is looking for other dedicated solutions that can cover a larger area, like providing a dedicated private LTE network with wide range and high availability.

Camera surveillance and motion detection equipment inside the Schiphol terminal are mainly connected via fixed networks but in some cases use wireless connections (Wi-Fi) for flexibility of use.

Secondary applications and supporting facilities at Schiphol Airport

Next to all the flight-related applications, Schiphol as a major “hub”-airport serves as a business and consumer hub, with tens of shops, hotels, bars and convention opportunities, all “packed” in a relatively small area. All those ventures have their own applications for logistics, ordering, internet-access, etc.

Applications used at Schiphol include:

- *Internet and Wi-Fi access for travellers through the arrival and departure all and at the terminals at Schiphol*
- *Internet and Wi-Fi access for businesses and conference centers and their visitors*
- *Logistic process related to (secondary) businesses like restaurants*
- *Public Transport near (from and to) the airport, like trains and busses*
- *Private Transport services such as hotel shuttle buses, valet parking etcetera.*
- *Non airport specific public security, safety and utility services*
- *Paid parking*
- *Location and navigation within the building using Bluetooth Low Energy (BLE) beacons (iBeacons for Apple devices)*

Although the challenges coming from those applications are not specific for Schiphol (they are similar to those in city centres), the fact that Schiphol contains many shops and buildings in a relatively small service area and needs to accommodate millions of visitors per year, combined with the fact that airport operations itself make intensive use of wireless communication, make that the challenges can be specifically severe.

3.1.2 Organisation and awareness

Schiphol as an organisation is well aware of the importance of mobile communication and that developments are fast moving in this field, with data centric applications becoming more important. An integral risk analysis is needed certainly with fast moving developments in the field of mobile communication. To tackle the challenges of the crowded radio spectrum Schiphol is a proponent to reserve (newly freed) spectrum for local use by industry or companies to give those parties dedicated spectrum in which they can build their own networks and in which protection from interference or from other users us obtained instead of auctioning all spectrum nationwide to nationwide operators.

A dedicated department *Ether Control Schiphol* is active to coordinate and monitor the use of wireless applications. *Schiphol Telematics* is the dedicated `service provider` for communication solutions at Schiphol and is aware of the large variety of communication systems used and the possible challenges that this poses to the continued operation. They aim to stimulate innovation and increase efficiency at the airport by implementing and offering modern telecom solutions.

Schiphol would prefer to create a dedicated LTE network with high availability (redundant network) for ground/operational services. Having control over the network is an important aspect since public providers often do not offer the necessary availability and priority that Schiphol deems necessary. For this they would prefer to use dedicated spectrum for which LTE equipment is available and which they can use for a period of 15 years or longer[15]; Spectrum in the 3.4-3.8 GHz band might be suitable for this in parts of the Netherlands (if client devices would become available in the coming years), however, current Dutch spectrum policy does not facilitate (local) spectrum under the right conditions for Schiphol to implement such a solution since licence duration is limited to 7 years.

3.1.3 Summary Schiphol Airport

Wireless applications

The directly flight specific applications are generally highly regulated and uses specific internationally standardised frequency bands. A large part of dedicated flight related applications uses dedicated frequency bands, but some applications use shared frequency bands or public mobile networks.

Trends

Increasing use of wireless connections for data transport. Increasing use of Wi-Fi and public mobile networks for flight related applications. Increasing use of (public) Wi-Fi by passengers. Increased need for dedicated spectrum for high availability data networks like private LTE.

Stakeholders

Stakeholders that can be distinguished at Schiphol Airport: the airport organisation itself, airlines, airside service providers, other companies not directly connected to air travel, and government authorities. A stakeholder analysis of international airports is described in paragraph 7.2.

Vulnerabilities

Flight supporting services and application more and more rely on mobile data connections. For this, often Wi-Fi is used but this is not ideal: Usage for business grows, and at the same time the use among the general public has massively increased in the last ten years. In the long term it is very important for Schiphol Airport to maintain a front position in optimising efficiency and quality and to support and facilitate innovation and progress in all services a

[15] At this stage they might be able to use LTE in part of the 3.6-3.8 GHz band but licences can be obtained for 7 years only which is deemed too short for Schiphol.

major Airport should provide. Availability and reliability of cost efficient broadband data connections for the companies are related to the primary processes at Schiphol Airport become more and more important for Schiphol.

Possible countermeasures

There is a need felt for more locally allocable radio spectrum that is not shared by passengers or visitors but can be used for flight related (data) services. Preferably such radio spectrum bands have to be allocated in such a way that it is dedicated for a certain location area and restricted to a specific user group, but usable for 'state of the art' communication equipment.

3.2 Technology and spectrum use in airports

At major international airports (like Schiphol) a wide variety of radio frequency bands, technology and standards is used in a relatively small area. Many of the used systems and protocols enable multi-purpose use, such as Wi-Fi (802.11), Bluetooth, Public Mobile networks (GSM/UMTS/LTE), Personal Mobile Radio and Trunked Radio Systems (including TETRA, P2000, C2000) and microwave point to point connections. Others are more specific, such as aviation radio beacons, specific aviation radio systems and RFID tagging. This investigation focuses on frequency bands that are not specifically dedicated to a special use or user.

For Air Traffic Management and flight-specific applications for air traffic control, air traffic management, and applications that are responsible for taking off and landing the aircrafts international standardised frequencies are used. This includes use of (common) spectrum like the internationally standardised 'airband'[16] (108-137 MHz VHF radio spectrum), of which a part (118–136.975 MHz) is used for radio communication with air traffic control, and the lower 10 MHz is reserved for navigational aids and precision approach systems like 'VHF Omni Directional Radio Range navigation' (VOR) beacons and the 'Instrument Landing Systems' (ILS) localisers (radio transmitter that provide direction for an aircraft approaching a runway). ILS uses (a.o.) the UHF frequency range of 329.3–335.0 MHz to indicate the glide path, the ideal slope towards the runway[17].

Flight specific applications are managed in international laws and regulation. International airports are members of IATA, which is a United Nation organisation responsible for arrangements to use spectrum and space for aircrafts. The IATA is just one of the international organisations that are working at this level. Aircrafts and international mainports are a high security concern, and risk management is an important aspect for airports and airlines, and governments make sure that spectrum use at that level is reserved for a limited user group and secured for interference.

[16] http://en.wikipedia.org/wiki/Airband

[17] A variety of other navigational aids use radio, like the MLS (5031 to 5091 MHz), beacon transponders for range and distance measurements (962 to 1105 MHz), and the Transponder Landing System (TLS) (1030 to 1090 MHz).

3.3 Risks, vulnerabilities and areas of concern

The fact that airports primarily focus on operating and flying airplanes, but also act as very busy 'hubs' on a small area make that the challenges related to wireless networks at airports can be specifically severe.

The primary services related to for example communication between traffic control and airplanes use specifically allocated frequency bands in which they have protection against interference.

However, shared spectrum and Wi-Fi is used for many of the supporting processes. Those supporting processes and the general economic activity around an airport are of importance for the position of an airport from a global point of view. There is a fierce competition between those 'hubs', and for an airport to keep being attractive for business travellers and to stay or become a major hub, those 'secondary applications' are of vital importance.

Large airports are often aware of the dependency on spectrum. For example Schiphol Airport performed an analysis and found that of the top ten risks three were directly related to wireless communication and radio spectrum use[18] related to Airside systems), PMR (Wireless connections Personal Mobile Radio, and Mobile telephony and data, and Schiphol has a department "Schiphol Ether Control" for spectrum management and contact with spectrum users and government, indicating they take the challenges related to spectrum very seriously.

Schiphol would prefer spectrum to be freed for flight related applications with the possibilities of local licenses for Schiphol (and at other locations for other industries or organisations) to allow them to build a radio network infrastructure that optimally fits their needs. License condition should be such that the spectrum can be used for at least 10-15 years.

GPS jamming is reported to be an increasing problem worldwide[19] for systems using GPS for accurate location or timing. Although no immediate threats where observed in this research, it might become an issue for some applications in the future and it is something that might require attention.

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[18] www.rijksoverheid.nl/bestanden/documenten-en-publicaties/vergaderstukken/2012/09/12/presentatie-schiphol-en-radiofrequenties/presentatie-schiphol-en-radiofrequenties.pdf

[19] See http://www.exelisinc.com/solutions/signalsentry/Documents/ThreatOfGPSJamming_February2014.pdf and http://www.commercialmotor.com/latest-news/use-of-gps-jamming-on-the-increase-warns-firm

4 Transport and Logistics in Ports

Transport and transhipment at large seaports are of major importance in the current world where products are produced anywhere and shipped to customers in Europe, or produced on mainland Europe and exported elsewhere.

A wide range of communication networks and tools is used in transport and shipping. Traditionally communication between ships and between ships and coastal services use Marine VHF radio (Marifoon). Both dockworkers and shipboard personnel require communication, preferably using standards-based ruggedized clients. On industrial plants in ports a variety of PMR systems is used for (on-site) communication between personnel. Wi-Fi or other data communication networks are used to exchange data, for example like work orders for the unload freight or for wall-ship communication.

The resources and players like ships, trucks, freight trains, people and containers form a complex system, and in recent years modern technologies have helped to increase the efficiency of the complex logistic processes that are involved. Examples are diversification of shipped material and goods, and unification of transport logistics and transport systems. Combined with technology advancements this has led to developments such as autonomous vehicles transporting containers around the terminal, automated warehouses, and extensive use of tracking, tracing of goods and use of sensor technology.

4.1 Case: A container port terminal

For this case information with regard to the use of wireless applications in a number of container port terminals from interviews and public information is generalized.

4.1.1 Applications

Container handling using Automatic Guided Vehicles

In the early 1990's Rotterdam introduced the world's very first automated container terminal, attracting visitors from all around the world to marvel at a terminal where unmanned Automated Guided Vehicles (AGVs) transported the containers across the quay. For communication an – at that time – 802.11 protocol was chosen in the - at that time - almost unused 2.4 GHz band: a protocol that would later become successful as Wi-Fi.

Robust radio technology with non-line of sight capabilities are essential because of the dynamically changing circumstances with regard to reflection of radio signals due to varying configurations of piles of metal containers, trucks and ships. Around 1990 emerging Wi-Fi standards and related (almost unused) frequency bands were an attractive combination for this innovative application, using a Wi-Fi-based protocol in the 2.4 GHz band with propriety 'add-ons'[20]. In Rotterdam ECT uses Breezecom[21], operating in the 2.4 GHz ISM band.

[20] such as the Siemens AGV-solution http://www.industry.usa.siemens.com/automation/us/en/industrial-communications/wireless-control/pages/automated-guided-vehicles.aspx and Motorola's industrial MEA MESH solution

From interviews and from literature it became clear that effective use of radio spectrum in container terminals is complicated: coverage needs to be such that even in between containers the network can be reached. In Rotterdam operational activities are moving towards more ´data/hungry´ applications, like adding video streams to AGV´s and cranes to further enable efficiency and remote control of operations, meaning more bandwidth is needed with an increased certainty of availability.

This innovative leadership in combination with long life span of equipment in ports and terminals pose some other challenges: protocol versions used are not compatible with nowadays' (802.11) Wi-Fi technology and the used frequency band has to be shared with growing amounts of Wi-Fi use by employees, truck drivers and ship personnel on or in the near vicinity of the container terminal. The frequency band (2.4 GHz) was originally at this portside location used solely for AGV communication. But in 15 years of use other users were allowed to be active, and now this 2.4 GHz band is under increased pressure due to the immense success of wireless internet access in homes and all kinds of devices.

An increase in interference and problems with the communication network is observed, and for the continued and undisturbed operation of the AGV's, and to achieve an increased efficiency in container handling (and freight) in general both effects poses a challenge for the future. From interviews it became clear that terminals in Rotterdam are looking for other (wireless) solutions, like private LTE, in which they have control over the network-implementation and where they can obtain a higher level of certainty of use of the spectrum.

Operations communication

Container terminals in Rotterdam use dedicated PMR channels for voice communication of personnel, in some cases specifically licensed to the terminal company, in other cases using a PMR service provider such as Entropia. Entropia provides voice and 'Push to talk' services on their network for the container-terminals for communication between crane operators and ground personnel on the terminal.

Data communication by visitors

More and more trucks and mooring ships use local wireless communication Wi-Fi networks that move around as the trucks and ships move, partly using the same radio bands as data communication for Automated Guided Vehicles that move around containers.

4.1.2 Organisation and awareness

The container terminals that were part of this research aim to improve efficiency and lower costs by well thought through introduction of technological innovations. The Life cycle of equipment used is generally 10 to 15 years. For innovations such as communication with Automated Guided Vehicles state of the art technology and pre-standards were sometimes used in almost empty frequency bands that are now widely used by several other parties. A desire is expressed to be able to use licensed or unlicensed location specific frequency bands for this kind of industrial innovations that become essential for primary logistic processes.

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http://solcomm.com.au/wp-content/uploads/2010/08/container-ports-market1.pdf ,
http://www.porttechnology.org/images/uploads/technical_papers/068-070.pdf

[21] http://www.vdcinfo.nl/content.php?&contentid=28

4.1.3 Summary Container Port Terminal

Wireless applications

Automation of transshipment processes involves more and more wireless data communication, for instance for controlling Automatic Guided Vehicles. Shared frequency bands or public mobile networks are used, but special care is needed to avoid non line of sight problems and robust and reliable operation in a rugged and radio wave-unfriendly industrial environment. PMR is used for operational voice communication. Other users on or in the vicinity of the terminal area use private data connections using their own Wi-Fi access points on visiting trucks, ships etc.

Trends

More automation, autonomous equipment and intelligent processes that interact with wireless data connections. Growing wireless data communication using shared frequency bands by visitors (truck drivers, ship personnel) and growing use of wireless data communication for several operational and business processes.

Stakeholders

Stakeholders that be distinguished at the container port terminal: The terminal company, port authorities, government, shipping companies, manufacturers of moving equipment, providers of communication solutions, truck drivers. For this case no stakeholder analysis is carried out.

Vulnerabilities

Frequency use of secondary users affects reliability and continuity of business processes. Innovation becomes difficult because long term reliability of used radio spectrum cannot be guaranteed.

Possible countermeasures

There is a need felt for more allocable radio spectrum that is not shared by visitors (and is guaranteed not to be used by others in the future) but can be locally used for specific industrial innovations (for example dedicated spectrum for wireless industrial applications in 5.725-5.875 GHz or private LTE spectrum in 3.6-3.8 GHz). Preferably such radio spectrum bands have to be allocated in such a way that it is dedicated for a certain location area and restricted to a specific user group, but usable for ‘state of the art’ communication equipment.

4.2 Other wireless spectrum applications in ports

4.2.1 Port authorities

Port operations and logistics require the exchange of voice and data between ships and port operations, pilot boats and control centres, shipping companies, terminal sites, etc. A large part of this communication is wireless and uses specific dedicated an internationally standardised frequency bands, for example Marine VHF radio using a radio frequency range 156.0 and 162.025 MHz.

4.2.2 Internet Access for ships in ports

To increase efficiency of shipping and port operations reliable data communication is needed for ships and docks to increase the availability of accurate (near)real-time information like information about arrival times and unloading and loading 'appointments'. Skippers need communication to react to 'new' cargo opportunities and to allow optimal allocation of ships to opportunities.

More and more of this communication is digital communication using email and modern applications and websites. For this, often mobile internet of public providers is used. The disadvantages are the cost (compared to a 'fixed' office DSL connection) and coverage along the rivers. To tackle this, there are a number of solutions under consideration. Harbours offer wireless internet via Wi-Fi[22] or WiMAX[23] for mooring ships and for other operators in the harbour and private LTE networks are considered as local solutions[24], either as 'backhaul' network in harbours or for direct connections to clients. The Dutch government initiative IDVV (Impuls Dynamisch Verkeersmanagement Vaarwegen)[25] aims to increase the availability of (wireless) internet along the waterways by stimulating the creation of Wi-Fi hotspots at mooring points and the availability of (public) LTE internet along the Dutch waterways.

ECC and ETSI are working on a proposal for dedicating spectrum in the 5725-5875 MHz range specifically for wireless industrial applications that is not being shared with Wi-Fi. Such dedicated spectrum can provide a solution for the interference problems in for example the 2.4 GHz band (if this band is kept free from interference), and, although it is shared with others, these others are industrial applications too so coordination can take place at a local level by 'spectrum managers' of those locally active parties.

4.3 Technology and spectrum use

A variety of technologies and spectrum are used in ports and their surrounding industries.

802.11-based solutions play a role in many industrial processes, but the increased strain on the 2.4 GHz band makes companies look for a new future proof solution that can give them a solution specifically fit for their purpose and if possibly using spectrum in which a certain degree of protection against interference can be obtained.

Also public GSM/GPRS or LTE data-connections are used, but often these networks do not meet the standards needed to operate in an industrial environment where high availability and coverage is needed, also in between ships and behind containers.

Private networks (like LTE networks) are considered since those might allow users to be 'in control' over both spectrum (to decrease interference) and the network implementation (for increased availability and to be able to achieve a high degree of coverage using a dedicated network planning for each site). The availability of equipment plays a role when considering

[22] http://www.omroepzeeland.nl/nieuws/2013-11-29/578789/wifi-netwerk-voor-binnenvaart-havens
[23] "Wireless Waterways Pittsburgh", http://www.port.pittsburgh.pa.us/index.aspx?page=210
[24] http://enterprise.huawei.com/en/solutions/trade/transportation/port/hw-198599.htm
[25] http://www.rijkswaterstaat.nl/zakelijk/verkeersmanagement/idvv/

private LTE networks: availability of equipment is high in bands where the large ‘public’ operators worldwide obtain spectrum and offer services, but this spectrum cannot be used for private networks (since it is licensed to operators). Use of the 3.5 GHz spectrum is considered for private LTE since equipment is becoming available, if it can be obtained under the right conditions (like being able to obtain the needed protection against interference and a long enough lasting license) [1].

4.4 Risks, vulnerabilities and areas of concern

Critical, nautical specific communication uses dedicated frequency bands, robust systems and well thought-out procedures. For many of the processes surrounding ports and waterways more general communication means are used, such as PMR, using dedicated radio spectrum and public mobile networks for voice and data communication with ‘non-nautical’ users.

Also regular mobile services (like GSM/GPRS and LTE) are used. However mobile network coverage of parts of the waterways, such as coastal waters, larger lakes, and rivers in rural areas is not everywhere sufficient, and mobile data usage can be costly when large amounts of data are sent or received regularly. There are initiatives to provide Wi-Fi connectivity at ports and around bridges and locks to provide better data connectivity for lower prices to inland shipping businesses.

For new innovative and specific applications in ports, such as control of Automatic Guided Vehicles that move around containers, the generic license exempt spectrum in the 2.4 ISM band proved to be a good communication means and was almost unused at the time that these applications were developed. However, as noted, the increased use of this band by more applications and users, including industrial applications in the transport sector such as truck drivers and personnel on mooring ships is evident.

Spectrum sharing between Wi-Fi and wireless industrial applications poses a challenge and parties are looking for ‘specific’ dedicated spectrum that can be used locally to ensure continued operation of critical wireless communication. Assigning a person to the role of ‘spectrum manager’ and having centralised coordination in a company or in a harbour area can further increase awareness about solutions, can help prevent (or at least coordinate) interference at a local level and can act as a counterpart for the Dutch Telecommunications agency in discussions about spectrum use.

5 ITS and the connected vehicle

Information technology has entered the cars and highways in the past twenty years, with dynamic traffic information above the road (“matrix signs”) and offline navigation systems (now common in most cars). More recently, information is provided to vehicles in a more dynamic, real-time way, and even experiments using “autonomous cars” are deployed. The future that is envisioned consist of ‘connected vehicles’ that use various means of communication to get (slow-changing) traffic information using GPRS or radio (RDS) to automatically inform a navigation system of delays to allow it to calculate an alternative route, and get real-time information that influences decisions made in (and by) the car in an autonomous fashion. However, initial focus of the EU ITS directive[26] (and of the Dutch ITS plan based on this directive [6]) is on providing better traffic and warning information and the introduction of e-Call.

ITS developments are mainly still in design and ‘pilot’ phases, so no ‘definite’ cases can be identified. In the next paragraph, we will focus on 1) the ITS “collaborative driving” developments, and 2) on the upcoming e-Call application.

5.1 Case: ITS Developments and Cooperative Mobility

“Cooperative Mobility” or ‘Cooperative Intelligent Transport Systems’ aim to influence the behaviour of a vehicle based on real-time information provided by nearby vehicles directly (Vehicle-to-Vehicle information, or V2V), or via Road Infrastructure (Infrastructure-to-vehicle information, or I2V), see Figure 3.

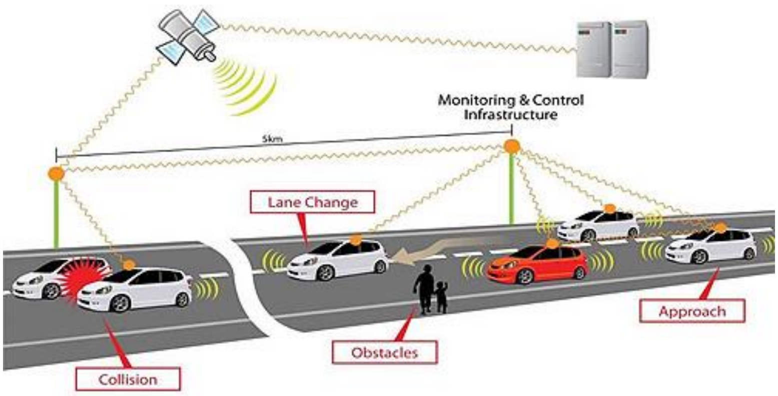

Figure 3: Illustration of envisioned safety scenarios, where cars communicate both with each other (V2V) and with roadside infrastructure (I2V) [27]

[26] http://ec.europa.eu/transport/themes/its/road/action_plan/
[27] http://www.goauto.com.au/mellor/mellor.nsf/story2/07EC51D606FC8C86CA25791A0006D3CA

In the following paragraph trends and developments in "ITS collaborative driving" are described (5.1.1) and in paragraph 5.1.2 status and development of E-Call are described.

5.1.1 ITS Application developments

Proposed ITS functions[28] range from 'Adaptive or Collaborative Cruise Control' and 'obstacle detection and can somewhat artificially be divided in those that are 'Traffic information' related, those that allow for automated collaborative driving, and those that are directly 'Safety related'. Active industry players in the Netherlands are for example NXP as chip developer for ITS systems and Nedap for identification systems, toll collection systems etc.

ITS Real-time Traffic information

One (and possible the first) goal of the ITS effort is to increase traffic efficiency through availability of better and more 'real time' traffic information[29], and includes presenting drivers with optimal (in-vehicle) information and advice about signage and speed limit, "Green Light Optimised Speed Advisory" information, and information and warnings for Road works and traffic jams on your route.

Those services increase the possibilities for drivers, aided by navigation systems, to take current traffic situation into account when calculating and deciding on alternative routes. This primarily aims at decreasing the drivers travel time by choosing an optimal route per vehicle. In the future if the information reaches enough vehicles and decision involving multiple vehicles are made 'in a smart and collaborative way' the overall traffic pressure can be further reduced[30].

No definite business model is decided on. Traffic information service providers like TomTom and Garmin show there is a market for good and accurate traffic information, and EC and Dutch government leave the business models and implementation to the market parties. ITS-systems can further enhance the availability of real-time traffic information, and those commercial parties can offer services using this information. Traffic information service providers can choose an implementation form and at this stage providers choose to use the existing GPRS /LTE networks, because of the omni presence of those networks throughout Europe and since it is at the moment the only effective way of distributing individual data to cars.

ITS Collaborative driving

ITS automated driving applications aim at locally increasing *traffic efficiency* (adaptive cruise-control is proposed to increase the effective utilisation of a road by coordinating speeds with cars up to tens of meters or more in-front and behind a vehicle) and at increasing *safety* in case of emergencies (i.e. a sudden stop of a vehicle in front of you triggering the brakes automatically and warning cars behind you at the same time).

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[28] See for example http://www.drive-c2x.eu/use-cases, ETSI-TR 102638 (2009-06) http://www.etsi.org/deliver/etsi_tr/102600_102699/102638/01.01.01_60/tr_102638v010101p.pdf and http://www.etsi.org/index.php/technologies-clusters/technologies/intelligent-transport/dsrc

[29] Traffic information is now distributed to cars using 'legacy' Radio Data System (RDS), and (since around 2008) also using 'connected' navigation like Tom-tom's and Garmin's Live Traffic.

[30] Note that sometimes the optimal alternative route for a driver is not the optimal route for traffic as a whole.

Collaborative driving consists of connected and adaptive cruise control, in which cars adjust their cruise control speed setting automatically based on not only on the car in front (this already exists in high-end cars using radar distance measurements) but also based on detailed information about the upcoming traffic situation and the cars somewhat further away. More safety related collaborative driving involves applications like digital emergency electronic brake lights and automatic breaks in case of an accident in front. Those applications bring a challenge both technically and legally in terms of responsibility and laws (who is responsible if a car suddenly 'breaks' automatically, based on traffic information it received from other cars?). From interviews it became clear that those kinds of applications are still a long way of, mainly due to those kind of considerations and because 'automated driving' remains a more sensitive subject than just providing better traffic information.

Trusted and standardised communication for collaborative driving

A standardised and trusted way of communication between vehicles is needed. In Europe spectrum is reserved for applications requiring vehicle-to-vehicle or vehicle-to-infrastructure communication and most likely will use the ETSI standardised 5.9 GHz ITS band (5.855-5.925, see 5.4.3) based on 802.11p/Wave.

Although standardisation efforts are ongoing, it became clear that the communication means on a higher OSI-level is not yet standardised in such a way that implementation and interworking are ready.

From an interview and from the status of the ITS standardisation efforts it becomes clear that further standardisation efforts need to be made. No fully standardised and secure method for collaborative driving is ready for EU wide implementation, and security implications need to be very well thought through in defining the ITS standards before ITS collaborative driving is ready for EU wide implementation.

However, industry and car manufacturers at this stage feel no urgency for this and focus on the 'easier' goal of providing better traffic information and other in-car services, and demand for such a system from drivers is not or barely present.

NXP indicates that the standardisation efforts spectrum-wise are largely successful, and spectrum issues are addressed at the right level. However, it became clear from literature and interviews that there is concern about proposals to share this spectrum with the 5 GHz Wi-Fi-band[31] and this requires attention to prevent any unwanted disturbances, since it is likely that coexistence with Wi-Fi will cause problems, and both industry and governmental parties should be aware of the dangers of sharing spectrum for safety applications with other types of use (like 'generic' Wi-Fi').

Organisation and awareness concerning ITS and vehicle applications

Although some of the possible applications are defined by for example ETSI, there is no driving organisation.

For many of the "better traffic information" related applications this might not be a bottleneck for implementation: The information needed is of a "near real time" nature and

[31] http://www.itsinternational.com/sections/nafta/features/need-to-analyse-risks-of-59ghz-spectrum-sharing/

can be transmitted using a variety of communication-solutions, including GPRS/LTE or the "ITS" spectrum bands. Better traffic information can come in a variety of ways and can be implemented in existing navigation systems in a natural way. People are prepared to pay (at least to some extend) for better traffic information.

For the "real time" applications related to safety and "collaborative driving" this is different: In order for ITS to be successful in terms of collaborative driving standardisation (of at least those applications) at an application level is vital since at least a large part of vehicles should be able to communicate with each other. At this stage no decisions or standardisations about those applications are finalised.

During interviews it became clear that there is a general notion (for example with the EC) that standardisation is needed, but the efforts to do this are designated to the market. Although this might be all right, neither the market (at this stage) nor the drivers feel any urgency for those applications to be implemented in the coming years, and drivers do not appear to be ready to pay for them.

Some parties argue that stronger governmental obligations for implementation, including an obligation for standardisation, helps to speed up introduction of ITS, certainly for applications where all types and brands of cars should be able to communicate with each other.

5.1.2 E-Call

Automated Emergency Call - or 'e-Call'- facilities are a proposed European Union system in which cars will – in case of a calamity – automatically warn an emergency call center, anywhere in the European Union, in a standardised way to ensure interoperability across the EU [15].

The 'emergency call' takes place within seconds after a collision takes places and contains coordinates of the vehicle, making sure emergency services go to the right location immediately and saving precious time compared to regular 112-calls and conversations[32]. Additional information like direction of travel and vehicle identification is sent, and could be extended with magnitude of the impact (by measuring acceleration/deceleration to allow for estimation of the severity of the accident), and number of people in the car (allowing for the right amount of personnel or ambulances to be dispatched).

Car manufacturers have a large amount of freedom in determining the exact implementation of e-call. For connectivity most car manufacturers consider the use of (or are using) public phone networks like GSM/GPRS or UMTS networks of the mobile operators to provide data communication with the car. BMW[33] already offers 'BMW assist Advanced E-call' in which BMW's involved in accidents use (at least for some of their cars) Vodafone M2M mobile subscriptions to provide information about accidents or emergencies to a BMW call-centre.

[32] Some parties claim a reduction of up to 40 or 50% in response time, http://www.heero-pilot.eu/view/en/media/news/20130114.html, *"Getting immediate information about an accident and pinpointing the exact location of the crash site cut emergency services' response time by 50% in rural and 40% in urban areas."*.

[33] http://www.euroncap.com/rewards/bmw_assist_advanced_ecall.aspx

Volkswagen and Audi use the Europe wide Vodafone[34] network for connecting their cars and plan on implementing similar e-call and emergency call-centre facilities.

The EC currently aims for the system to be implemented by (approximately) 2017 in new cars on European Roads[35] (earlier plans stated 2015 as implementation date).

Organisation and awareness concerning E-Call

Introduction of e-call is (or is to become) mandatory in new cars sold in the EU. The way e-call is implemented is left to the market players, and a variety of views on this exists, which means the system will (most likely) not be uniform. However, as long as a number of basic requirements are met this is not necessarily a problem and e-call could be implemented without complete standardisation of the system, since no real-time car to car communication or actions are needed.

5.1.3 Summary ITS developments and E-Call

Wireless applications

Intelligent Transport Systems is a label for an umbrella of applications that are generally still in the research and development phase. Application categories include active road safety (such as driving assistance, cooperative awareness, road hazard warning), cooperative traffic efficiency (speed management, cooperative navigation), cooperative local (location based) services and global internet services.

E-Call is a more concrete and specific application that enables cars to automatically warn an emergency call-centre. Although its functionality is standardised, the implementation of the wireless communication that is used is not.

Trends

Several EC research project have been carried out as part of ITS development, and there is standardisation effort ongoing for the European wide allocation of frequency bands for ITS application classes with different availability and robustness requirements (see paragraph 5.4.3). Manufacturers claim that ETSI-ITS and IEEE 802.11p rapidly become mature and usable for implementation. Definitive ITS standardisation is ongoing but not completed. E-Call legislation is expected.

Stakeholders

Several stakeholders are involved in E-Call: drivers, the EC, car manufacturers, telecom service providers and emergency services. A brief indicative stakeholder analysis of this case is given in paragraph 7.3.

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[34] http://telecoms.com/230372/vodafone-signs-connected-car-deals-with-vw-and-audi/
[35] http://ec.europa.eu/digital-agenda/en/ecall-time-saved-lives-saved

Vulnerabilities

If part of critical applications for ITS use radio bands that are allocated for general use now or in the future this may cause problems, and good care is needed to ensure no security, availability and privacy issues occur when the applications are introduced on a large scale.

Possible countermeasures

Robustness of critical application can be solved at many functional levels. If availability of capacity of a specific radio spectrum band is essential than special care is needed in spectrum allocation, definition of robust and secure transport protocols and enforcement measures.

5.2 Other examples of Transport Applications

5.2.1 Real time traffic information in general

The increased availability in real time traffic information, first using matrix signs and DRIPS above the roads and Radio Data System (RDS), and since around 2008 using 'connected' navigation like Tom-tom's and Garmin's Live Traffic services increase the possibilities for drivers, aided by navigation systems, to take current traffic situation into account when calculating and deciding on alternative routes.

This primarily aims at decreasing the drivers travel time by choosing an optimal route per vehicle, while in the future if the information reaches enough vehicles the traffic as a whole can be further optimised.

5.2.2 Automated road tolling

Many of the toll roads now offer the possibility of automated payment of the fee using an RF DSRC-tag connected to the front window of the car that is read-out on (low speed) passing of the portals. This increase travel-time, reduces congestion at the 'toll stations' during peak hours, and reduces the 'hassle' for both driver (having to pay in cash or using a bank card) and for the toll-operator. Automatic toll collection is used at toll-roads in countries like in Portugal, Austria and France [7].

5.3 Trends and Future applications

In order for ITS to be successful in terms of collaborative driving standardisation (of at least those applications) at an application level is vital since at least a large part of vehicles should be able to communicate with each other. At this stage no decisions or standardisations about those applications are finalised. For better traffic information this does not need to be a problem since the various providers choose their own implementation.

However, for collaborative driving applications a standardised and secure car-2-car communication systems needs to be developed. It is to be expected that these kinds of applications will take years to be implemented in a standard way.

5.4 Technology and spectrum use

5.4.1 802.11 p-Wave

Vehicle-to-vehicle and infrastructure-to-vehicle communications poses high demand on the used technology because of the need to share information between a 'random' set of cars, meeting on roads and moving at high speeds (with regard to the infrastructure and to other vehicles). The communication needs to be fast (i.e. the communication channel needs to have a low latency). For use in ITS standardisation efforts of IEEE and ETSI have focused on proposing 802.11p/WAVE, a set of communication protocols based on 802.11 (see Figure 4), and some field-tests have been carried out [8].

WAVE is based on 802.11a Wi-Fi standard and designed for use in the 5.9 ITS-band, specifically adapted for the low latency, high client velocity demands that are posed by use for ITS. WAVE was also considered for dedicated short range communications (DSRC).

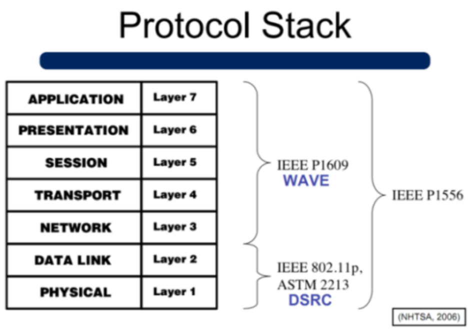

Figure 4 : 802.11p/WAVE communication stack

5.4.2 Public telecommunication networks

For a number of applications, including non-time critical applications like sending traffic information, public telecommunication networks like GPRS and in the future LTE can be used.

These applications depend on the availability of those public telecommunication services, and thus on the spectrum. But since this is licenced to the telecom operators for a long duration discussions about coverage and availability can take place at a higher level than at the physical spectrum level.

However, specific arrangements should be made, since e-Call connections should come through especially in case of an emergency, and should be treated like 112-emergency calls (i.e. any network can be used, even if the preferred network on the SIM is not available, etcetera).

5.4.3 Spectrum

Spectrum for road tolling: 5,795-5.815 GHz

The 5,795-5.815 spectrum is standardised and in use for automatic toll collection at toll-roads in Portugal, Austria and France.

Spectrum for ITS: 5.855-5.925 GHz

For short-range direct contact between vehicles and between a vehicle and roadside infrastructure 5.855 – 5.925 GHz spectrum for ITS in the 5 GHz range is proposed.

In Europe 5.875 – 5.925 GHz is reserved for ITS road safety applications [11]. To be able to differentiate for the importance of the communication the lower 30 MHz of this part (the upper 20 MHz is reserved for future extensions) is divided into 3 channels [12] of 10 MHz. Channel 1 is used for 'safety and efficiency messages' (optimised for high throughput, safety messages with medium priority, using multiple hops between cars). Channel 2 is a service channel used mainly between vehicles and roadside stations (optimised for peer-to-peer communication). Channel 3 is a control channel and can be used for time critical messages.

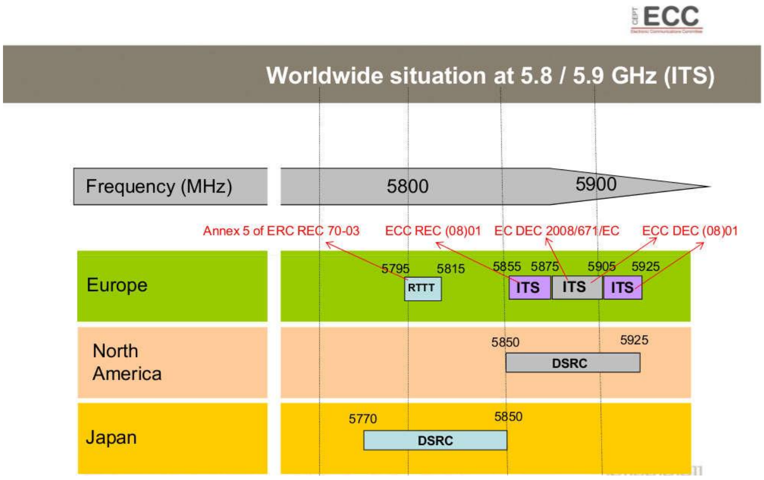

Figure 5: Spectrum allocation for ITS applications in various parts of the world (source ECC [10])

There are proposals to share this spectrum with the 5 GHz Wi-Fi band[36], which requires attention to prevent any unwanted disturbances. Mechanisms similar to Dynamic Frequency Selection is proposed[13], but questions remain about the viability of such a system[14]. If the 'back-off' mechanism is not 'strict' enough, there might still be risk of interference, while on the other hand stringent restriction make the spectrum less favourable for Wi-Fi use (for example, there are indications that some manufacturers might not support those channels with strict DFS-obligations[37], although this might change if scarcity increases).

In Australia possible interference of ITS communications in the 5.9 GHz spectrum with satellite communication by Fixed Satellite Systems (FSS) ground stations was investigated[9]. Requirements such as proper angles for satellite dishes are sufficient for coexistence of FSS and ITS spectrum use outside a contour of 1km around such ground stations.

[36] http://www.itsinternational.com/sections/nafta/features/need-to-analyse-risks-of-59ghz-spectrum-sharing/
[37] http://www.networkcomputing.com/wireless-infrastructure/dynamic-frequency-selection-part-3-the-channel-dilemma/a/d-id/1234489?

6 Wireless technologies and radio spectrum

Wireless communication and radio spectrum are used in applications related to transport and logistic systems and operation as can be seen in chapters 2 to 5.

In this chapter the approaches to the use of radio spectrum are described and organisational choices and considerations, decisions regarding technology and spectrum use. Also additional observations and complications are described. More on the types of communication technologies used in Transport and Logistics can be found in Annex A.

6.1 Spectrum for Transport and Logistics

Although the question of what *technology* and what *spectrum* to use are technically speaking separate issues, in practice there is a direct link between the two, since equipment is available for specific technologies in specific bands (for example LTE equipment for 800 MHz), although this 'link' gets weaker with the advent of 'single-ran' and 'multipurpose' network solutions and software defined radio.

We can (a bit artificially) distinguish the following types of spectrum: a) Licence exempt, generic used spectrum (like the 2.4 GHz ISM band) and licence exempt / unlicensed spectrum for specific application, b) nationwide licenced spectrum for generic use (like the spectrum used for GPRS and LTE public networks), and c) licensed spectrum for specific parties, companies, or organisation (with local permits and conditions).

Licence exempt spectrum

The licence exempt 'generic' spectrum is for example the 2.4 GHz and 5 GHz band ISM bands, generally used for Wi-Fi, Zigbee, and other applications. Applications in transport use this spectrum, usually for applications that are not 'critical' in a sense that the spectrum is directly safety-related. However, many logistic processes, varying from connecting vehicles in container-terminals, to Metro-trains, depend on the availability of this spectrum. The increased use of these bands poses a challenge for those applications, as is indicated by the parties depending on those processes.

Spectrum licenced for public networks

This spectrum consists of the various bands (800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz) used by the five public GSM/GPRS, UMTS and LTE service providers (and by other MVNO's, which use the networks of one of the service providers). Transport applications often use those public mobile services for convenience and because of the omnipresence of those networks.

Licensed spectrum for local or specific usage

Another form of licensing is spectrum for local use by specific parties, companies, or organisation (as is possible with local permits in the 3.6-3.8 GHz band[38]). For stakeholders in the Transport and Logistics sector locally licenced spectrum gives the opportunity to obtain

[38] This spectrum cannot be used in the North of the Netherlands (roughly above Amsterdam-Zwolle)

full control over network implementation (to allow for high availability and to optimise network parameters like radio-planning and latency) and to obtain protection from interference and congestion caused by other users. Preferably, spectrum is used in a band in which equipment is readily available, for example a band in which LTE can be used.

Making spectrum available for local applications can be a good idea and could solve some of the issues experienced by local authorities and industries. Care should be taken that the spectrum is used efficiently and fragmentation is prevented, for example by requiring that the requesting party makes a detailed analysis of the spectrum needed. Also an obligation for usage of the spectrum could be set, initial provided spectrum should be periodically reviewed so that the spectrum keeps being used efficiently, and there should be sufficient incentives (or obligations) to return (part of) the spectrum if that is not the case.

6.1.1 Variants and innovations

Variations of the above mentioned types of spectrum are possible, such as sublicensing of spectrum not used by the primary license holder, local use of white spaces between frequency bands, or cognitive radio solutions where devices dynamically choose 'free' radio spectrum to communicate [18][19]. These types of innovative radio spectrum use are still in a research and pilot stadium and may need changes in spectrum governance to be successful [20], but may be an interesting option for some (non-critical) transport and logistics applications in the future.

6.2 Organisational considerations regarding technology and spectrum choices

From the cases we see that organisations make choices about technology platforms and radio spectrum to be used for applications based on a wide variety of reasons: existing (industry) standards, regulation, availability, costs, robustness, life span needed, etcetera.

From the interviews related to the various cases it became clear that sometimes choice about technology and spectrum is made based on an 'ad-hoc' basis, for example because it is available, cheap, or easy, and sometimes there is no overall strategy within an organisation about what technology to use in what case. Next to this, industrial systems (in harbours, cities and on airports) have lifespans of 15 years, and therefore it is obvious that legacy systems exist in such environments that cannot be easily 'switched' to more modern telecommunication systems.

This brings additional costs since a central thought-through approach to data-communication might be more beneficial than each department ordering 'a few lines' or 'a few sims' as need comes by.

In addition, this brings risks since usually not all departments have enough knowledge to make a well informed decision, while a more central approach to telecom allows companies or sectors to share information, and make decision based on specific telecom knowledge and 'lessons learned.

Large organisations, like Schiphol Airport (with a dedicated telecom provider and a department 'ether control') or large municipalities, are well aware of the spectrum challenges and questions related to those choices, but even then no ‘one size fits all’ solution might be obvious. In the cases that involve currently deployed systems (Amsterdam, Schiphol Airport, and in the case of the container terminals in ports) parties currently consider using private LTE networks (for example in the 3.6 GHz range) or (private) Wi-Fi networks in the 5 GHz.

In some cases public operators are willing to provide dedicated network services with specific tailor made network planning as a solution. However, this usually means a vendor lock-in since the (high) initial cost of a dedicated network are made upfront, but are tailor-made for the spectrum of the operator, making it hard to switch operators later on. A worry here is that the timespan of operators aims mainly at consumers (1-3 years) or at companies using ‘regular’ telecom services (with contract times of maybe up to five years), which is too short for dedicated industrial applications that are implemented for 10 years or more.

6.3 Observations and complications

6.3.1 Standardisation and innovation

A large variety of devices and software, implementing functionality at various levels of the OSI network-model, is used for transport applications. The life span of transport applications and equipment is generally much longer than the lifespan of the applications used in the more fast moving consumer market: consumers renew (smart) phones on average every 2 to 4 years, wanting to use the newest technology like LTE for faster connections, while machine-to-machine and other industrial applications are implemented for timescales of a minimum of 5 to 8 years and often longer.

Historically grown ecosystems often combine several functional layers, and due to such legacy applications incompatible standards and ‘technology islands’ are in use in the transport sector at present. A slow trend can be seen towards standardisation of applications on IP (Internet Protocol) based networks so that those applications can function independent of the underlying physical technology.

For certain applications, standardisation at an application level is key for success. For example, for ‘cooperative driving’ and ITS cars need to be able to communicate with each other, and a set of specific standardised communication means is needed.

Innovation of applications and technology platforms

Innovation at a functional layer can take place if the necessary underlying infrastructure that forms a standardised functional layer is omnipresent and can be regarded as a ‘commodity’.

Standardisation of a functional layer can often stimulate innovations on layers on top of this. For example, ‘standardisation’ of IP as a higher level network protocol stimulates innovation on top of the IP layer and allows for of all kinds of applications to function independently of the lower lying physical transport layer.

This happened when applications in the transport sector where developed (first as small scale pilots) on the assumption that IP over Wi-Fi was a good choice for wireless transport: the relatively empty frequency bands allocated for Wi-Fi provided a high enough availability for the relatively limited data use of the applications developed. As applications evolve, the related data consumption tends to grow, while at the same time the used Wi-Fi frequency bands become more crowded with other users and other types of use.

New applications and innovations (as well as existing ones) in the transport sector would benefit from a network solution that can provide the necessary solid underground for new innovations.

Part of this 'underground' can be provided by using Wi-Fi in the 5 GHz band (instead of 2.4), and part can be provided by using LTE (instead of GPRS networks). Although both offer advantages over their 'predecessors' (respectively being less crowded and providing higher bandwidth), there remains a gap in the specific needs for control of the network for some applications, like more critical applications, and both may become more crowded with other use and users in the future.

Using dedicated spectrum to provide an IP network (for example by using private LTE networks) can provide a solid basis for innovation and further use of advanced solutions in transport and logistics. Key for this is that such dedicated spectrum can offer enough certainty for companies to invest in those networks, including local protection from interference and a long enough licence term[39].

6.3.2 Awareness of dependencies and vulnerabilities

2G/3G/4G networks are used for a variety of applications. However, experiences are mixed, and business and consumer use and users share the resources of the wireless networks and their demand for resources cannot always be sufficiently separated: although the availability of mobile connections over these networks is relatively high, the networks are most heavily used when a large number of (regular) phone users are present, and those moments coincide with the moments of the most dense traffic situations. This means the networks tend to be insufficiently available when they are actually needed.

[39] An example is the 3.6-3.8 GHz band, but this band cannot be used in the northern part of the Netherlands and the maximum duration of a licence is 7 years.

7 Stakeholder analysis

The whole range of applications in the Transport and Logistics sector using wireless communication involves such a variety of stakeholders in different cases that a general high level analysis is not possible.

In this chapter a stakeholder analysis is described for a number of specific applications. Together they illustrate the kind of stakeholder complexity that can be found in the use of wireless connections for applications in the Transport and Logistics sector as a whole.

For an analysis of three of the cases with regard to stakeholders and their actions, the work of Michell et al. [21] is used. For analysis of stakeholder actions this publication distinguishes three attributes:

- *Power*, defined as a relationship between stakeholders where one stakeholder A can get another stakeholder B to do something that B would not have done otherwise
- *Legitimacy*, defined as generalised perception that actions by a stakeholder are appropriate within a system of norms
- *Urgency*, the degree to which stakeholder claims call for immediate attention.

A Venn diagram such as depicted in Figure 6 with attributes is then used to categorise the stakeholders. The claim of the publication is that pressures from stakeholders are more successful if they accumulate the attributes. Stakeholders with all three attributes (*'definitive stakeholders')* are considered most effective in getting their priorities accepted.

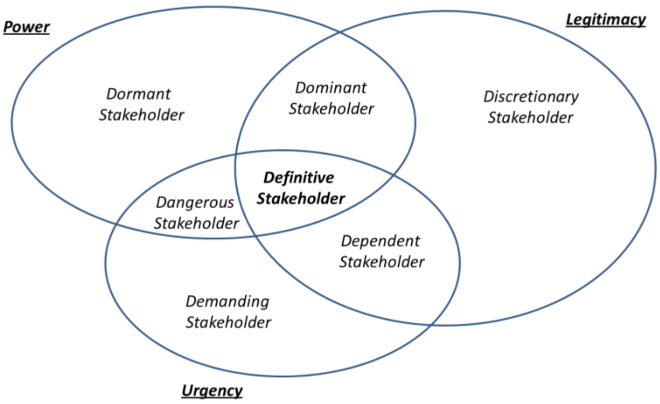

Figure 6: Stakeholder typology (see [21], p. 874)

Although it is not always clear how to determine the stakeholders and how to define them at an equal level (one can often divide stakeholders into smaller parts, for examples departments each with their own agenda) , or what power to attribute to them (since this is quite complex in some cases), the Venn diagram gives an idea about the perception of the position of the relevant players, and can as such provide insight into the acts of players or can act to visually represent perceived roles of stakeholders.

7.1 Stakeholders Metropolitan Traffic Management

The following stakeholders can be distinguished in general metropolitan traffic management situations:

Drivers (as users) benefit directly from efficient traffic management since it reduces congestion, optimises the system and reduces traffic time to a destination or a suitable parking place.

Citizens (other than drivers) can benefit since more efficient traffic management can reduce noise and pollution and reduce automotive traffic in some areas.

City Government / City traffic department has to implement the technical systems to actually use traffic management. The city (as government) has the power to choose for the use of traffic management and to set the 'rules' (i.e. 'low emission zones')

Telecom service providers have the power to provide the necessary telecom systems, but would not feel the specific urgency and do not have the legitimacy to create a city-wide traffic management system.

Traffic service providers might use the information in a 'city traffic management system' to incorporate in their traffic information systems (like the one provided by f.e. TomTom), thereby providing their customers with a more complete overview.

Customers: There are no definite paying customers in this model in which the government implements the traffic control systems.

Government authority and specifically the Radiocommunications Agency can play a role in facilitating disturbance free spectrum for wireless communication systems in urban areas.

Discussion: City-wide traffic information systems use a variety of telecom solutions. Drivers might benefit from city-wide traffic information systems, but – in the case of city-wide traffic information systems - city government (which has to provide the means), the City Traffic Department and the citizens have the most 'legitimacy' when it comes to deciding about a traffic system and about the telecom solutions in use. The Radiocommunications Agency can play a role in providing support and knowledge about possible telecom solutions and can – if needed by municipalities – provide licences under the right conditions for spectrum for private networks like private LTE.

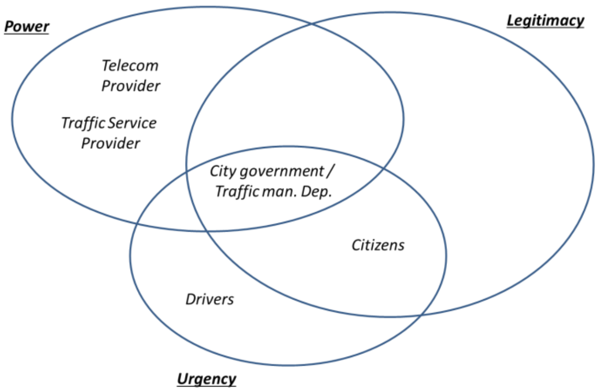

Figure 7: Illustration of stakeholder position in the case of wireless technology usage in metropolitan traffic management

7.2 Stakeholders Airports

(note that this is about the spectrum used for non-vital systems; Spectrum used for vital Flight related systems are heavily standardised and strict international rules set by IATA apply).

The Airport: The airport organisation itself is running the airport and facilitates airlines and their subcontractors, and facilitates other companies and organisations (with services and with for example office space) to be able to operate at the airport.

Airlines are the major customers of the airport, paying for 'landing rights', renting space at the airport for loading/unloading of passengers and for maintenance.

Airside service providers provide services like baggage handling, refuelling, catering for the airlines.

Other Companies not directly related to air-travel are the many businesses and shops that are active at major airports.

Government authorities play an important role in safety issues. The Dutch Radiocommunications Agency and the Ministry of Economic Affairs play a role as a facilitator for spectrum use (reserving spectrum space for specific applications) and planning implementing long term spectrum policy that fits in both national and international context.

Discussion: At airports, numerous parties use spectrum for communication and for automation of their processes on behalf of the airlines carrying passengers and freight. They all feel the importance of being able to use data and speech telecommunication with a high availability to increase efficiency. The urgency for overall spectrum management is present with airlines, airside service providers and the airport. Individual airlines would in most cases not have the power to enforce change at an airport, but the airport (on behalf of a large majority of the airlines) has.

The airport itself is the key player that has the power (within certain limits) to organise wireless communication at the airport and is the major play when discussing spectrum issues with government.

When looking at the wish to obtain further control over dedicated wireless solution for supporting 'airside service providers' their power is more limited due to the limited possibilities for using (local) dedicated spectrum. (in this case the airport would be moved out of the "power" circle and do definite stakeholder can be assigned; airport and government together can decide).

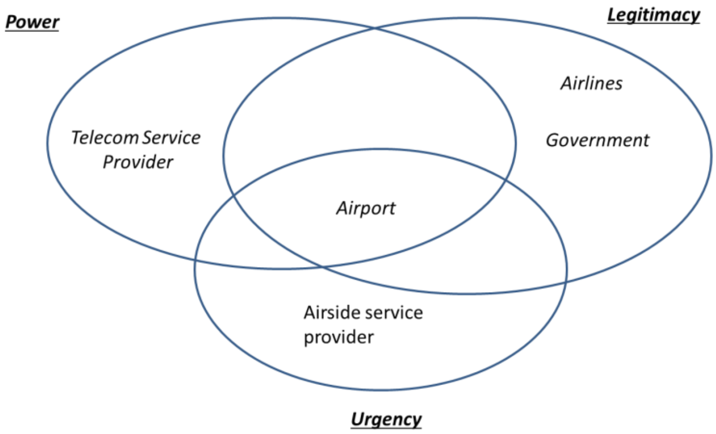

Figure 8: Illustration of stakeholder position in the case of wireless technology usage in Airports

7.3 Stakeholders E-Call

Drivers (as users) are the group most likely to benefit directly from E-call in case of an accident (drivers involved in accidents). As a general rule, drivers (and people in general) feel less urgency for very specific safety measures when not involved in an accident.

EC (as government) has the power to implement rules for an E-call system and has the 'legitimacy' since a standardised, Europe wide system can bring advantages. In case of E-call they apparently did feel the 'urgency' on behave of their citizens since they adopted rules for mandatory implementation.

Car manufacturers have the practical power to implement E-call in new cars.

Telecom service providers have the power to provide the necessary telecom systems, but would not feel the specific urgency and do not have the legitimacy for an entire E-call system.

Emergency Services might feel the urgency if they feel that they can drastically increase their efficiency and capability to help by arriving precious minutes earlier at an accident, and have more accurate information (like number of people involved) then would have been the case if a person made a 112-call. However, If the system produces 'fals calls' or proves to be less accurate then promised, the 'urgency' feeling might disappear.

Customers: There are no definite paying customers in this model (which might explain reluctance to implement). But other stakeholders may view others as customers, and this may have privacy and security implications that have to be taken into account.

Discussion: E-call has been mandated by the EU on behalf of its citizens, but the actual power of implementation lays mainly with the car manufacturers who need to implement e-call hardware in their (new produces) cars and need to make the car connect to an emergency call-centre. However, since the EU has stopped short of actually defining the implementation, discussions are still ongoing about the actual responsibilities (had the EU mandated a specific or more well defined system they might have moved to a "power" position, making them a definite stakeholder). This vacuum led to delays in implementation (now set for late 2015 but this seems unlikely), and makes that car manufacturers all act on their own regarding to implementation. The Radiocommunication agency can play a role in furthering standardisation of the telecom layer for ITS.

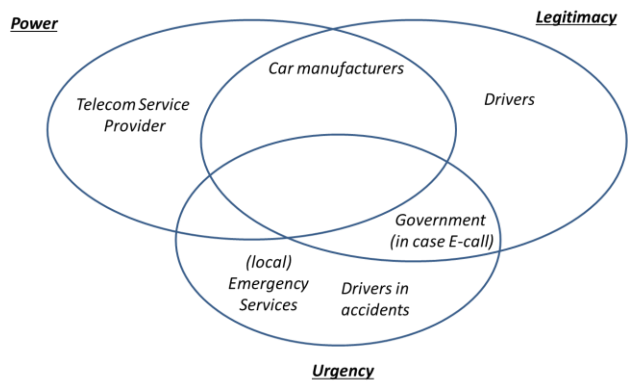

Figure 9: Illustration of stakeholder position in the case of wireless technology usage in E-Call

8 Summary and conclusions

8.1 Summary

Wireless communication is of vital importance for the efficient operation of logistic and transport related processes in the Netherlands and there is a trend in further growth and dependency of use of communication.

Transport services that are directly safety related and need time-critical, secure, or robust voice or data connections generally use specific systems and specifically allocated and regulated frequency bands protecting those systems – to some extent - against use by others. In depth analysis of such highly regulated spectrum was outside the scope of this report, but it is clear that the Radiocommunications Agency plays an important role in safeguarding those applications against interference.

Many other applications related to transport services use 'general purpose' or shared data communication in the form of shared spectrum (like Wi-Fi in the 2.4 GHz band), or in the form of general purpose networks (like GPRS/LTE services).

Use of the 2.4 GHz ISM band is very attractive because it is a license-exempt frequency bands and, in case Wi-Fi technology is used, because of the availability of standard compliant hardware and firmware. Currently the 2.4 GHz is under increased pressure since this spectrum is shared with other users and Industrial application in the Transport and Logistic sector experience increasing challenges to meet the demand for higher bandwidths and availability in this ever more crowded spectrum. The 5 GHz band offers more spectrum space, but it is expected that usages of that band will also grow in coming years. Examples from the cases in this document are use of the 2.4 GHz band for baggage handling processes in Schiphol, Automatic Guided Vehicle control in container terminals, and communication with moving Metro equipment in Amsterdam.

The use of general GPRS, UMTS and LTE networks poses challenges since those networks are not specifically tailored for industrial needs. Overall coverage in the Netherlands might be good, but industrial environments like ports pose additional requirements on coverage, availability and robustness that are not always offered by the conventional operators. The availability of these networks cannot be guaranteed by the mobile service providers and this poses challenges in busy situations (crowds, traffic congestion) where some services (like road traffic management and control or crowd control) might be most needed.

Although in the cases in this report we observe a general awareness of dependencies on telecom, it was pointed out that this might not be the case in general. Even within certain organisations telecom policy can be fragmented and departments make their own telecommunication choices at an ad-hoc basis without overseeing all options or the overall picture. Coordinating telecom policy between companies (for example in a large industrial areas or a harbour in which many parties operate) is even harder, but can be organised using a common interest-group or organisation. Having the right level of knowledge of telecom is not trivial for smaller companies (or even for many large companies or organisations).

Organisations with an organisation-wide spectrum and telecom coordination better optimise their telecommunication by combining expertise and looking at the broader picture, which allows for better integral risk-management. This coordinator can address interference issues and can act as a counterpart for discussions with other parties using the spectrum and with the Radiocommunications Agency.

Interference in shared bands forms a major challenge in the transport sector and parties involved look for spectrum in which they enjoy local protection from interference and which is available under the right conditions (usability for a certain capacity in a certain area with certain robustness). Also, equipment should be readily available. This issue is partly addressed by the spectrum in the 3.6-3.8 GHz band, although the current duration of the licence is deemed too short to warrant the necessary investments.

8.2 Recommendations

Many processes in the Transport and Logistics sector depend on telecommunication, but telecommunication is often not a subject that is at the highest of the agenda. In general it is recommended that organisations:

Discuss and implement telecom-strategy at management level

Telecom decisions can be streamlined, for example by appointing a telecom coordinator or department. In this way experiences can be shared, specific telecom knowledge concentrated and telecom solution can be implemented more efficiently.

Make telecom dependency an integral part of risk management

By making telecom dependence an integral part of risk management in organisations that depend on telecom measures can be taken to avoid unwanted (and definitely unknown) dependencies on telecom systems, for example by allowing processes to continue for at least some amount of time if communication is temporarily unavailable, or – if this is not possible – to make sure there are independent backup communication systems available.

For the Radiocommunications Agency to aid the Transport and Logistics sector the following recommendations are made:

Increase awareness of risks of and dependencies on telecom.

Awareness of the importance of telecom is in general present with those responsible for (specific) telecommunication solution, but telecom policy is often fragmented throughout a company or organisation. Also applications are often introduced as 'nice to have' functionality but then gradually become an essential part of these processes while no 'rethinking' of telecom dependence takes place. Increased awareness at a higher level allows for better 'organisation-wide' risk assessments and allows organisations to more efficiently organise their telecom needs.

Increase knowledge about telecom developments and solutions.

Part of the larger organisations seem to be aware of the challenges they face when using certain telecom solutions, but are not always aware of all alternatives that might be available, and specialist telecom knowledge is not always widely available in organisations related to transport and logistics. The Radiocommunications Agency can increase knowledge by guiding discussions and by increasing awareness of possible alternative solutions since it has a wider view on the possibilities (and impossibilities) that is most likely not present at (smaller) companies and organisations.

Continue to facilitate local spectrum for private networks and optimise conditions.

There is a need for private network solutions with high availability and optimal coverage. Although this is already partly possible (f.e. in the 3.6-3.8 GHz band), a dilemma is the limited duration of spectrum licences of 7 years which is deemed too short by the organisations in the Transport and Logistics sector. Another dilemma is the availability of hardware for specific bands for industrial use, and spectrum policy for local spectrum should take into account the ability to use the spectrum in conjunction with widely available clients.

Further ITS policy and standardisation is needed before it can be safely implemented.

There is standardised spectrum available for use in ITS applications, but at this stage there is a lack of further standardisation, partly due to a lack of urgency to introduce (advanced) ITS services like collaborative driving. The Radiocommunications Agency can play a role in furthering ITS policy and standardisation efforts in cooperation with Dutch industry by participating in those efforts at European level.

8.3 Research questions and conclusions

This paragraph summarises the answers to the primary research questions.

1. ***Which wireless applications are used for different functions in the Transport & Logistics sector?***

For traffic flow management fixed lines and GPRS are used to send information to the DRIPS (Dynamic Route Information Panels). KAR (Dutch 'korte afstands radio', or 'short range radio') is being introduced, for communication from emergency vehicles and busses to traffic lights. Parking management uses fixed lines for the garages and GPRS for communication with electronic signs indicating free parking spaces, and local sensor networks are used for information about parking bays on streets. The Metro system uses a dedicated 5 GHz communication system around the rail tracks for data communication with central control. GPRS is used for communication with trams, buses and platforms, while for speech a private trunking solution is used.

At airports for voice communication PMR/tetra is used. Next to this various application that are supportive of the business use wireless communication in shared spectrum like in the 2.4 GHz band (mainly Wi-Fi based), for example for luggage scanners, for tablets on the tarmac for working orders, for information signs, etc. RFID is used to identify pieces of luggage.

For ITS dedicate spectrum is reserved for future collaborative driving applications based on 802.11p/WAVE. The e-call solutions currently proposed mainly use the public mobile networks for contact with the various emergency callcenters.

At container terminals, wireless connections play an important role in the guiding of automated vehicles that transport containers. At least in some cases shared spectrum in the 2.4 GHz is used, although using other spectrum is considered. Wi-Fi is used for general data communication and work-orders for truck drivers and terminal personnel.

Most wireless applications in the transport & logistic sectors use one or more 'application platforms': a combination of standardised equipment, radio frequency bands, transmission standards and in some cases user procedures.

Wireless communications *directly related and essential* to the primary processes of specific modes of transport generally make use of dedicated platforms working over allocated frequency bands. These solutions that support essential and time critical information exchange are often historically grown, highly organised, and use industrial grade, robust equipment and systems, designed and used with awareness of possible vulnerabilities. Examples are Airband and VHF maritime radio.

However there are some exceptions, such as the use of general or shared frequency bands for specific platforms for new, innovative or emerging transport applications. An example of this is the control of Automatic Guided Vehicles for container transport in container terminals, where there is future risks of interference in the shared 2.4 GHz band (see also questions 2 and 3).

Wireless communications *closely related but not essential to* the primary processes of specific modes of transport generally use multi-purpose platforms: Two variants can be distinguished: communication in allocated frequency bands using semi-specific platforms, (such as PMR) and communication in general purpose/shared frequency bands using more general platforms (such as public mobile networks).

Wireless communications *indirectly related* to modes of transport generally use more generic solutions (like Wi-Fi or public mobile networks) and 'general purpose' and/or shared networks or frequency space. Trunked Radio or Personal Mobile Radio using dedicated frequency bands is (still) widely used for general purpose wireless voice and data communication within transport organisations and businesses of most of the researched cases. Although these systems are generally appreciated for their robustness and availability, their use as a general purpose platform is limited and they are generally more expensive than smart phones and tablets. Also the use of specific frequency bands – and sometimes specific protocols and systems - poses limitations.

2. *What are the most important trends in this sector regarding wireless applications?*

Wireless communication becomes omni present, and there is extensive growth in the amount of devices, the number of communication sessions and the amount of data exchanges within communication sessions. Data communication is becoming more important, complementing or replacing voice communications. The use of limited sessions of information exchange such as short conversations is replaced by an 'always on' approach in which everything is to be connected always and everywhere and information can be requested or provided at any time; more and more software applications are based on this principle.

From the cases a paradox became clear between the need to use flexible, general, multipurpose equipment as available on the fast-moving telecom market for mobile devices, and specific protocols and ecosystems as available for industrial processes in which investments have a horizon of 10 years or more. Lower costs of public mobile network connection and Wi-Fi networks make the use of those general platforms attractive from a point of view of (cost) efficiency. However, since Wi-Fi (due to the spectrum being shared with other users) and public mobile networks (due to the network being shared and operators focusing on consumers) cannot always satisfy the degree of robustness needed. This leads to a need for private, local solutions in which there is protection from interference at a spectrum level, and in which the network can be purpose-build, while still taking advantage of general available equipment.

Innovative transport applications can be devised because of the presence of a working and trusted network connection. The availability of such network connections are a precondition for further innovation, and the Radiocommunication agency can aid companies in providing such a network, by helping them choose optimal and future proof telecom solution and by providing the (spectrum) framework in which those companies can build those networks themselves. The spectrum framework should allow for a long enough duration of spectrum licences for the investment to be warranted and for the full economic lifetime of the investment to be met.

3. *Which vulnerabilities can be identified?*

A vulnerability already experienced by Schiphol and other companies is the interference that may occur in shared frequency bands, and this problem is becoming specifically severe since the enormous success of Wi-Fi and the increase in the amount of (portable and fixed) Wi-Fi capable devices.

Another vulnerability is that the availability of generic mobile service like GPRS/LTE is not guaranteed, and at a cellular level no backup is present, because public mobile operators operate their network for the general public, and not as such for specific industrial applications that may pose severe demands on availability, coverage and other aspects of the service.

Also using a shared network means the network may experience unavailability coinciding with moments when the primary process needs the network the most. An example of this is crowd control and traffic management, which is needed when there are many vehicles. This relation is not always clear to all stakeholders involved since they might decide on 'overall' availability numbers and might not take other aspects into account. Integral risk management is needed to resolve those issues.

Sometimes local communication -important for business processes- is performed using national public mobile networks that depend partly on network elements of providers that are placed elsewhere and are shared with many other users, which might not be desirable for some business processes.

Licensed and allocated PMR frequencies for temporary special events sometimes coincide, which is a well-known concern.

4. *What are the developments of ITS and which risks are involved?*

Intelligent Transport Systems (ITS) and extensive use of wireless connections in vehicles are not only a promise for the future: There is a variety of pilot projects for applications aiming for more security, road efficiency and lower traffic costs. Also many applications that use radio are already present in newer cars and trucks. Examples are parking radar, assisted cruise control, and intelligent navigation systems using dynamic traffic updates, etc.

ITS standardisation efforts such as ETSI-ITS and ETSI TG37 resulted in proposed frequency bands allocated for ITS use. In these frequency bands a separation is made between bands for critical, non-critical and future use. Three types of wireless connections can be distinguished: Car to car, car to roadside (and vice versa) and car to infrastructure (and vice versa). At this moment there are no definite standards for collaborative driving efforts at a telecommunication level or at an application level, and most car manufacturers act on their own. Communication for ITS should be secure to address information security, (vehicle) safety and privacy concerns but is not yet standardised at a sufficient level. Potential vulnerabilities may occur where choices concerning frequency band allocation in combination with criticality and priority of emerging applications do not match[40]. Standardising secure car-to-car communication is a prerequisite for the wider use of the higher level "collaborative driving" applications. At a higher level the applications are not standardised, and it is unclear how they will deal with temporarily unavailability of both specific (ITS) network connections as well as general purpose network connections. This has to be addressed in standardisation. At this stage there is a lack of standardisation at an application level and there is no definite stakeholder for the proposed ITS applications. EC gives guidelines but leaves standardisation to the market, while car manufacturers focus on their own applications first.

E-call is a separate application. The EC aims to implement E-call in new cars from 2017 on. Here the responsibility for implementation lies with the car manufacturers and various brands are working on (their own) system for implementing E-call, primarily based on commercial available telecom providers using GSM/GPRS/ UMTS or LTE. Since in E-call there is no car-to-car communication, the lack of standardisation is not as large an issue as it is with some other (ITS) applications. Discussions surrounding privacy issues might come to play when cars become 'always online'.

5. *What is the approach of different actors and stakeholders with regard to risk factors related to the use of wireless applications?*

Historically the approach of actors and stakeholders in the transport and logistics sector with regard to risk factors related to the use of wireless applications is thoroughly and well-thought through: wireless communication has been a beneficial companion for many forms of transport since its introduction and robustness and safety have always been key aspects

[40] Also implications for security, safety and privacy in case of large scale deployment and related necessary precautions are not yet clear but ideally these issues should be tackled on application level.

of its use. Many transport related systems and applications are historically designed to work stand-alone (like for example traffic light systems).

The omni presence of low-cost general purpose equipment and systems for wireless communication lead to possible attractive use cases: mobile connections over general purpose or license exempt frequency bands promise cost-effective and flexible communication opportunity with reasonable robustness: more networks are accessible via more access point providing more bandwidth at more locations. There is a need felt for further uniformity, more general platforms and simpler data exchange. Transport specific, historically grown, communication ecosystems do not always provide the flexibility and cost effectiveness that actors are looking for.

In practice parties react when wireless networks do not function as planned and practical issues related to new and innovative applications lead to a change in focus on how to use radio frequency (‘learning by doing’).

Industrial and governmental actors contemplate the use of local assigned (private) spectrum that is usable with general purpose equipment or platforms. This allows them to implement a dedicated network with high availability and specific coverage for their needs and gives protection against interference. This is already possible in part of the 3.6-3.8 GHz spectrum, but for some applications the conditions (mainly the duration of the license of 7 years) are not optimal.

6. ***What are possible countermeasures for risks that pose a large impact on society?***

There are a number of possible countermeasures for risks and vulnerabilities related to the use of radio frequencies in the transport sector that potentially pose a large impact on society.

First, it is important to ensure that actors and stakeholders are sufficiently aware of the possible vulnerability of wireless communication related to primary transport processes: Can systems function stand-alone for some time? Is there some means of fall-back communication possible? Is the designated fall-back communication method really redundant (and not using elements that are too closely related to the primary means of communication and thereby potentially reducing the redundancy)?

The allocation of Private LTE frequency bands for a limited geographic area to businesses and (semi-)governmental organisations is a suggested solution for specific or new but geographically concentrated use (cities, seaports, airports).

For ITS there is an ongoing discussion on sharing of spectrum between ITS (on or near roads) and making this spectrum available for Wi-Fi (for in-house use). This can lead to unwanted disturbances in the future. For uninterrupted and secure use of ITS sufficient safeguards should be put in place in spectrum policy and allocation. Protection or prioritisation mechanisms (like DFS) can work if it sufficient safeguards ITS. A long term countermeasure may be to actively support international efforts to optimise efficient use of frequencies essential to, or directly related to, transport processes. Transport related communication systems that have proven to be robust and safe in the past can be very inefficient when compared with state of the art solutions, and a more efficient use providing the same robustness characteristics using more modern technology can free up frequency space. Such long term countermeasures include being involved in standardisation of more efficient protocols and more efficient frequency band allocation.

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Annex A Communication technologies for Transport and Logistics

In this Annex a brief overview of various communication technologies is given based on the technologies encountered in the cases.

B.1 Data Connections

Public telecommunication networks GSM/GPRS, UMTS, LTE

Due to the mobile nature of 'transport' the use of omnipresent GPRS (and often UMTS and LTE) networks are an obvious candidate for all kinds of vehicle communication. Another general advantage of GPRS over dedicated data networks is that clients are widely available in all kinds of form-factors, from (ruggedised) smartphones and tablets to modem modules to be built in an application.

We notice that GPRS is often used 'for convenience', i.e. as a 'simple' way to get connectivity to some (static) place without the need for cables[41,42]. The choice is often made because it can be far easier to 'plug in' a GPRS modem than to implement a DSL or Ethernet line.

Private LTE

Many parties consider the use of Private GSM/GPRS or LTE networks as a way to obtain a large amount of control over the network, while keeping the advantage of using a widely used technology with client devices readily available.

In the Netherlands, 2x5 MHz in the 1800 MHz 'GSM/LTE' band is available for licence exempt use. This gives the opportunity to utilise dedicated, private (voice) networks based on GSM. LTE can be used in this band, but since the available amount of spectrum is limited this may not be a preferred option for data intensive applications.

Another option is to use private LTE in the 3600-3800 MHz range for which a local licence can be obtained. This means local protection against interference can be obtained in this band. Disadvantages of this band are that at this moment the number of readily available LTE clients for this band is limited (but growing), and that the duration of the licence is 7 years. This is deemed too short by companies for some types of use to give enough certainty to allow for a positive business-case, since it typically takes at least a year to implement a new network, and equipment is often used for 8-10 years or more (while equipment is bought 'along the way', i.e. replacement takes place in phases, and the equipment bought in 4 years' time needs to be supported 8 years from then on). From industrial point of view, longer is better, but parties indicate that 10 years would already allow for much more certainty for investments to be justifiable.

[41] This argument is valid for M2M in general. For example companies that place vending machines at other companies' premises prefer public GPRS above using the 'local' network since the latter would mean getting access to the secure company network. GPRS is used for some static 'smart meters' instead of the already available internet connection.

[42] For example, some digital road and public transport signs (for traffic information and real-time bus arrival times) use GPRS, see chapter 2.

802.11 General purpose Wi-Fi

Wi-Fi in the 2.4 GHz band (2,400–2,475 MHz) is the most common technology in use for private data networks at companies and homes, and is widely used by players in the transport sector. Wi-Fi allows for high bandwidth connections in an owned network, but only works 'on premise' of a company or organisation.

Specifically in the transport sector a number of applications already have a considerable life cycle of 15 years or more. Often they were deployed as innovative solution and initially working without much problems since the (Wi-Fi or related) networks for those applications were the only local wireless networks at those locations at that time: no smartphones existed, and laptops where not 'standard' equipped with Wi-Fi.

This band only allows for three independent non-overlapping channels, and much has changed since 2000, and private persons carry Wi-Fi-enabled devices (that can act as access-points too), causing a large increase in the number of active devices in the 2.4 GHz spectrum. And since it is so widely deployed by consumers and companies, congestion is becoming a problem.

Since then, more spectrum became available in the 5 GHz range (5.15-5.725 GHz) that is still relatively unused can be used as a substitute for the (crowded) 2.4 GHz. However, industry is worried that this band will get crowded within a couple of years as well. Another concern is the higher frequency, which might make it harder to obtain sufficient coverage in industrial environments like large logistic centres with containers.

Organisations providing and using industrial applications (including those in transport and logistics) are now looking for future proof solutions. For some the envisioned solution is a less crowded frequency band to use in which spectrum rights can be obtained for a longer period of time and in which the application is protected from interference from other users. However, although the problem is often recognised, a clear solution is not always available.

802.11p / Wave for automotive and ITS

For automotive and ITS, spectrum and short-range communication for direct contact between vehicles and between a vehicle and roadside infrastructure 5.855 – 5.925 GHz spectrum for ITS in the 5 GHz range is standardised for use with 802.11p/WAVE (Wireless Access in Vehicular Environments). 802.11p is based on the generic 802.11 standards but is optimised/adapted for low latency connection and communication between 'high velocity clients' (like vehicles) to allow for the demands that some of the (proposed) ITS applications need.

B.2 Short Range Devices and RFID Sensor networks

A number of communication protocols in various bands are used for (short range) low bitrate communication for sensor-networks, RFID and M2M and 'Internet of Things'-applications.

RFID technology

RFID technology is used in logistic management of products and goods and in a wide range of other applications, requiring reading ranges of 2 meters, up to 5 meters to 10 meters for large packages or 'bulk' packaged goods (i.e. a large box containing a large number of RFID-tagged items).

Short Range Devices (SRD's) and sensor-networks

Sensor networks allow for devices to communicate with each-other (for example in a mesh-structure) or with a gateway. Active short range devices and sensor-networks differ from RFID-tags in that RFID-tags are 'passive' tags, waiting for a pulse from a reader, while sensor-networks are active devices (with their own power source) sending / exchanging information with other devices or a gateway for central processing.

Spectrum

Short Range Devices often operate in licence-free spectrum such as 2.4 GHz ISM or 865-868 MHz, using a variety of protocols are used in the 868 MHz band. RFID often uses the 865-868 MHz spectrum. Extension of this spectrum to include 870-876 MHz for SRD's and 915 MHz to 921 MHz for RFID is discussed by ETSI in a Technical Report [16]. Although for now usage is limited, a concern is that the use of this band might grow enormously with the advent of cheap, overall sensors in houses, roads and for other applications. Also, part of the 868 MHz spectrum may be vulnerable to LTE disturbance caused by bordering LTE frequency bands [17].

B.3 PMR

There is a variety of systems supporting 'push to talk' functionality to groups of users in a limited area, in some cases combined with capabilities for data communication in such groups. Generally these systems are labelled 'PMR' although it varies for which words this abbreviation stands (Professional Mobile Radio, Private Mobile Radio, Personal Mobile Radio). Lower end systems (marketed for both leisure as well as business) use unlicensed spectrum (such as in the 446 MHz band), working in ranges varying from a few hundred meters in cities to a few kilometres in rural areas. Industrial PMR use licensed spectrum to enable a specific user group in a specific area to use a shared radio voice channel. High end solutions use 'trunked radio' systems for organisations that allow sharing of relatively few radio frequency channels – licensed to that organisation - among a large group of users. In such systems frequency space is allocated to user groups on demand by a central controlling entity. Some organisations still use analogue variants such as MPT1327, others use digital variants based on TETRA (Terrestrial Trunked Radio) or Push to Talk over Cellular (PoC) such as CDMA or UMTS/LTE. Some companies operate country wide systems for trunked radio (for example Entropia) that sell subscriptions to organisations that work in larger areas such as taxi companies.

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