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Communication Architecture in the Chosen Telematics Transport Systems

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1. Introduction

The term telematics comes from French *télématique*, and emerged at the beginning of the seventies as a combination of the words telecommunications (*télécommunications*) and computer science (*informatique)*. At the end of seventies it started to be used in English. Nineties made it more widespread in Europe, when the European Union had introduced telematics development programmes to various sectors. It is one of those terms, which are by-products of scientific progress, namely in this case, tremendous advance of transportation and information technologies. The term is predominantly used to describe structural solutions integrating electronic communication with information collection and processing, designed to cater for a specific system's needs. It also pools different technical solutions, which use telecommunications and IT systems (Wawrzyński W., Siergiejczyk M. et al., 2007, Wydro K. B. ,2003).

Telematics can be defined as telecommunications, IT, information and automatic control solutions, adapted to address physical systems' needs. Those solutions derive from their functions, infrastructure, organisation, and processes integral to maintenance and management. In this case, a physical system consists of purpose-built devices, and comprises administration, operators, users and environmental considerations.

Technical telematic solutions use electronic communication systems transmitting information. Among those systems are WAN (Wide Area Network) and LAN (Local Area Network) networks, radiowave beacons, satellite systems, data collection systems (sensors, video cameras, radars, etc.) and systems presenting information both to administrators (e.g. the GIS system) and to users (variable message signs, traffic lights, radio broadcasting, WAP, WWW, SMS).

The very essence of telematics is data handling, i.e. collection, transmission and processing. Data collection entails gathering multivariate data from sensors and the environment through purpose-built devices. The data are then transmitted over dedicated transmission mechanisms - assuring reliability and good transmission rates - to the processing centres. In case of data transmission and processing, one should pay attention to issues of signal usefulness and its functional intent. Furthermore, an important feature of telematics-based applications is their capability to effectively integrate different subsystems and make them interoperable. Apart from various applications of telematics (medical telematics, environment telematics and other), its broadest application area is transport.

The following chapter discusses data exchange architecture in transport telematic systems. The issues concerning the structure and a means enabling information exchange between different parts (elements) of transport telematic systems (means of data stream transmission) were presented across four subsections.

The second part of the chapter delves into the very essence of transport telematic systems. The concept of a transport telematic system is outlined and the transport telematics itself is situated among other fields of knowledge and technologies. Information flows in telematic systems were then analysed, concentrating with due diligence on transmission of telematics-based information. Functions of transport telematic systems were defined, as a service intended for a diverse range of target audiences directly or indirectly connected with transport processes of people and/or goods. Delivering those services requires building data transmission networks between entities using telematic systems to provide transport services

The third part of the chapter discusses the fundamental nature of communication architecture as well as defines and determines the structure and a means enabling information exchange between different parts (elements) of a system (means of data stream transmission). Based on literature analysing data exchange in Intelligent Transport Systems, such architecture was illustrated in an integrated urban traffic/public transport management system. Another example of telematics-based data flow is data exchange between highway management centres and highway telematic systems. Communication architecture of highway telematic system was presented along with schematically depicted data transmission in a highway management centre.

The subsequent section concerns the issues of building a teleinformatic infrastructure enabling rail transport services. General architecture of rail infrastructure manager's telecommunications network was discussed, and services provided by that network characterised. IT standards required to deliver integrated rail transport IT systems were discussed as well. Wired and wireless communication networks were presented. Teleinformatic services dedicated for rail transport were analysed.

The final part of the chapter discusses the issues of teleinformatic networks used in air traffic management systems. Higher number of aircrafts within individual sectors, is only acceptable should concurrently data transmission systems, informing about situation in individual sectors of airways be improved. Basic issues related to migration of X.25 networks to networks using the IP protocol in their network layer were presented. The concept includes the AFTN, OLDI and radar data transmission networks alike. One of the most important surveillance data distribution systems – ARTAS – was also described. Finally, presented was the possibility of deploying SAN networks – characterised by integrated architecture – in order to enable exchange of construction data, planned and real airspace restrictions.

2. Information flows in telematic systems

2.1 Transport telematics

The field concerning application of telematics in transport systems is called transport telematics. It comprises integrated measuring, telecommunications, IT and information systems, control engineering, their equipment and the services they provide.

Said equipment and services are provided as telematics-based applications, i.e. purpose-built tools. Example of such an isolated application is a road weather information system, which informs users e.g. about crosswind.

Transport telematics marked its presence in Polish publications in mid-nineties. Already back then, efforts were made to identify conceptual range and field of applications of transport telematics (Wawrzyński W., 1997). Consequently it was defined as a field of knowledge and technical activity integrating IT with telecommunications, intended to address transport systems' needs.

Transport telematics is a field of knowledge integrating IT and telecommunications, intended for needs of organising, managing, routing and controlling traffic flows, which stimulates technical and organisational activity enabling quality assurance of transit services, higher efficiency and safety of those systems (Wawrzyński W., Siergiejczyk M. et al., 2007)

Cooperating individual telematic solutions (often supervised by a superior factor e.g. an operator supported by purpose-built applications), create Intelligent Transport Systems (ITS). Convergence of telecommunications and IT, right through to Intelligent Transport Systems has been presented schematically in figure 1.1.

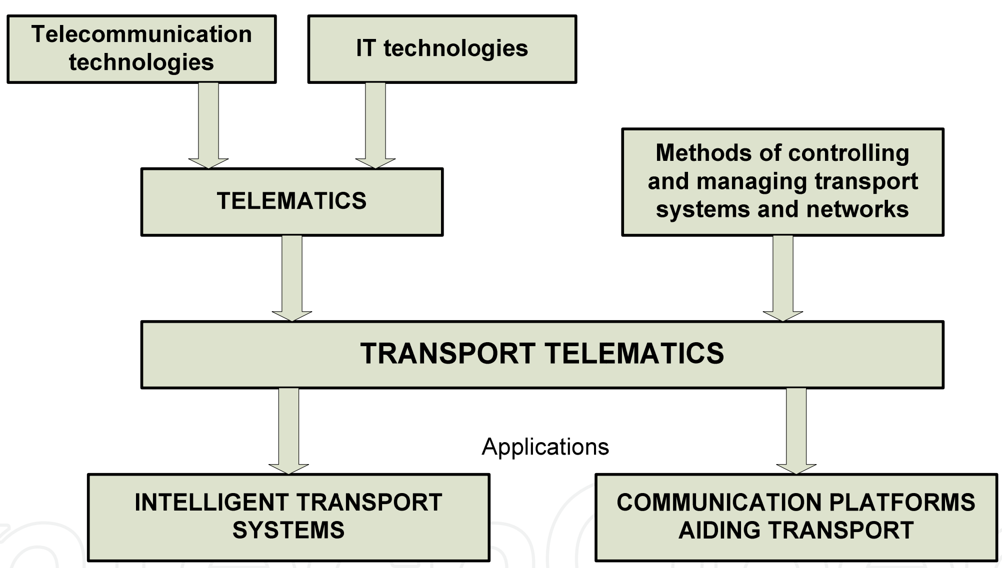

Fig. 1.1. Transport telematics amongst related fields of knowledge and technology

The name Intelligent Transport Systems was accepted at the very first world congress held in Paris, 1994, in spite of proposal made by International Organization for Standardization of RTTT (*Road Traffic and Transport Telematics*). Regardless of the name, those systems create architecture, designed to aid, supervise, control and manage transport processes and interlock them. Transportation Management Systems, integrating all modes of transport and all transit network elements within a given area, are also referred to as ATMS (*Advanced Traffic Management Systems*) (Wydro K. B. ,2003).

Key functionalities of telematic systems are information handling functionalities. Namely its collection, processing, distribution along with transmission, and its use in decision-making processes. They are both the processes carried out in a pre-determined fashion (e.g.

automatic traffic control) and incident-induced processes (decisions of dispatchers and real-time information supported, independent infrastructure users) (Klein L.A., 2001).

Telematics-enabled physical infrastructure – called intelligent systems – can vary in function and dimensions. However, not only the range and number of elements constitute the size of a telematic system. First and foremost the quantity and diversity of information fed through and processed in the system matters, followed by the number of entire system's domains of activity. In a broad sense, intelligent transport systems are highly integrated measuring (detector, sensor), telecommunications, IT, information and also automatic solutions. Intelligent transport integrates all kinds and modes of transport, infrastructure, organisations, enterprises, as well as maintenance and management processes. Used telematic solutions link those elements, enable their cooperation and interaction with environment, users in particular. Telematic solutions can be dedicated for a specific type of transport (e.g. road transport) and operate within a chosen geographic area (e.g. a local administrative unit). They can also integrate and coordinate a continental or global transport system.

Such solutions normally have an open architecture and are scalable: if required they can be expanded, complemented and modernised. Their aim is to benefit users through interaction with individual system elements assuring safer journeys and transit, higher transport reliability, better use of infrastructure and better economic results plus to reduce environmental degradation.

The fundamental feature of telematics-based applications is the capability to disseminate and process vast amounts of information adequate to a given function, adapted to consumer needs – users of that information, specific for right place and time. Information can be communicated either automatically or interactively, upon user request. An important feature of telematics-based applications is their ability to effectively integrate different subsystems and cause them to operate in a coordinated fashion.

2.2 Information transmission in transport telematic systems

One of crucial properties of telematic systems is broadcasting and transmitting information, i.e. its flow. Distribution of telematic information is strictly linked to telecommunications, i.e. transmission of information over a distance through different signals – currently, often electric and optic signals. Telecommunications services can provide multivariate data: alphanumeric data, voice, sounds, motion or still pictures, writing characters and various measuring signals, etc. The information chain is the salient aspect of telematic information distribution in terms of telecommunications. In essence, the chain transmits multivariate messages from transmitter to receiver, thus concentrates on two data exchange points. However, the fact the transmission took place matters, as opposed to the way the information was transmitted. The way of transmitting information matters in case of a communication chain, which is part of an information chain. In case of a communication chain, important is data transmission from transmitter to receiver without data identification. Important here is the message conversion to transmittable signal and the transmission medium. During transmission, the signal is exposed to interferences, thus often becomes distorted. Hence it is crucial, that the signal transmitted to receiver is the best reproduction of original signal. The transmission medium is called communication channel which is usually a wire (twin-lead, coaxial), optical fibre or radio channel (Siergiejczyk M., 2009).

Telematics-based systems interact with many other systems and environment, and can encompass many constituent subsystems. Hence the aforementioned elements have to interchange information (figure 2.1). In order to facilitate dataflow, required are different types of transmission media, without which data distribution would not be possible. Transmission media are used for both quick and reliable communication with widespread systems, demanding tremendous amounts of data to be long-distance transmitted, and short-distance transmission of basic control messages or measuring data from sensors. Therefore, in case of systems on the table, transmission media and transmission mechanisms play an important role.

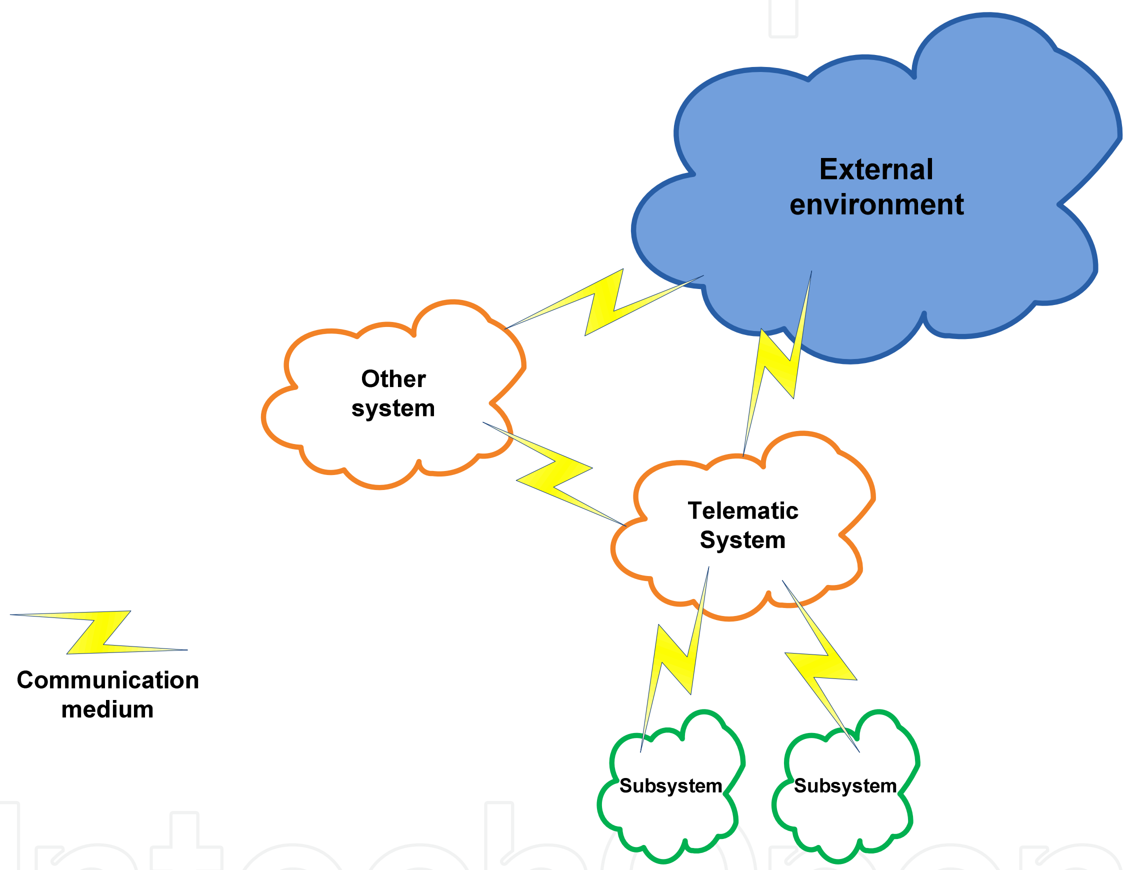

Fig. 2.1. Telematic data exchange

The focal point of the entire telematic system is the traffic operations centre (management centre). Flowchart in figure 2.2 illustrates telematics-based information flow.

Different methods and transmission media of data have to be used due to characteristics of information transmitters and receivers. Both the method and medium depend on used devices and their technological advancement, channel capacity requirements, power supply, etc. Moreover, significant factors include weather conditions, likelihood of electromagnetic interferences, whether elements are mobile or fixed, working conditions, software and telecommunications-imposed requirements. One of the most important factors are the set-up and maintenance costs of chosen medium and the method of transmitting telematics-based information.

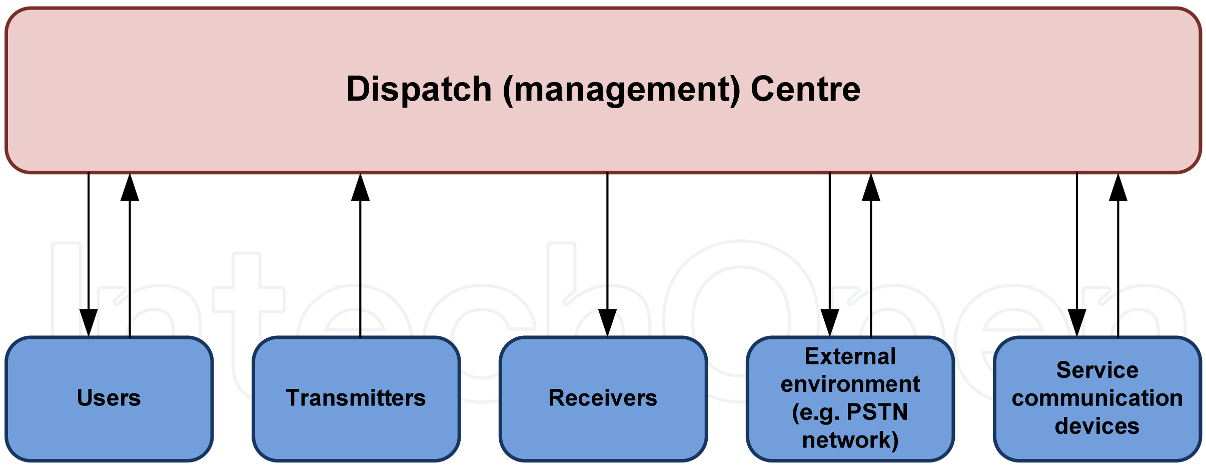

Fig. 2.2. Flowchart illustrating telematics-based information flow

3. Communication architecture in road transport telematic systems

3.1 Determination and functions of transportation architecture of telematic systems

Transport architecture of transport telematic systems defines and determines the structure and a means enabling information exchange between different parts (elements) of a system (means of data stream transmission). It concerns two mutually complementing facets, distinguished by different operating principles: assurance of a means enabling point-to-point data transmission; assuring reliability of transmitting and interpreting telematics-based information.

The issue of assuring a means enabling point-to-point data transmission and ensuring the chosen means are valid in terms of costs, maximum distortions or signal latency, concerns description and definition of communication mechanisms. They correspond to the first four OSI (*Open System Interconnection*) model layers, namely physical layer, data link layer, network layer and transport layer. The communication platform has to be independent of used technologies and specific products to a maximum extent. In order to do that, envisaged are e.g. physical dataflow analysis in most representative example systems. On that basis, the most representative telecommunications needs can be recognised in a telematic system, including necessary interfaces. Spelling out such typical telecommunications needs is an important advantage of transportation infrastructure. Ever-changing telecommunications technologies impede developing technologically independent architecture, up-to-date over longer time horizons. However, put forward overview of typical dataflow, will remain valid as long as the most representative system image does not substantially alter. Thus, said methodology lays the grounds for analysing loosely telecommunications-related issues in ITS systems.

Apart from strictly telecommunications-related issues, one has to bear in mind the problem of ensuring reliability of telematics-based information transmission and its correct interpretation. It is a problem of standards, which would guarantee to communicating parties reliable and efficient data exchange. In reality though, a system's capability to provide services relies to a great extent on data, which the system can process within a time unit. Thus, not only the type of data processed by a system matters, but also their level of detail available for designing a service or other operation needed by a telematic system. Other technical issues, such as data storage, storage location should not be ignored as well. That solution can cause the need for a diversified way of data exchange, and consequently e.g. different message display standards (Siergiejczyk M. ,2009).

The communication part of a telematic system, determines links between environments of transport and telecommunications. Due to rapid development of telecommunications, telematic systems designers have a wide selection of means at their disposal, enabling them to accommodate needs induced by variable implementation circumstances. Communication architecture does not hint though, on particular systems of technologies, instead merely identifies technology-based capabilities. Four types of media were listed here, all suitable to transmit information in transport telematic solutions. Those are the following telecommunications systems (Wawrzyński W., Siergiejczyk M. et al., 2007):

- wired (stationary point to stationary point connectivity);
- long-distance wireless (stationary point to mobile point connectivity);
- dedicated short-distance (stationary point to mobile point connectivity);
- between mobile in-vehicle terminals (mobile connectivity).

It is worth pointing out, that there are numerous transmission techniques used for communication between stationary points. E.g. proprietary or leased communication channels can be used to operate traffic control subsystems. With intended other applications, they can be microwaves, spread spectrum radio systems or local radio networks.

Structure of physical architecture envisaged subsystems of the Control Centre (Management and Supervision) connected with a wired network. It allows every subsystem to collect, integrate and disseminate information to other subsystems in line with mutually accepted communication and coordination rules, positively affecting operational effectiveness of those subsystems. Depending on range and coverage, there are two types of wireless communication. The first is long-range wireless communication, stipulating means used in case of services and applications, where information is sent over long distances and regional full coverage is required, providing constant network access. Further distinction concerns one-way and two-way communication, as it influences the choice of technology (e.g. radio transmission is possible with one-way communication). Short-range wireless communication is the second type, used to send information locally. There are two types, vehicle-to-vehicle and DSRC (*Dedicated Short Range Communications*). The former is used i.a. for collision avoidance systems, whereas DSRC – for electronic toll collection, access authorisation etc. Generally, it is fair to say that the analysis of traffic assignment and required data feed rates, and the analysis of available transmission techniques lead to the conclusion, that commercially available wired and wireless networks are capable of accommodating current and future transmission needs in terms of telematics-based information.

3.2 Communication architecture in road transport

The KAREN (*Keystone Architecture Required for European Networks*) framework architecture introduced by the European Union, implies support mechanism for information exchange between different system elements. Such exchange should comply with the following:

- the mechanism should enable data transmission between relevant parties and be sustainable in terms of cost, accuracy and transmission latency;
- assure correctness of data transmission and interpretation.

Both those conditions require:

- introduction of detailed analysis of definitions and descriptions of communication connections in main interfaces of physical transport subsystems;
- defining necessary communication protocols.

Physical structure of a system i.e. elements identification, which i.a. exchanged data are classified under Physical Architecture in KAREN. Identified were five main types of elements and characterised were requirements concerning data exchange between such elements (KAREN, 2000, Wawrzyński W., Siergiejczyk M. et al. ,2007, Wydro K. B., 2003):

- *Central* – the place which is used to collect, collate and store traffic data and to generate traffic management measures, or fleet management instructions (e.g. Traffic Control Centres, Traffic Information Centres or Freight and Fleet Management Centres);
- *Kiosk* - a device usually located in a public place, providing traveller information (e.g. tourist information, often self-service)
- *Roadside* – the place where detected are traffic, vehicles and pedestrians, tolls collected and/or traffic management measures taken, and/or information are provided to drivers and pedestrians;
- *Vehicle* - a device that is capable of moving through the road network and carrying one or more people (e.g. bicycles, motorcycles, cars, Public Transport Vehicles) and/or goods (any form of road going freight carrying vehicle);
- *Traveller* – a person driving or using a vehicle.

Because communication with environment requires systemic description of that environment, its active elements are defined as terminators. A terminator can be a person, system or a unit, from which data would be received and which are sent requests. Especially, they can be:

- road infrastructure („roadside”);
- emergency system;
- external service providers;
- measuring systems;
- multi-modal transport structure;
- travellers.

Figure 3.1 illustrates example data exchange in an integrated traffic and road transport management system. In order to describe data exchange, the following have to be distinguished:

- communication channel, i.e. physical data transmission medium;
- location, data source and sink, i.e. place where data originates or is received;
- physical interfaces, i.e. system elements enabling data exchange.

Systemic characteristics of data exchange processes requires dividing that area in two:

- internal communication, comprising data exchange between system's diversely located elements,
- system-terminator communication.

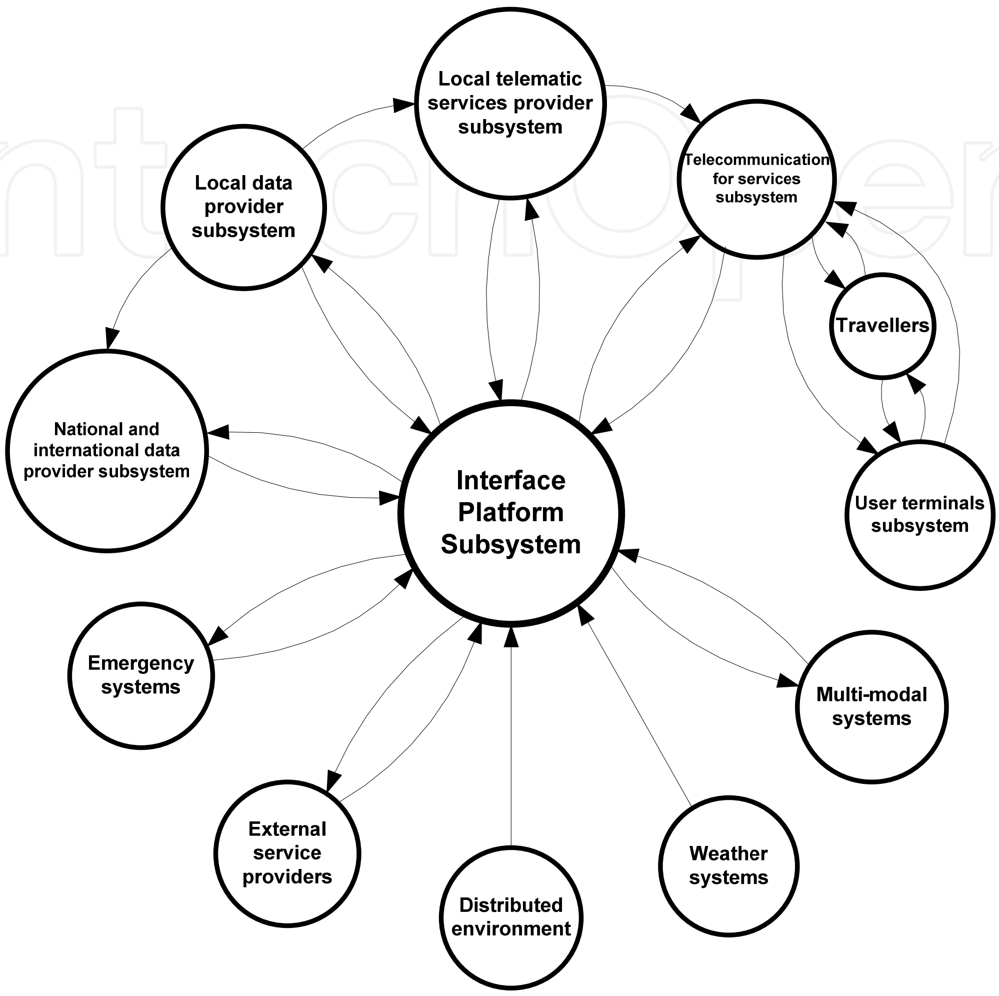

Fig. 3.1. Data exchange in an integrated traffic and road transport management system (Wydro K. B., 2003)

3.3 Communication structure of highway telematic systems

Another example of telematics-based data flow is data exchange between highway management centres and highway telematic systems. Highway management centres are centrepiece and the most important elements of highway telematics infrastructure (Highway Management Center/ Traffic Management Center). A centre receives any data from telematic systems located along a highway, and manages as well as operates those systems. Using dedicated devices and software, variable message signs and cameras placed along supervised section can be controlled. The centre can also process emergency calls and have systems for collecting and analysing weather data. It also carries out functions of comprehensive highway monitoring systems and provides information to users (drivers) (Wawrzyński W., Siergiejczyk M. et al., 2007).

Among highway management centres' functions are:

- traffic management;
- weather and traffic conditions monitoring;
- road surface monitoring;
- emergency situations management (accidents) and emergency calls processing;
- providing information to travellers both before and during the journey;
- visual highway monitoring and adequate reactions;
- maintenance services management.

An important aspect concerning highway management centre is its location. Centres are located about every 60 km. The reasoning behind such practice is to assure maximum distance of an accident from the nearest centre to be less than 30 km. Close proximity from centres of maintenance and emergency services additionally further the case. Nevertheless, in some cases big highway traffic monitoring and surveillance centres form, whose range reaches up to several hundred kilometres. Also important is for the centre to be located in heavily populated areas and on their periphery due to availability of highly qualified staff and infrastructure elements.

Usually, the infrastructure of a modern highway management centre combines routers, servers, LAN workstations, high resolutions screens with dedicated controllers and drivers, peripheral devices and other network devices and an array of telecommunications connections. Most crucial is the router, which is charged with receiving, transmitting and routing packets in the network. Servers can support routers, and what is more, they are equipped with high capacity hard disks enabling video recording. They also support local network workstations and execute automated processes of telematic systems. Dedicated servers are also used to process pictures captured by surveillance cameras, which replaced thus far used analogue devices (multiplexers, video splitters). On centre's walls hung are high resolution screens, which display CCTV footage, feed from different applications, maps showing position of highway patrol vehicles etc.

An important element of management centre's architecture, are workstations performing the function of a dispatch station operated by qualified staff. Powerful PCs equipped with computer monitors and keyboards are used. A reliable operating system is also crucial. Dedicated console or station built-in workstations are also often used. Using specialist software, an operator can monitor and analyse data from weather stations and roadside sensors. Moreover, thanks to the Internet current weather in the country can be previewed – the system automatically generates alerts and takes action, thus aiding human decisions. Using the workstation, an operator can manage messages displayed on variable message signs, RDS/DAB (*Radio Data System/ Digital Audio Broadcast*) system messages and operate a parking guidance system. Chosen stations can process emergency calls from the highway communication system without having to use dedicated dispatch stations. After the call is answered, the number of column issuing the report is displayed on the computer screen. The conversation is held by using headphones with microphone connected to a computer and saved to the hard drive. The number of stations processing emergency calls should be sufficient to assure instant connection with the dispatcher.

In order for the highway management centres to function efficiently, data transmission has to be assured (figure 3.2). Communication with telematics-based highway systems is crucial (emergency communication, traffic-related weather forecasts, video surveillance) as is data

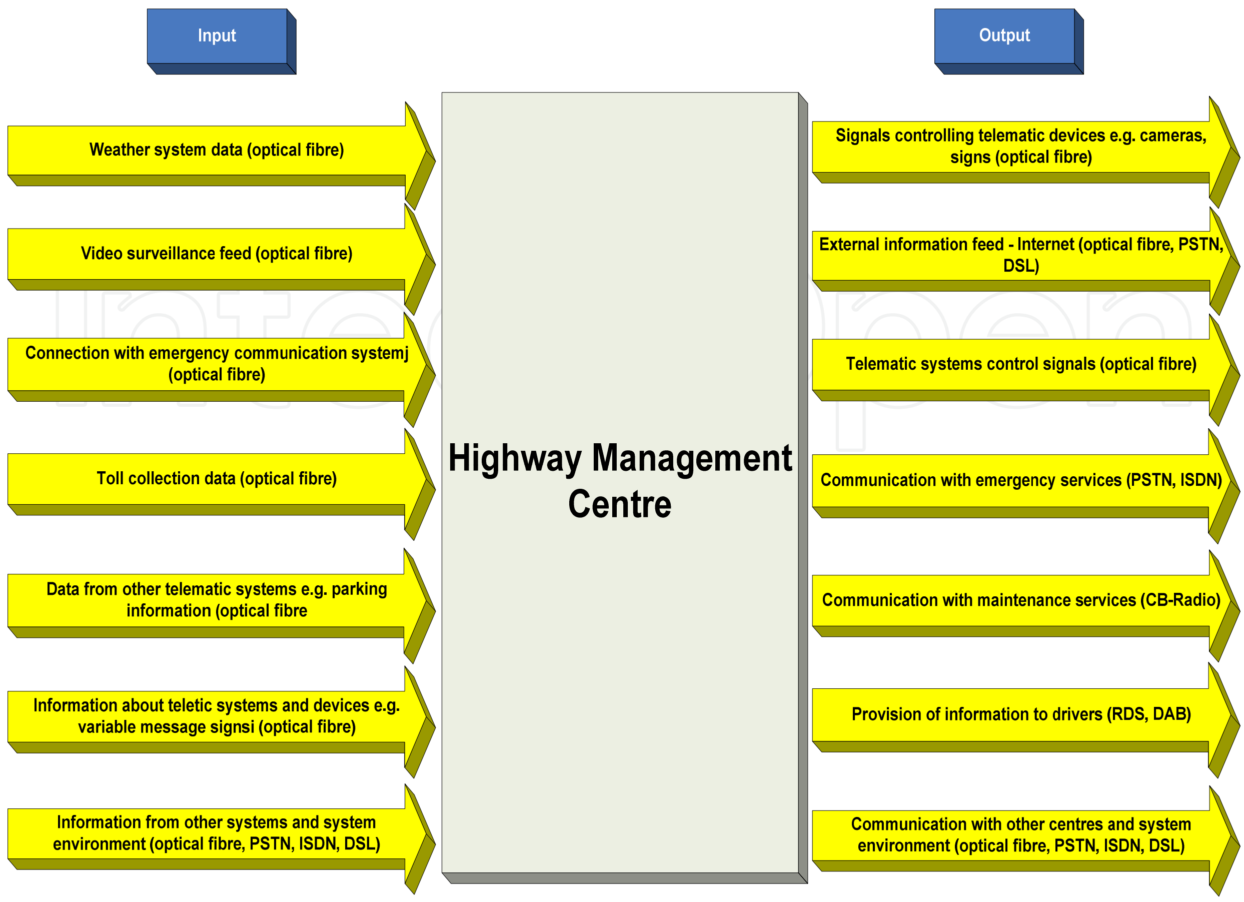

Fig. 3.2. Data transmission in highway management centres

exchange with other management centres, which currently is enabled by optical fibre running along a highway. Subsequently, signals are converted, decoded and read by dedicated applications (Siergiejczyk M., 2009).

Communication with emergency services is also important, which has to be direct. Connection is established instantly upon operator's call. The PSTN (*Public Switched Telephone Network*) telephone network is used for that purpose, and more modern systems use the ISDN network (*Integrated Services Digital Network*) with the "hot line" service. To communicate with regional maintenance service the CB (*Citizen-Band*) radio communication is used (long-range antenna fitted to rooftops).

4. Communication infrastructure in rail transport

4.1 Introduction

Railway operators almost always have used means of communication to provide efficient rail services. It is clear, that communication have been a tool, which to a great extent streamlined rail traffic management. Along with rail network development and technical advancement of telecommunications, those tools seem to have penetrated the transit process and are deeply embedded in rail transport. E.g. rail traffic control. Currently, the introduction of TCP/IP- enabled *(Transmission Control Protocol/Internet Protocol)* networks have contributed to deploying telecommunications services in the processes of transport and customer (passenger) service. Examples are data centres, recovery data centres, and virtual private networks dedicated for individual railway sectors or even applications (train tracking, consignment tracking, online tickets booking etc.). Those services increase the competitiveness of rail carriers and railway companies. The above-mentioned example services could not be provided without an adequate telecommunications network (in this case TCP/IP-compliant networks).

Building a telecommunications network is a process, which once started – according to experience – has to be constantly continued. It is "induced" by several facts (Gago S., Siergiejczyk M. , 2006):

1. Telecommunications infrastructure is meant to last many years, e.g. telecommunication cables (both conventional and optical fibre) are used for several dozens of years.
2. Such long usage of optical fibre cables (over twenty years) will cause over that period telecommunication services to evolve and develop, as it was seen in case of telephone networks. Originally, telephone networks provided only voice broadcast services, subsequently joined by telefax and ultimately complemented by the ISDN networks (voice broadcast and data transmission). In the nearest future, voice broadcast services will be provided only through convergent networks – *„voice over packet*".
3. Technological advancement of telecommunications networks causes new generation networks NGN (Next Generation Networks) to form, which are capable of handling every telecommunications service. In a different domain, the technological advancement leads to creation of optical internet networks supporting DWDM *(Dense Wavelength Division Multiplexing)* systems using GMPLS *(Generalised Multiprotocol Label Switching)* protocol, i.e. so called IP over DWDM.
4. Requirements of telecommunications systems (teleinformatic, telematics) users are ever-increasing in terms of provided services, illustrated by words
   - now,
   - everywhere,
   - free of error,
   - safely.

Due to those reasons, core telecom network designers have to accommodate the following:

- quantitative and territorial network expansion,
- qualitative network development i.e. possible technological advancement in terms of teletransmission, switchgear and managing devices,
- advancement in terms of creating and introducing new teleinformatic services to the network e.g. database services (CDN – *Content Delivery Network*, SAN – *Storage Area Network*) etc,
- implementation of ever newer and better secure data exchange and processing systems.

Physical telecom/teleinformatic/telematics rail network (hardware) should be built in such a way, to accommodate current and future services demanded by users:

- Telecommunications,
- Teleinformatic,
- Telematics.

The role of communication devices is accurate data transmission over specified time from transmitter to receiver. Both transmitter and receiver can be people, devices, different IT, telematics and information systems etc. In modern, digital telecommunications, application systems decide on transmitted data interpretation. Data can be interpreted as part of voice, video, control signal etc.

4.2 Systems and telecommunications services of the infrastructure manager

Systems and devices necessary for efficient controlling, routing and managing railway traffic, using telecommunications technology can be classified as follows:

1. Railway traffic controls.
- station equipment,
- wire equipment,
- regional equipment (remote control and dispatch),
- level crossing traffic safety equipment,
- CCTV equipment for monitoring level crossings,
- CCTV equipment for end-of-train detection,
- train control equipment.
2. Telephone service communication equipment.
- traffic control communication:
  - announcement communication,
  - train radio communication,
  - station communication,
- dispatch communication,
- conference communication.
3. Telematics-based devices (systems) concerning safety and comfort of people and goods.
- train emergency systems,
- signalling devices:
  - fire alarms,
  - anti-theft system,
  - burglar alarm,
- traction substation control devices,
- railroad switch warming devices,
- non-traction energetics control devices (station and platform lighting etc.),
- CCTV equipment for monitoring immobile and mobile railway stock.
4. Communication devices and systems related to traffic and company management.

4.3 Wired communication systems

Telephone network

Thus far, the role of communication related to traffic and company management was played by:

- general-purpose telephone network available for virtually every employee. It is a means for the employees to communicate internally and with entities outside the railway,
- telephone traffic network, for traffic-related communication, i.e. employees directly dealing with train traffic, traffic safety assurance e.g. so called train radio cammunication,

- telephone dispatch network assisting train control and management, almost exclusively used by dispatchers,
- teleconference phone network assisting operational company management.

The services provided by the aforementioned networks are still going to be useful and used in transport and company management processes.

Data transmission networks

Railway companies operate generally nationwide. Their management is computer-aided. Data required by those systems have to be collected nationwide also. In order to do that, a data transmission network is needed. Quality_of_service of data transmission has to cater for particular applications. Factors, taken into account in service quality evaluation are first and foremost the BER (*Bit Error Rate*) and data transmission latency. Preferred currently are TCP/IP-compliant convergent networks. Via that network, not only conventional data transmission services can be provided but also other teleinformatic services, which were created over the course of telecom, IT and media services convergence e.g. e-business, e-commerce, e-learning, CDN, SAN etc.

4.4 Wireless communication networks

Analogue radio communication

Wireless communication systems operating in 150 MHz band are currently used for railway needs. That band, divided into adequate number of channels is used for a range of different radio transmission technologies and applications, intended both for train control (train radio communication) as well as managing individual applications in different railway sectors (switch control radio communication, maintenance, Railroad Police etc.). Analogue communication is technically and morally outdated and increasingly expensive (due to channels in 25 kHz steps, however a change is planned to 12.5 kHz steps and in the technology itself).

GSM-R digital cellular network system

Under Polish conditions, the GSM-R system is going to be the direct successor of the aforementioned wireless communication system. The GSM-R system is a wireless convergent network, which enables voice broadcast and data transmission services. Both those services are commonly used in European railway companies, which have already implemented those systems. The technology of deploying that system without having to disrupt transport, requires introduction of additional, detailed temporary procedures. That temporary period can take least a few years.

GSM-R networks are already operational worldwide, including European countries. In the nearest future, the GSM-R is planned to be built in Poland as well. Currently used at Polish Railways communication uses 150 MHz band which reached its maximum capacity, hence does not meet today’s technical requirements, norms and standards, and lacks the necessary functionalities. The quality of connection is unsatisfactory. Major difficulties start to show upon crossing the country border. Consequently, either the train radiotelephone or the locomotive has to be replaced for one, which supports the type of communication used in the given country. The UIC *(French: Union Internationale des Chemins de fer)*, or International Union of Railways envisaged predominantly the unification of European train communications systems by deploying the EIRENE project (*European Integrated Railway radio Enhanced Network*) (UIC EIRENE FRS, 2006). Implementation of GSM-R translates into tangible financial benefits for the railway industry. Railway line capacity improves substantially, border crossing time shortens to minimum. Concurrently, the service quality improves (e.g. by introducing consignment monitoring). There is a possibility to deploy applications capable of: automatic barriers control at level crossings, direct video feed from unattended railway crossings to the train driver, or voice messages communication over platform speakers. By using those solutions, train traffic safety increases considerably. Implementation of railway-dedicated mobile communication system will be the milestone for Polish railway transport, allowing it at the same time to technologically catch up Western Europe.

GSM-R is a digital cellular network system dedicated for railway transport. It provides digital voice communications and digital data transmission. It offers expanded functionalities of the GSM system. It is characterised by infrastructure located only in close proximity to rail tracks. In order to counteract electromagnetic interference, the 900 MHz frequency was used. GSM-R is intended to support deployed in Europe systems: ERTMS (*European Rail Traffic Management System*) and ETCS (*European Train Control System*), which is charged with permanent collection and transmission of rail vehicle-related data, such as speed and geographic location. GSM-R as part of ETCS mediates in transmitting information to the train driver and other rail services. By deploying the above-mentioned systems, train traffic safety increases considerably, real-time vehicle diagnostics is possible along with consignment and railroad car monitoring. Moreover, railway line capacity at individual lines substantially increases due to accurate determination of distance between trains (Bielicki Z., 2000).

Three fundamental types of cells are used in GSM-R systems. They were illustrated in figure 4.1 The first (1) are cells, which are assumed to cover only the railway line area. They are characterised by elongated shape and small width. The second (2) are cells covering station areas and partially railway lines. They are usually circular or elliptic. The third (3) are large cells, covering railway areas such as sidetracks, railway building complexes etc. Every type of cell supports all types of radiotelephones. Size and shape of cells can be altered by adjusting telepowering or using omnidirectional antennas, either broadband or linear. The GSM-R system is intended for railway applications only, thus the coverage does not exceed railway areas.

Data transmission in GSM-R provides four fundamental groups of services: text messages, main data transmission applications, automated faxes and train control applications. Text messages can be distributed in two ways: point-to-point between two users or point-to-multipoint to many users simultaneously. Data transmission service concerns remote on-board and traction devices control, automatic train control, railway vehicle traffic monitoring and passenger oriented applications. Passenger-oriented services can feature schedule information, weather information, Internet access. Known from public solutions, GPRS and EDGE packet transmission services were introduced to the GSM-R network. GSM-R normative documents stipulate minimum data transmission rate of 2.4 kbit/s. Moreover, railway communication network gives an option of implementing packet data modes such as GPRS or EDGE. Those standards were discussed in the previous chapter. In the GSM-R system, both the infrastructure and data transmission mode bear no difference to those used in public cellular networks.

Infrastructure of railway mobile communication, in principle resembles the one used in public GSM networks, however, in order to provide rail services they had to be complemented with certain elements: group call register (known also from GSM Phase 2+), functional addressing register, dispatcher centre and elements supporting the ATC (*Automatic Train Control*). GSM-R system elements communicate with each other via Signalling System No 7 (SS7) (Siemens, 2001).

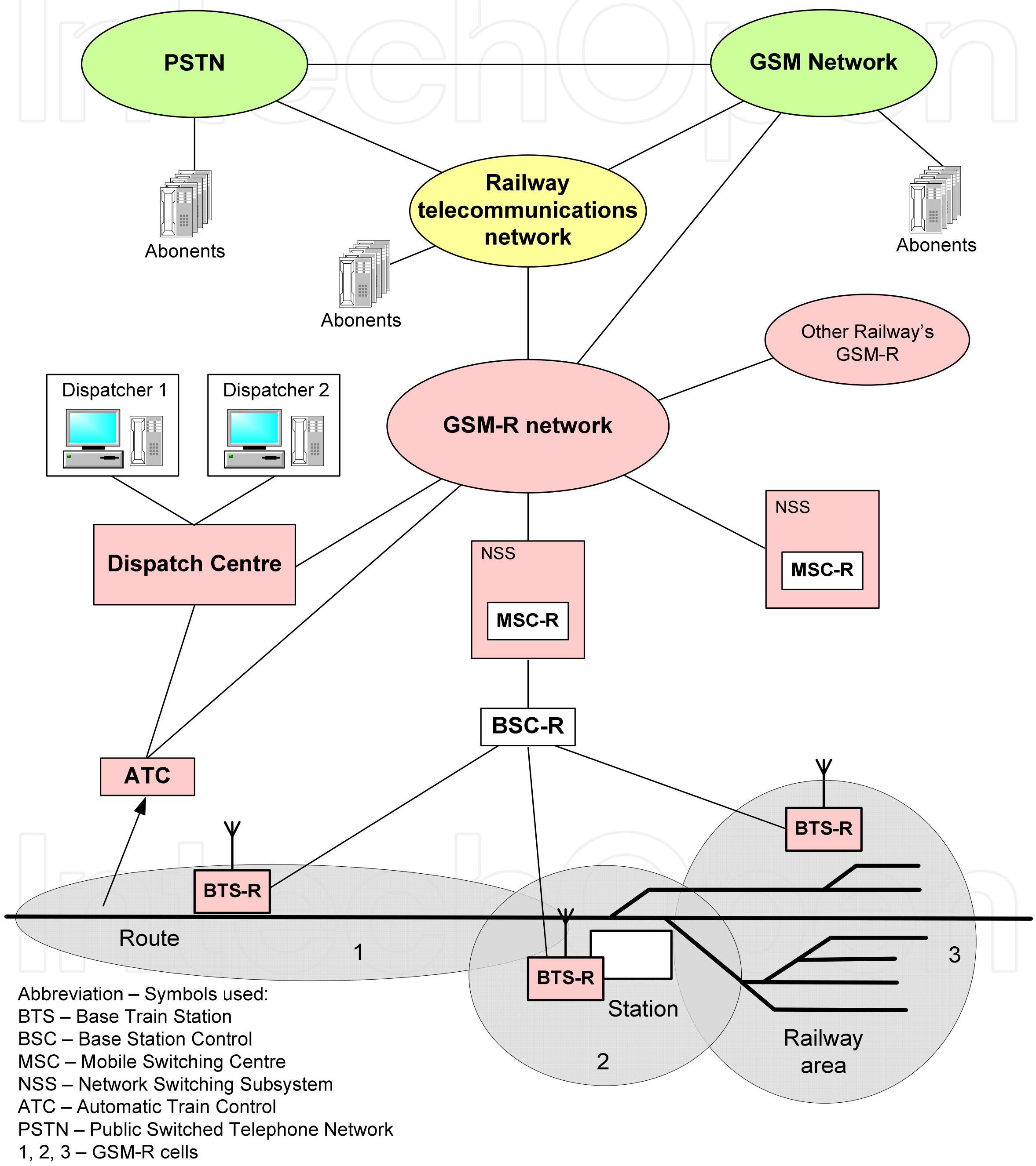

Fig. 4.1. Diagram of GSMR network at Polish Railways

Among the most important GSM-R services are (Urbanek A., 2005):

- point-to-multipoint communication, i.e. voice broadcast call

- functional addressing , where functional numbers are given to each user, by which they are identified based on their function;
- voice group call, point-to-multipoint, call set-up over a duplex connection,
- high-priority calls, which are quickly set-up. Set-up time should not exceed one second. The eMLPP (enhanced Multi-Level Precedence Pre-emption) mechanism prioritises the calls;
- position locating through transmitting short ID numbers of the base station, where the train currently is;
- emergency call. Those are calls of highest possible priority. They are made in case of an emergency.
- short message service known from public GSM networks have been deployed in railway network to i.a. transmit encoded messages, imposing execution of different actions related to railway vehicle control;
- Direct Mode communication enabling communication without a fixed mobile system infrastructure.

GSM-R can also handle diagnostic data transmission: data collection from measuring instruments located in various parts of railway vehicle, collected data bundling and transmission of collected diagnostic data over the GSM-R network to Maintenance Centre.

4.5 Teleinformatic services for railway transport

Teleinformatic and telematic services related to:

- traffic control,
- train control,
- company management,
- collaboration with carriers

Along with those services' parameters should give guidelines for building telecommunication networks catering for needs of companies operating in the railway transport sector, both the physical layer i.e. optical fibre cables and the data link layer i.e. transmission systems (e.g. SDH, Ethernet). As experience would suggest, there is currently – in every aspect - no better transmission medium than the optical fibre (broadband – several THz, low attenuation etc.). Solely on those grounds, an investor deciding to build a network of optical fibre cable should use that medium to a maximum extent. Due to Railway Company characteristic applications, broadly defined terminal devices are included in data transmission process, thus protocols of network and transport layers of the aforementioned ISO/OSI model (e.g. IP, TCP, UDP protocols) will be also used.

According to TSI requirements: "the originator of any message will be responsible for the correctness of the data content of the message at the time when the message is sent. (...) the originator of the message must make the data quality assurance check from their own resources (...) plus, where applicable, logic checks to assure the timeliness and continuity of data and messages". Data are of high quality, if they are complete, accurate, error free, accessible, timely, consistent with other sources and possess desired features i.e. are relevant, comprehensive, of proper level of detail, easy-to-interpret etc.

The data quality is mainly characterised by:

- accuracy,
- completeness,
- consistency,
- timeliness.

Accuracy

The information (data) required needs to be captured as economically as possible. This is only feasible if the primary data, which plays a decisive role in the forwarding of a consignment, a wagon or a container, is only recorded, if possible, on one single occasion for the whole transport. Therefore the primary data should be introduced into the system as close as possible to its source, e.g. on the basis of the consignment note drawn up when a wagon or a consignment is tendered for carriage, so that it can be fully integrated into any later processing operation.

Completeness

Before sending out messages the completeness and syntax must be checked using the metadata. This also avoids unnecessary information traffic on the network.

All incoming messages must also be checked for completeness using the metadata.

Consistency

The owner of the data should be clearly identified. Business rules must be implemented in order to guarantee consistency.

The type of implementation of these business rules depends on the complexity of the rule. In case of complex rules which require data from various tables, validation procedures must be implemented which check the consistency of the data version before interface data are generated and the new data version becomes operational. It must be guaranteed that transferred data are validated against the defined business rules.

Timeliness

The provision of information right in time is an important point. Every delayed data looses importance. As far as the triggering for data storage or for message sending is event driven directly from the IT system the timeliness is not a problem if the system is well designed according to the needs of the business processes. But in most of the cases the initiation of sending a message is done by an operator or at least is based on additional input from an operator (e.g. an update of train or railroad car related data). To fulfil the timeliness requirements the updating of the data must be done as soon as possible also to guarantee, that the messages will have the actual data content when sending out automatically by the system. According to TSI the response time for enquiries must be less than 5 minutes. All data updates and exchange must be done as soon as possible. The system reaction and transmission time for the update should be below 1 minute.

Currently almost all teleinformatic services have to be protected against:

- data modification,
- data destruction,
- data interception.

Due to its core activity, Infrastructure Manager has to prioritise data security issues. All data concerning controlling, monitoring, and management of train traffic have to be protected at each layer of the ISO/OSI model. Perhaps train control devices and systems are equipped with autonomous security systems, nonetheless data transmission process has to be secured. Other systems e.g. company management aiding systems should also be protected, because they contain critical company data, e.g.:

- financial data,
- development plans,
- pricing plans,
- network topology,
- device authentication data etc.,

or companies are legally obliged to protect them – e.g. personal data.

Telecommunication services, which are and will soon be provided to the Infrastructure Manager, can be listed as follows:

- telematic services (control, monitoring),
- telephone services,
- data transmission services,
- information services,
- multimedia services (e.g. videoconference).

Competition, clients and technical advancement induce informatisation of the Infrastructure Manager i.e. deployment of ERP, CRM class systems or other, aimed at improving company competitiveness. Company informatisation has its share in reducing overheads through so called database services. They require the data to be constantly available and always up-to-date. In order to assure both, IT devices are needed e.g. servers and teleinformatic networks.

Among database services, which are set to become tools used in a company acting in capacity of Infrastructure Manager are:

- Data Centre – various databases e.g. clients database, assets database, employee database etc. Databases have to be systematically updated.
- Recovery Data Centre – recovery databases, which have to be synchronised with the main database.
- Content Delivery Network – servers, databases containing information for:
  - clients,
  - employees,
  - business partners.

In those cases, data access through telephone is limited to relevant groups of interest.

- Storage Area Network – well-protected memory resources warehouses placed in adequately adapted rooms. Those warehouses store data, which are available exclusively to data owners.
- Industry portal – contains information about a company's commercial activity in terms of completed tenders for services or supply of materials and devices. Companies, which would like to offer their services to or collaborate with the PKP PLK company, can

advertise through that portal. Their offers may concern e.g. supply of materials, provision of services, prices, ads etc.

- B2B e-commerce. This service allows buying, selling and payments online.
- Contact Centre – is a touchpoint, an interface of a service provider – in this case PKP PLK – with the client. Currently, this service has strong growth dynamics worldwide.
- E-learning – a service useful in training staff, allowing to communicate e.g. rationale behind board's or senior employees' decisions.
- Virtual Private Network – virtual application-dedicated networks. This service substantially increases application security, at least because of limited access (only authorised users/entities can access the application).

Generally all the above-mentioned services can be provided through adequately designed, TCP/IP-compliant convergent network equipped with powerful hardware. Adequately designed and equipped TCP/IP network is capable of assuring equally adequate security:

- infrastructure security (connection and node redundancy with specific switch-over times in physical, connection and network layers),
- data security – thanks to relevant devices (BER appropriately low, below 10^{-12} – practically of $10^{-15} \div 10^{-17}$ order), IPSec type protocols, TLS etc., and using appropriate encryption of key size up to 256 bits.
- data traffic security – thanks to adequate architectures and protocols (Diffserv, MPLS, RSVP –*Resource reSerVation Protocol* enabling traffic engineering e.g. multiple priority queue management.

5. Communication networks in air traffic management systems

5.1 Introduction

Air transport is one of those transport sectors, which experience dramatic growth in provided transport services. Increased demand for both people and goods transport causes air operations volume to grow by over a dozen percent year-on-year.

For many years, a solution to the airspace capacity problem have been on agenda of air traffic engineers. The underlying assumption, however, is that no action they undertake, can cause decrease in air traffic safety and high probability of air collisions. Hence a higher number of aircrafts within individual sectors, is only acceptable should concurrently data transmission systems, informing about situation in individual sectors of airways be improved.

The ever-increasing air traffic volumes, entails the necessity to modify existing air traffic management systems. The changes on the table are of organisational and procedural nature, and involve modifications to existing ICT-aided management systems, used to assure smooth and safe air traffic. Commercial aviation is possible thanks to aeronautical fixed telecommunication networks, as they enable data exchange between groundcrew, without which aviation could not operate. It is the groundcrew, between which over 90% of information related to flight safety is exchanged. Collection of atmosphere and airport-related information, services availability, imposed restrictions and subsequent teletype message transfer is possible due to aeronautical fixed telecommunication networks. Flight plan reporting and processing, air traffic control coordination are merely a part of the entire torrent of information (Sadowski P., Siergiejczyk M., 2009).

The notion of aeronautical communication is mostly associated with air-ground communications. In reality, an equally important and even more extensive are ground data networks. In order to assure a safe flight, all services need to communicate with each other, namely: aeronautical information service, weather station, air traffic controllers, and many other airspace users. Network technology heavily influenced the way information is being exchanged today in air transport. That is because computer networks enable creating, expanding and modernising ground systems assuring smooth and safe air traffic. Development of aeronautical telecommunication networks aims to integrate networks and services operating as parts of national air traffic control systems, and in the future to extend those solutions to airborne aircrafts.

5.2 Telecommunication networks in air traffic management

The X.25 protocol was a widely used communications protocol in aviation. It was used in backbone networks transmitting teletype messages – AFTN, SITA, OLDI *(On Line Data Interchange)* systems, radar data transmission systems (ASTERIX over X.25) and aircraft charging systems used by the *Central Route Charges Office* (CRCO).

The The AFTN (*Aeronautical Fixed Telecommunications Network*) network uses an old technology – telex. The AFTN messages transmission protocol is a set of rules, which guarantees consistency of exchanged data and provision of information to receivers according to hash tables. This protocol derives from obsolete (still used in aviation and marine NAVTEX system, delivering meteorological information) ITA2-based teletype transmission mechanisms. All air traffic control services are main AFTN users, who predominantly request information about filed flight plans and flight status (take-off, delay, landing), emergency situations and issues teletype messages concerning take-off, delays and landing. Meteorological offices provide AFTN with TAF and METAR teletype messages, using information from other offices themselves. NOTAM offices generate NOTAM and SNOWTAM teletype messages. Briefing offices feed NOTAM, SNOWTAM, TAF and METAR information to the pilots. Airline operators often have their own operating divisions, which use the same information as briefing offices do. Civil aviation and the air force authorities also own AFTN terminals. The CFMU (*Central Flow Management Unit*) – European air traffic management system, which issues slots – is predominantly communicated with via AFTN (Sadowski P., Siergiejczyk M., 2009).

A modernised version of AFTN, which breaks with the telex tradition, is the CIDIN (*Common ICAO Data Interchange Network*). Development of that solution had begun already during the 80's, however, it is being implemented into commercial use now – CIDIN was implemented in Warsaw in May 2002. From the AFTN end-user perspective, introduction of CIDIN entailed swapping an old computer terminal for a more modern one, equipped with characteristic liquid crystal display. Real changes came in form of data transmission method. CIDIN brings civil aeronautical network closer to the standard, internet user have long been familiar with. The previously used standard was the telex protocol, however, currently the network is based on either TCP or IP X.25. It resulted in considerably higher data transmission capacity and reliability – max capacity is currently 64 kbps. Both in Poland and most countries in the world, the standard is 9600 bps – completely sufficient at current network usage intensity.

The OLDI (*On Line Data Interchange*) system is responsible for communication between neighbouring traffic control areas. Precisely speaking – interconnected air traffic control systems. It replaced voice information exchange concerning control hand-off over aircrafts en route (EUROCONTROL/IANS, 2006). The system leans on exchanging i.a. ABI (*Advanced Boundary Information*) teletype messages – informing the ATC (*Air Traffic Control*) system about an aircraft approaching the handover point.

Due to low data transmission error level, it could be used for connections characterised by low technical parameters. The protocol's drawback was its feature – connectivity. Prior to data transmission, connection between communicating devices had to be established by using a dedicated connection.

Due to current development of local and wide area network infrastructure and used high-reliability transmission media, Air Traffic Management (ATM) systems are being introduced with datagram data transmission technologies. Wide area networks can be built as multi-component structures thanks to the IP protocol. Those structures are built using different technologies – both standard and very unconventional. That flexibility is possible due to developed network protocol stacks (TCP/IP), which is supported by the majority of hardware and software platforms.

The above-mentioned actions cause the X.25 protocol to be withdrawn from many aviation applications in favour of the IP protocol. Another powerful fact acting to disadvantage of the X.25 protocol, is that manufacturers of hardware (X.25 switches) supporting the protocol discontinued their sale and the technical support for X.25 solutions will have been unavailable by the end of the XXI century's first decade (EUROCONTROL/IANS, 2006).

Because aeronautical data transmission is inherent to ATM, the above-mentioned factors affect considerably air traffic management systems (ATM). Thus, many key for ATM systems will be subject to modification in the future, in a bid to adapt them to IP data exchange technology. Among the systems, which first should undergo modification are:

- surveillance data distribution systems: ARTAS, RMCDE (*Radar Message Conversion and Distribution Equipment*), ASTERIX-compatible radar stations (*All Purpose Structured Eurocontrol Surveillance Information Exchange*),
- aeronautical teletype message distribution and airport planning systems
- existing: AFTN, CIDIN, WPPL,
- implemented at PAŻP (*Polish Air Navigation Services Agency*): TRAFFIC (PANSA, 2008),
- weather information distribution systems,
- air traffic control systems: PEGASUS_21 (PANSA, 2009),
- airspace management system: CAT (*Common Airspace Tools*) (PANSA, 2008),
- aircraft charging system: CRCO.

5.3 The concept of IP protocol migration and implementation into ATM systems

In 2001 at EUROCONTROL the IPAX working group was set-up to develop a plan of IP protocol migration and implementation into ATM systems. It was charged with adapting industrial standards of packet (IP) data transmission to data exchange standards in ATM/CNS systems (*Air Traffic Management / Communication Navigation Surveillance*). IPAX group's action plan included:

- transition from X.25 network layers to IP with its integral security mechanisms,
- modification of existing applications and systems so they would be compliant with secure IP networks (developing interfaces of existing systems with IP networks),
- maintaining application interfaces for operational users in order to protect investments put into ATM systems.

One of the earliest modifications made in relation to X.25 protocol replacement with the IP protocol, was the change implemented into the OLDI (*On-Line Data Interchange*) system. The OLDI system has been operating using the X.25 protocol, which was implemented with a higher layer protocol – FDE (*Flight Data Exchange*). Due to X.25 layer replacement with the IP layer, the higher layer protocol was also reimplemented. In order to adapt the OLDI system to packet data transmission, the FDE protocol was replaced by the FMTP protocol (*Flight Message Transfer Protocol*) (EUROCONTROL, 2008).

ANSP (*Aeronautical Service Provider*) centres across Europe are envisaged to ultimately be introduced with that change. Its deployment overlaps with requirements stipulated by the FDE/ICD (*Flight Data Exchange/Interface Control Document*) and it is the fundamental requirement of the COM-04 objective contained by the ECIP (*European Convergence and Implementation Plan*) document. During transition to FMTP, Eurocontrol will support FDE-based solutions (OLDI over X.25) until OLDI over TCP/IP is activated Europe-wide (see figure 5.1.).

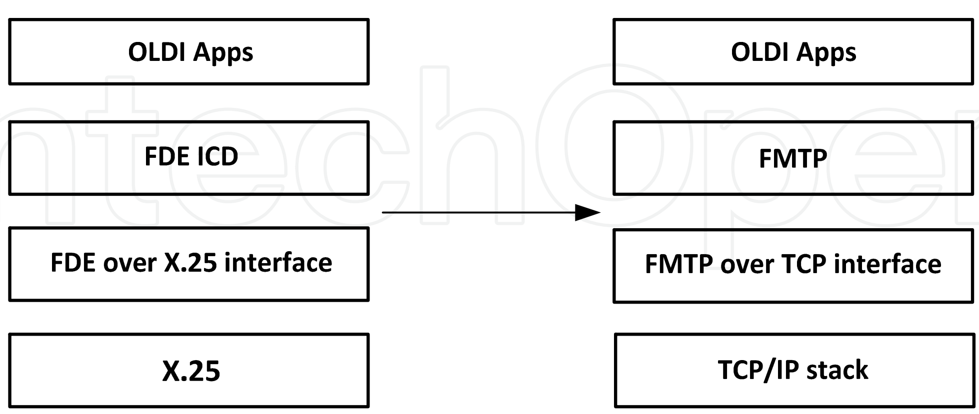

Fig. 5.1. FMTP implementation into OLDI system

The other large-scale change is modification of aeronautical teletype message distribution system – AFTN/CIDIN ground-ground network. That network is currently the main medium for flight plan forwarding and exchange of airport planning related data. That change aims to migrate the X.25 technology – used for establishing inter-centre backbone connections – to IP technology using AMHS (*ATS Message Handling System*) gateways. The IPAX group set about deploying that solution in PEN (Pan European Network). The task aims to build a global IP network supporting data exchange between air traffic management systems.

The system intended to replace the AFTN/CIDIN network uses the X.400 protocol implemented in IP networks. X.400 and AFTN network will be linked over the transition period via gateways converting teletype messages format between protocols - AMHS/AFTN GATEWAYS (Sadowski P., Siergiejczyk M., 2009). In figure 2.2 illustrates AMHS/AFTN network architecture.

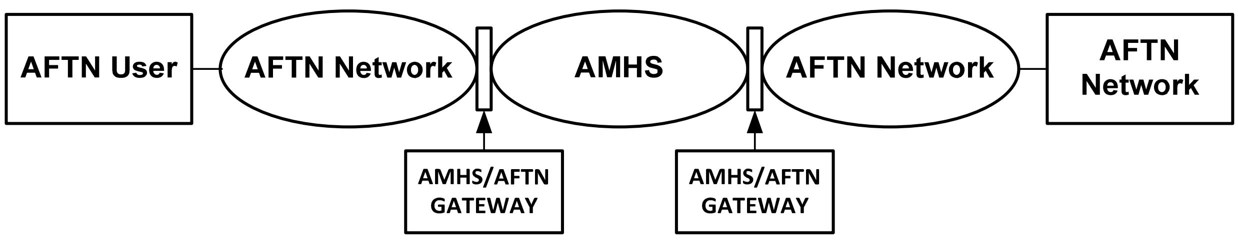

Fig. 5.2. AMHS/AFTN network architecture

In order to assure continuous operation and interoperability of two heterogeneous systems, AMHS/AFTN gateways have to have the following functionalities:

- two-way teletype message conversion,
- AFTN and AMHS teletype messages mapping and redirection
- connection to external AFTN/CIDIN centres and AMHS gateways,
- syntax validation and error correction,
- teletype message tracking and network traffic logging,
- API (Application Interface) for interoperability with other IT systems.

The AFTN protocol has many limitations. AFTN network adaptation to IP standards – and in higher layers to X.400 – yields a range of benefits, amongst which are i.a.:

- binary message forwarding,
- unlimited message size (1800 characters per AFTN message).

5.4 IP protocol in surveillance data distribution

ARTAS (*Advanced Radar Tracker and Server*) is a system designed to establish an accurate air traffic picture and to distribute the relevant surveillance information to community of user systems. It is a surveillance data distribution system using tracks (radar data reports about aircraft position). The ARTAS system has a distributed architecture, composed of co-operating subsystems, called ARTAS Units, which form a consistent estimate of air traffic situation, based on radar data reports. Radar data are collected from ARTAS Unit-connected radars (primary and secondary) either through the RMCDE (*Radar Message Conversion Distribution Equipment*) devices or directly. ARTAS Units and RMCDE devices are connected to the LAN/WAN network and can communicate over

TCP/IP protocols. ARTAS Units were implemented with the following functionalities (EUROCONTROL/IANS, 2007):

- tracker – processes radar data and presents the most current, air traffic situation, based on radar data reports,
- server – provides track and radar data to online users, and forwards radar data to the tracker.
- system manager – administers the ARTAS system.

ARTAS connections require constant data stream transmission, hence PVCs (*Permanent Virtual Circuits*) are used. Assuring continuity of data transmission is a significant issue. Routing mechanisms ensure possibly low redundancy. System nodes are connected by many alternative routes. In addition, every radar station has at least two connection points with the core network. Communication is established through access networks, which are independent for each node. Illustrated in figure 5.4 is the communication architecture between ARTAS Unit modules – ARTAS surveillance data distribution system.

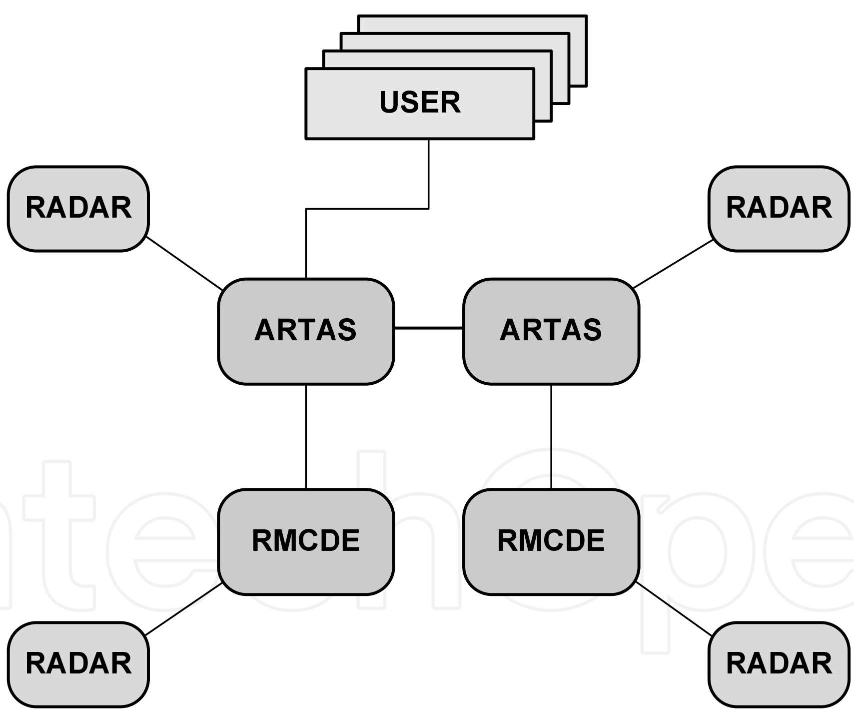

Fig. 5.3. ARTAS architecture

ARTAS modules communicate via a LAN/WAN network. ARTAS-connected users communicate with the modules also via TCP/IP protocols. ARTAS Units - kilometres from each other - are connected to a wide area network, and communicate via TCP/IP protocol stack.

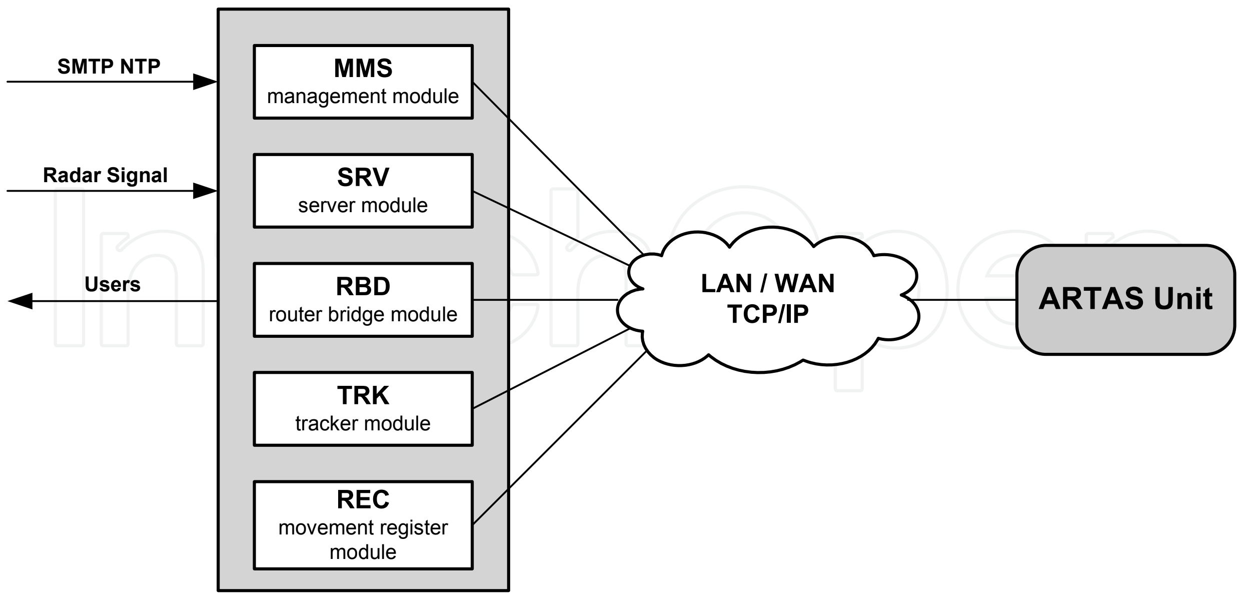

Fig. 5.4. ARTAS modules

5.5 Fibre channel over IP in civil aviation

SAN networks are centrepiece of creating backup data centres and efficient backup systems, due to high-volume data transactions between devices composing the solution. The technology central to implementation of SAN networks is the Fibre Channel protocol. It is a high-speed, serial dedicated interface connecting servers and mass-storage devices. Fibre Channel is a hybrid protocol i.e. network and channel protocol, defined as open ANSI and OSI standard. The channel is a closed and predictable mechanism transmitting data between a limited number of units. A typically set-up channel usually requires very little input for subsequent transfers, thus providing high efficiency. Very little decisions are made over the course of data transmission, enabling the channels to be established by the physical layer. The most popular channel protocols are SCSI (*Small Computer System Interface*) and HPPI (*High Performance Parallel Interface*). Networks are relatively less predictable. They adapt to changeable environment and can process many nodes, however, establishing communication channels between those nodes requires more decisions, resulting in significantly higher latencies compared to channel transmission (Sadowski P., Siergiejczyk M., 2009).

Fibre Channel model consists of 7 layers. Layer models (commonly known seven-layer ISO/OSI model) enable single layer operation, independently of the layer immediately beneath. Fibre Channel's layers meet ISO/OSI model specification and are divided into two groups: physical and signalisation layers (0-2) – FC-PH and Upper Layers (3-4) (Janikowski A. (2002).

FCIP (*Fibre Channel over IP*) is a mechanism tunnelling the FC (*Fibre Channel*) mechanism used in SAN (*Storage Area Networks*) in IP wide area networks. Such solution enables communication between scattered data centres, using secure network infrastructures (using

SSL, IPSec etc. mechanisms). FCIP protocol causes rapid development of wide area data exchange and storage networks, increasing at the same time capabilities and efficiency of built systems. Due to range of existing IP networks, FCIP enables building global data storage systems. In figure 5.5 is presented SAN architecture of ARMS and TRAFFIC systems.

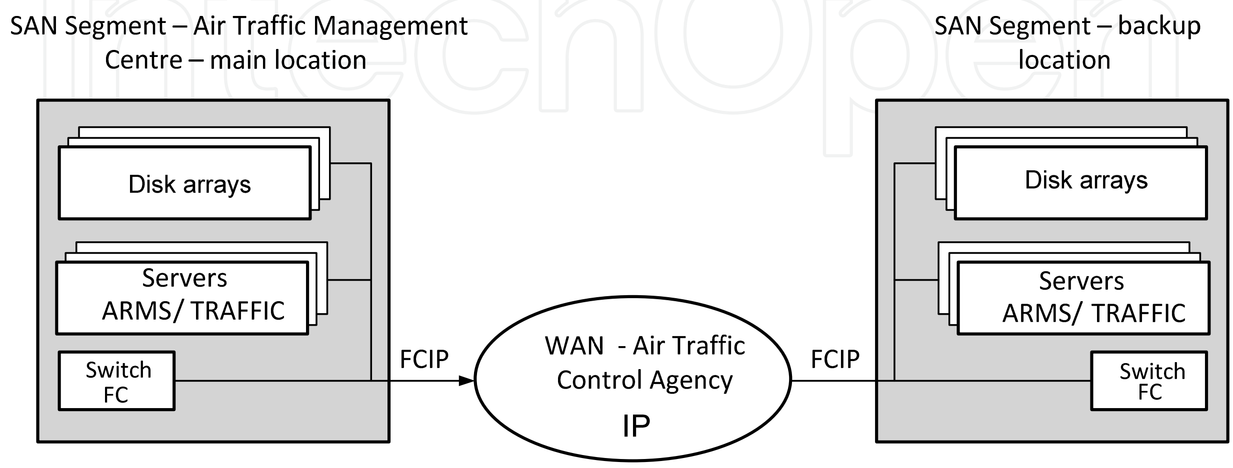

Fig. 5.5. SAN architecture of ARMS and TRAFFIC systems

Advantage of SAN/FCIP-enabled data transmission systems is first and foremost low cost of establishing connections over long distances and IP-native data encryption. Disadvantages of FCIP-enabled systems include data transmission latencies due to IP networks' characteristics and that transmission disruptions (connection malfunction) cause SAN network segments' segmentation.

Architecture design of SAN (fabric – segment of the SAN network) ARMS and TRAFFIC systems envisages interoperability enabling exchange of construction data, planned and real airspace restrictions. One of functional and technical requirements (PANSA, 2008). is the concept of a backup data storage centre, both for transactional and archival databases. That requirement is met with the Fibre Channel SAN architecture with data matrix relocated by the FCIP protocol outside the Air Traffic Management Centre. The concept of a backup data storage centre intended for an Air Traffic Management Agency is presented in figure 5.5.

Reconfiguration of existing systems, so they would use IP networks for data transmission, is aimed at achieving global interoperability of air traffic management systems. Unification of aeronautical data processing and exchange technologies is necessary to reach that objective. That process will have positive bearing on data processing time and will eliminate irregularities, which cause delays and inconsistency of air operations. Interoperable data exchange technologies used in ATM systems, will render feasible airspace unification programmes in Europe (SES – Single European Sky) and globally. The global AFTN message exchange network is a salient example. Its migration to AMHS standards, maintaining old infrastructure elements, enables forwarding teletype messages about planned air operations. In dramatic cases they originate from technologically out-dated teletype terminals and are fed to highly advanced AMHS systems.

6. Summary

An important issue facing transport in general is information exchange between supply chain actors. Enabling that information to be transmitted, requires creating data (information) exchange touch points (interfaces) and determining access privileges and methods for different entities participating in transport processes.

The ever-expanding range of applications for telematic systems poses – thus far difficult to evaluate – a potential, future risk to undisturbed functioning of transport telematic systems. The telematics-induced "networkisation" and integration of computer systems present a tangible and ever-increasing threat of both novel attacks taking advantage of network access and deliberate damage to critical system elements. Further development of telematics should take place in line with the "Fail-Safe" rule.

Systematic implementations of telematic technologies cause telematic systems to become a viable consideration for development of multimodal transport. A potentially limiting factor here can be the trend to use a single transport system in transport planning. However, one of the biggest obstacles impeding further development of transport telematics is the technology integration of different systems. This problem is driven by fast-paced innovation and mostly inadequate standardisation.

Touch points of different systems have to be normalised, functions and services standardised and costs analysed, all in a bid to allow such integration. It can stifle, however, development prospects for transport telematics. The solution comes in form of a gradual standardisation system, compatible at each stage. Benefits reaped from deployment of transport telematic systems could not be quantified, until their impact and results are recognised. Also, a line has to be drawn between telematics-related benefits for transport, environment, economy and the society, hence providing reasons for detailed economic analysis scrutinising implementation of transport telematic systems.

Providing telematic services supporting transport tasks and processes is one of fundamental tasks of transport telematic systems. The quality of telematic services in transport depends on network integrity, understood as the offered service being independent of the access method and the communications protocol. Regardless of how information is transmitted to the user, the service provided has to maintain constant parameters. Service quality of a telematic service should remain the same at different locations. Thus, a need arises to create and analyse functional-operating models in terms of availability and continuity of telematic services in transport.

The other problem obstructing further development of transport telematics is the typically long time of implementing the system. Deployment time often exceeds the total time needed to develop a new technology. Hence, as practice shows, a system might become technologically outdated by the time it is mature enough for practical applications. Effective technologies, however, should not be replaced by newer solutions if telematics was to develop. Many sectors manage to continue using obsolete, but proven technologies to their advantage, because a transition to new technologies would be too financially strenuous (e.g. flight and railway security).

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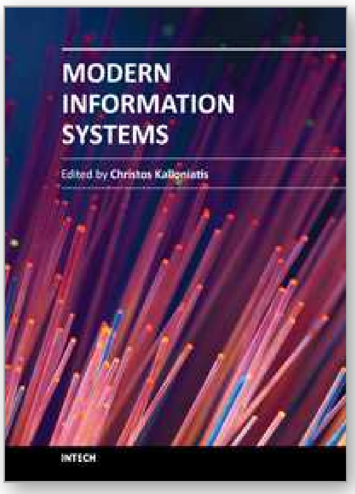

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