Guidelines for application and development

E-TRAIN - Broadband Communication with moving trains

Technical Report

Technology state of the art

Author: G. Barbu on behalf of the UIC E-TRAIN project team

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1 Executive summary

In a first instance, it is demonstrated that the satisfaction of the info-mobility of passengers is affordable with employment of a range of technologies capable of creating a standard WLAN connectivity inside the train and a broadband telecommunication link between the moving train and a track-side telecommunication service provider (e.g. internet provider). A second development is the data communication between the moving train and the ground operation services to improve the productivity, availability and maintainability of the rolling stock and introduce other services (such as dynamic seat reservation, e-ticketing, on-line crew assistance, security survey and other).

Technically, there are several options available to satisfy the broadband communication needs with moving trains.

It could either be created separate services for passengers and for the train needs (decoupled from technical and operational viewpoints) or set up a common technical arrangement capable of satisfying the two communication categories.

It has been an initial decision to leave the GSM-R and its specific migration outside from these problems, since the GSM-R is not, as a matter of fact, a broadband communication system, and its functions and capacity are especially conceived and realised to provide the radio carrier system for the safety related railway operations, ERTMS/ETCS messaging and stringent traffic control needs.

The E-train project has investigated the current stage of the needs and the options of the railway companies and train operators. It has also carried out the technology survey, in common with ESA who initiated the “Broadband for trains” ESA/ESTEC project in the framework of the ARTES-1 R&D program.

The document presents the state of the art of the needs and requirements for broadband communication of trains, the available technology and the migration trends of the technology.

The document includes also considerations with regards to the minimum Quality of Service in relation to the existing achievements and the best practice for passengers’ internet on trains. Although currently realised in heterogeneous technical frameworks (satellite Ku band communication plus gap-fillers, pure ground based train communication or even mixtures of techniques) the operators share the conclusion that the services addressed to travellers should be based on market connectivity standards in trains (e.g. WiFi 802.11g) as well as in stations or other relevant access points. It is also a conclusion that the train operators will cooperate with the broadband service providers to realise an end-to-end connectivity. It is also concluded that the IP technologies are the central technique to realise the converging networking capable of following up the migration in the mobile telecommunication domain.

The satisfaction of the increased needs for train-ground communication in the scopes of enhancing the productivity, availability and maintainability of the trains and also a better interaction with the railway infrastructure, remains a further option for future development.

It can be recommended that the future systems of the train-ground broadband communication will join the two problems on the same technical system, where the separation of the passengers’ data traffic (in a business vision) from the other operational communications can be safely realised with affordable networking technology. The existing and emerging technologies do offer such opportunities. As demonstrated in the document, the QoS for telecom services are the base for driving the dimensioning and detailed design of the future systems, with all their options and facilities for the customers, operators and other actors involved.

2 Abbreviations and explanation

Name or abbreviation	Explanation
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
ERTMS	European Train Management System
ETCS	European Train Control System
UIC	Union Internationale des Chemins de Fer / International Railway Union
MOWGLY	Mobile Wideband Global Link System
GSM-R	Global System Mobility – the Rail application of the commercial GSM standard
INTEGRAIL	EC integrated project for use of information in the railway system performance
WiFi	Wireless Fidelity – names the 802.11g standard radio link
WiMax	Names the 802.16 radio-communication standard
VPN	Virtual Private Network
VOIP	Voice transmission using the internet protocols
WLAN	Wireless Local Area Network
RAILCOM	EC R&D project / research on the electromagnetic compatibility in the railway area for train detection systems and radio-communication systems
DLR	German Aero-Space Agency (Deutsche Luft- und Raumfahrt)
ATP, ATS	Automatic Train Protection (System)
GPRS, UMTS	Next generation of mobile communication systems following to the GSM
TCP	Transfer Control Protocol
GPS	Or NAVSTAR, the USA satellite positioning system
HTTP	Hyper-Text Transfer Protocol
DNS	Domain Name System
NOC	Network Operations Centre
RU	Railway Undertaking
IM	Railway Infrastructure Manager
WSN	Wireless Sensor Network
QoS	Quality of Service
ITU	International Telecommunication Union

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4 Introduction

More and more, European citizens are demanding mobile access to broadband networks, including while they are travelling. The user is already accessing these services on the stations and airports, and the logic extension is their provision on board of trains during the journey.

More and more, the efficient operation and management of the infrastructure and rolling stock requires intelligent integration of real time information in the operational and decisional process.

All this has the consequence of significant increase of needs for communication between the moving trains and the track-side systems.

The data and information flow dedicated to passengers and to the real-time monitoring of the on-board technical systems exceeds by far the capacity of the existing standard train-ground communication system GSM-R. The system was initially dimensioned to correspond to the ERTMS/ETCS train control safety related functions. Even this radio system is now in the needs to increase its capacity such as to cover the safety communications in large, intense traffic and marshalling zones and in some trans-frontier areas.

Consequently, the railway undertakings, train operators and the infrastructure managers are in the situation to examine together the alternatives and to take options with regards to the future communication systems which should comply with their requirements. The major options to apply could envisage:

- To join the passengers' broadband communication with the train and vehicles' monitoring and diagnosis, crew communication and traffic optimisation data communication. The common approach could lead to a unique broadband telecommunication system on board, capable of satisfying the common needs.
- To decouple the passengers' dedicated services from the other telecommunication needs on board. This option could justify a phased approach where initially, the immediate commercially driven priorities could be satisfied. The other telecommunication aspects would be either added to the passenger commercial system or satisfied by additional systems, based on independent technical means.

Each of the options has its advantages and disadvantages. They will not be evaluated in detail in this document. In any case, it is for sure that the existing standard radio system GSM-R is conceived to correspond to the transmission of train-ground voice and data for safety purposes, especially for the ERTMS/ETCS and is not suitable to cover broadband and high data flows. It has to be discarded from any option in the scopes shown before.

Starting from the year 2004, the European Space Agency initiated the actions to enlarge the utilization of the satellite supported communications to the mobiles, envisaging the application of this technology to broadband telecommunication for the moving trains, aircrafts and ships (Project MOWGLY – Mobile Wideband Global Link System). It has been proven that technically and economically affordable solutions are feasible for the trains – especially including the high speed trains. Based on the MOWGLY architecture, options can be made and solutions be conceived to use the satellite telecommunication and to fill with other means the communication gaps in zones where the satellite is not visible (e.g. in tunnels).

The train operators participating in the ESA-ARTES programme have developed business oriented concepts and technical systems based on the available technologies. Given the largely differentiated operational and business conditions, the pilot solutions are very heterogeneous and may correspond to the different visions on passengers' info-mobility needs and to different added value services on board.

It was therefore a natural requirement to expect the harmonisation of the minimum level of performance of the "broadband on board" such as to make possible a seamless acceptable international service for passengers.

The UIC has actively participated in the ESA actions and has opened the E-Train project in the scopes to:

- Create the cooperation framework at international level favourable to the railway companies and train operators to harmonise their service levels and to promote the best practice;
- Survey the technology developments and guide on the opportunities, taking also into consideration the evolution of needs, systems and operational conceptions on a harmonised international level;
- Secure the position of the GSM-R as prominent radio for ERTMS / ETCS and its migration options in a coherent framework, where the safety relevant information shall have the non contested priority and pre-emption.

During the work, it has appeared that also other problems need harmonised solutions such as to enable the provision of seamless international information and info-entertainment services to passengers. These problems are of legal nature (authoring rights, cross-border roaming conventions) and should mostly require harmonisation of legal aspects.

This document is the synthesis of the results obtained so far by the project team in the fields of:

- Inventory and set up of the broadband needs for services, basic characteristics and quality aspects involved in the passengers' access to internet and to other services from on-board;
- Survey of applicable technologies and of the development trends;
- Provision of a large framework vision for train-ground telecommunication aspects where the criteria for next options have to be considered.

This document provides also conclusions to be eventually considered for the development of the broadband train-ground telecommunication systems, where, joining the currently separated options can lead to cost/effective optimised systems and enhanced interoperability in an international harmonised frame.

5 Needs and requirements

The needs and requirements reported in this section are the synthesis from two different sources:

- The UIC activity on a concrete questionnaire, in direct dialog based with the railway undertakings and infrastructure managers, especially targeting also the train operators willing to organise on-board info-services for passengers. Other UIC data include the data derived from the EU project INTEGRAIL. The objective is the integration of information in the complex process of railway system operation and management. INTEGRAIL has realised an important survey of the information needs and of the systems capable of collecting, harmonising, processing, transmitting and using the information;
- The ESA-ARTES project “Broadband for trains”. This project has tested the basic technologies and realised the survey of information needs for passengers and train operational purposes. The UIC has actively participated, but did not directly interfere in the business oriented options of the train operators.

The data in provenience from the two streams coincide to a large respect. Therefore they are synthesised and conclusions are consolidated on the commonalities.

5.1 The UIC data

The UIC questionnaire sent to all train operators from Europe intended to capture the opinions and options of the managers of passenger services which organise (or intended to organise) telecommunication services on board of moving trains accessible to passengers, crew and automatic train diagnosis systems (if available or intended to be introduced). Such telecommunication services refer in general to:

- internet (all multi-media services accessible through internet connection),
- specific data and voice transmissions dedicated to the train crew in relation to the traffic control, train operator or other correspondents,
- data transmission in provenience from the train automatic monitoring and diagnosis systems (if available or service not assured by other means),
- specific "infotainment" services with provenience from inside of the train (offered by the crew, on demand or by standard procedure).

The responses to the questionnaire could form the basis for an agreement, among the passenger services of rail undertakings to realise a kind of a “catalogue” of services and of minimum service quality. The aim should be to support the seamless provision of internet and telecom services at a minimum acceptable quality in the land and international traffic. It can be also envisaged, that the common position of railways undertakings might strengthen their position the relation with the telecom service provider(s).

It is of prime importance to notice that the railway undertakings are aware of the responsibility they have to their clients. The passengers perceive the RU as the only interface to the offered services. It is obvious that each RU trends to differentiate services offered to clients and in this situation the "commercial confidence" can justify that no details are included in some more extended description of services or of their actually offered quality.

In this sense the UIC did not interfere with the options and with the business interests of any of the railway undertakings.

The UIC work and the conclusions on the base of captured needs and requirements do not suggest any specific technical solution. It leaves open any technical development, including migration, renewal and/or extension, subject the accessibility to services and the basic minimum quality are not sensibly affected.

It is also intended, for reasons of cost, accessibility to technology and access to telecom service providers to frame the type of services, their characteristics and quality and the subsequent resulting techniques in the existing standards, technologies and services otherwise available in the large telecommunication market.

It is supposed that the passengers (and the crew members) dispose of standard devices (such as laptop, PDA, telecom mobile terminal, smartphone, etc) capable to be connected via a standard either wired (example ETHERNET to connect to the crew desk) or wireless system (example WiFi to connect inside the coaches). These standard systems will be not addressed as particular solutions.

The questionnaire has requested reports on the following information items. Each information was explained in order to enable homogeneous data to be collected.

Service is a generic denomination, where more types of information are simultaneously included (example: internet, where the internet may include all utilities accessible through the standard internet – such as multimedia, mail, voice over internet protocols, file & data transfer, VPN...). In the case of internet services it will be requested to detail by type of the internet service (example: mail, VoIP, file transfer, VPN), and include each of them as individual services. The questionnaire names a number of services, but this is not an exhaustive or a maximum vision.

Description may include a brief description of the service's particular facilities / utilities which are important in the vision of the RU.

Accessibility should briefly describe the category of users which may access the service and the overall (generic) procedure applicable to enable connection to / and disconnection from the service (example: passenger, authenticated access through login and password; crew member by automatic access through crew desk.... and, disconnection - automatic at leave, or other similar).

Availability will indicate the ratio (percentage) of the time when users are continuously connected and the service will function at a minimum satisfaction of the utility (example: internet 80 % in case of mail, or 60 % VoIP...). The availability should indicate the expected average (or minimum) rate of provision of the named service when the expected maximum number of simultaneously individuals will use the service resources.

Simultaneous usage - Maximum (average, expected) number of simultaneous users will indicate the maximum number of individuals simultaneously using the service and benefiting from a minimum quality.

Tolerance to temporary disruption will indicate if there is acceptable or not a temporary interruption of the service (once it is connected), the duration of this disruption in conditions when the service remains connected and recovers automatically after the availability of the transmission is regained (example: file transfer/download TTD = 2 minutes).

Priority shall indicate if a specific service has a higher priority – shall remain connected in case of congestion of the network, or shall discard other connected services in order to get access to communication. The priority will be ranked with a score from 1 to 5, 5 being on highest priority. It will be also indicated if more than ONE service on the equally ranked priority is envisaged to co-exist

Comments, other statements provide the opportunity to complement the characteristics of the service with any other element which is not covered by the other columns of the questionnaire.

The UIC did not intend to address any particular technology for the train<>ground communication. The interoperability inside the train is unanimously recognised to be the WiFi wireless LAN and the on-board architectures should be free to be applied as far as the user can access the services via the WIFI WLAN standard (IEEE 802.11g specification).

The choice of train-ground telecommunication technology is a particular business oriented problem and is submitted to rapid changes, migration and constraints. It should be a non-realistic task to "harmonise" any technology-based service, but to address the service categories based on information categories and info-service mapping under internet.

10 European railway undertakings have responded to the questionnaire. Additional meetings and expertise consultations have been organised with representative of SNCF, DB and SNCB.

5.1.1 Mapping of info-services

Internet and internet-multimedia services are the generic category of information to be accessible to the railway passengers.

5.1.1.1 The access

The passengers' access is conceived via the WIFI 802.11g standard. It builds a seamless universally recognised connectivity. The same standard is used inside the stations and in the hot-spots available in cities, tourist centres, information points. This access gives the traveller a uniform and mass-standard connectivity when he uses the mass computer technology facilities (Laptop, PDA, Smartphone…). Studies carried out under the RAILCOM EC project […] has shown that the convenient propagation problems inside the railway coaches can be solved by the smart choice of the position of the hot-spot antennae. The EM interference noise inside the coaches has no significant disturbing effect in the 2,45 GHz frequency band and is not affecting the WIFI connectivity.

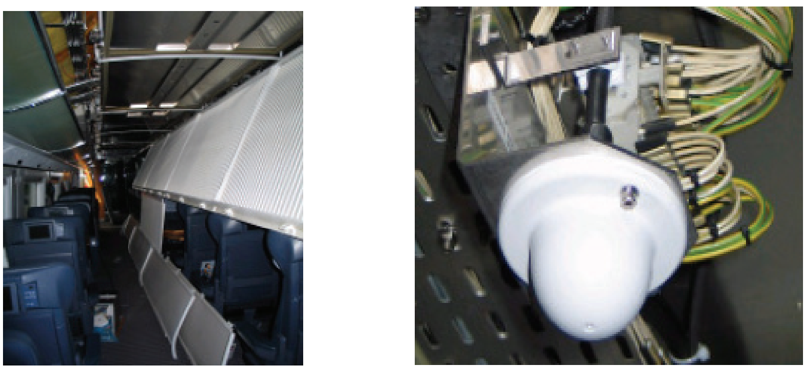

Figure 1 : Cabling and hot-spot arrangement inside an ICE coach

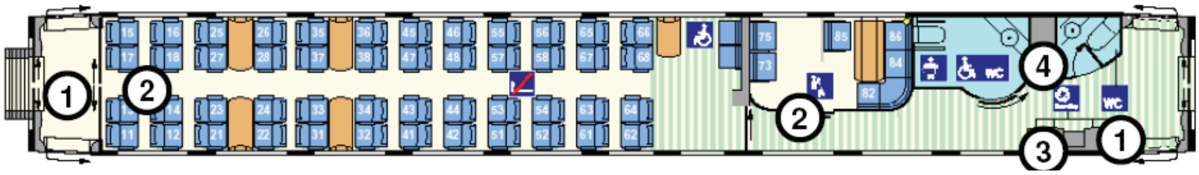

Figure 2 : Example of WLAN and connectivity equipment disposal inside an ICE coach: 1-communication between coaches, WLAN bridge antennae 2-WLAN access point antennae for passengers' connectivity 3-WLAN system internal control logic 4-Online connection content memory, antenna on roof, WLAN server rack

5.1.1.2 Information categories

The internet service facilities delivered to the passengers include the following categories:

Travel Info
- Train position and speed
- Timetable/Delays/Connections
- Train Allocation
- Arrival Time
- Route Planners
- Traffic problems
- Telemedicine
- Booking/(Hotel/Taxi/Car)
- Touristic Info About Arrival Sites

Business
- E- Mail
- Intranet
- Video Conference
- Cloud Computing

Depending on the conventions the train operator has with the internet service provider, other services could be added. The actual bandwidth available is also determining the internet services accessibility.

Nowadays
- Ticketing

Future
- Seat reservation
- National/International Ticketing
- Crew Messages
- Security
- External Control Messages
- Telemedicine
- Others....

Crew and onboard–desk communications as above have not been considered priority. Although they are accessible via the same on-board technology, the train operators do not currently envisage the use of the broadband communication in the operational scopes.

The INTEGRAIL project has captured more than 200 individual information consists capable of being harmonised, processed, transmitted and included in the railway system management process. The train monitoring systems and the information systems on-board form a special information category to which the project INTEGRAIL has dedicated a specific work on "Intelligent monitoring systems IMON". Figure 3 presents an exhaustive information inventory which is usable in the railway system train management and steering of the train-infrastructure interaction.

Currently this information is not sufficiently defined and evaluated. The methodology proposed by INTEGRAIL considers the application of ontology theory to formalise and uniformly describe the information and the context in which the information is captured and used.

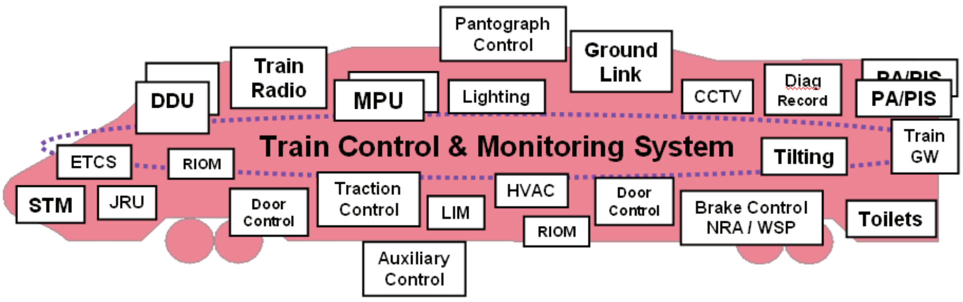

Figure 3 : Train control & monitoring system and the full information vision on-board

Currently the research work is ongoing and the rolling stock industry and the railway supply and integration industry are step by step approaching the harmonised use of the information on-board. This image gives the dimension of the important needs for increasing the communication capacity with the moving trains. The same IP based technologies should be uniformly used, when also the existing train-connection standards (CAN, TCN) shall be enforced and not limited to the exclusive use in the safety purposes.

5.1.1.3 Availability of the info - service

The UIC captured data indicates that different information categories have different requirements for availability:

- The train monitoring information which is sensitive to the rolling safety or to the overall availability of the train should have maximum availability, e.g. > 98 % during the time and in respect to the communication coverage along the train route.
- The passenger information systems, including the access to the internet may have less availability, but 80 % is considered a minimum level for satisfactory service.

5.1.1.4 Tolerance to temporary disruption

All information categories are tolerant to the communication disruption. Depending on the relevance of the information to the safety or security of the train, acceptable disruption is between 5 seconds and 2 minutes. Obviously the robustness and availability of the communication on time is relaxed for the information and internet services for passengers. The inclusion of the train monitoring information in the same transmission system will require the construction of an expensive system. Therefore, at the current stage, the applied technology is only considering the satisfaction of the passengers' information and access to internet, with no severe requirement for the transmission disruption. 30 seconds is an average value for an acceptable good service quality.

5.1.1.5 Priority

Currently, no priorities have been expressed when addressing the passengers' access to internet. The general accepted principle is the share of the instantly available communication resources under the normal specification of the multiple WLAN use. Moreover, the currently applied WLAN inter-coaches connectivity applies the same principles which may lead to extension of a single WLAN resource along the train.

In the case of inclusion of the additional information related to the train monitoring and to the crew communication, it is obvious that a priority policy has to be applied. The UIC captured data (including the INTEGRAIL research) have not yet defined and fine-tuned a priority ranking of the info-communication.

It is generally accepted that currently, the safety related and the operational information is using another system (GSM-R).

5.1.1.6 Number of the simultaneous users

The current practice (SNCF-Orange service on TGV, 21-Net on Thalys) confirm that 20-30 simultaneous users can share 1 Mbps downlink capacity with the average 30 seconds delay for connection to the distant server.

5.2 Data in provenience from the ESA / ARTES study "Broadband on trains"

The following figure 4 shows the mapping of information dedicated to the passengers in the ESA / ARTES study entrusted to DLR:

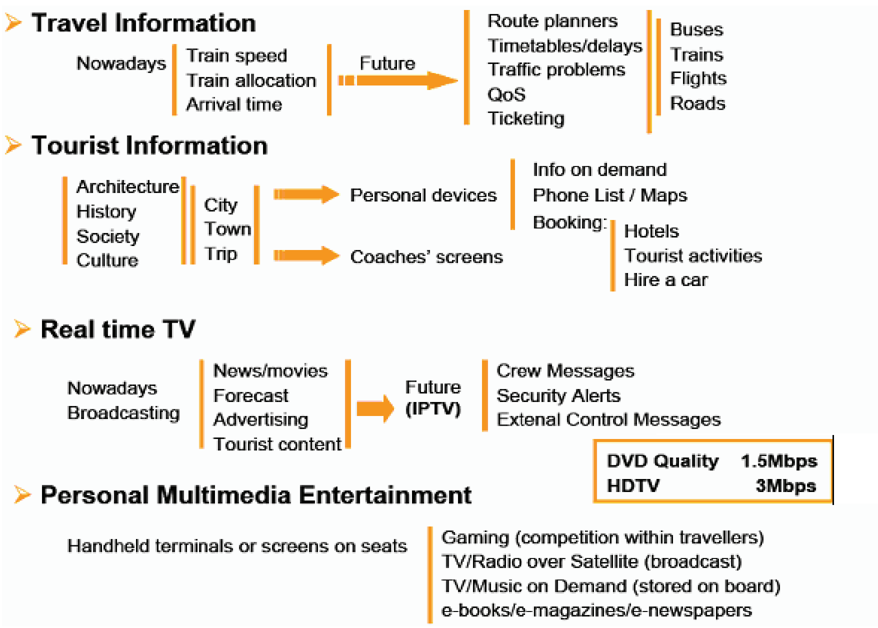

Figure 4 : Results of the ESA / ARTES study on the inventory of the passenger oriented services

As obvious the data coincide with the UIC study. Although the real-time data transmission has not yet been available in real-scale tests, its availability is mentioned.

The services and data dedicated to the train monitoring and crew services are shown in figure 5.

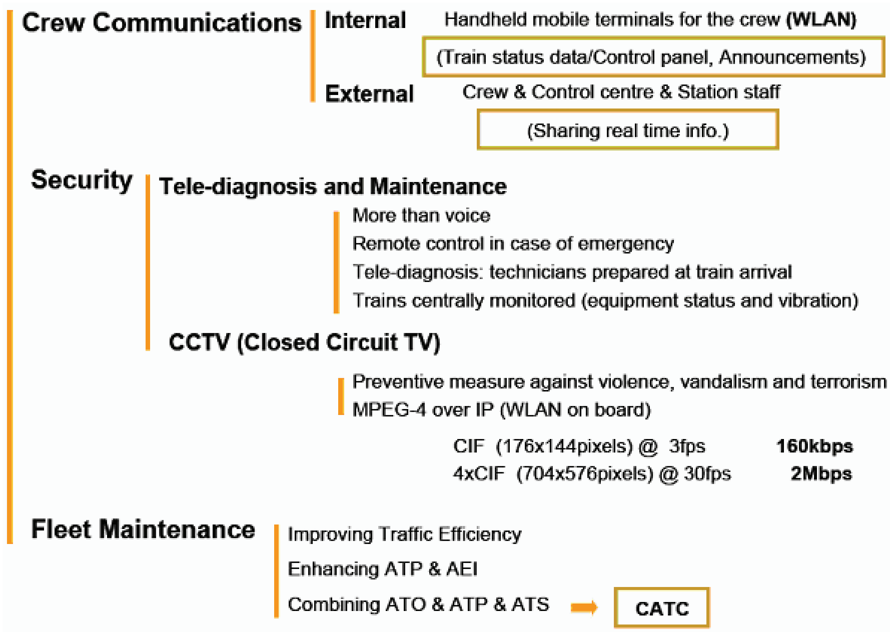

Figure 5 : Train monitoring and crew services resulting from the ESA / ARTES study "Broadband on trains"

The data and the associated services are shown in a future vision. Some security services are shown in detail and the bandwidth needs are evaluate on the basis of the existing voice, data and image real-time transmission requirements.

With regards to the ESA evaluations it should be noticed that some data on the fleet and rolling stock monitoring and maintenance should be corrected in the sense that the ATP, ATS and other are safety related application. They are now under the ERTMS/ETCS specifications for interoperability and the dedicated radio-communication system is GSM-R.

5.3 The overall common conclusions of the UIC and ESA

The conclusions related to the connectivity needs and currently acceptable levels of service are as following:

- Internet services which cover the whole area of standard multimedia services accessible via the internet access should be available with a **minimum of 80 % of time or coverage;** these services need a near-stable train-ground telecommunication access. This access is currently supported in the relation train operator – telecom provider; this relation is well supported in the domestic framework (e.g. SNCF-Orange, DB-T-Online) but is not solved in the cross-border operation. The problems arise from the technology differences in link with the options the telecom provider has offered to the train operator.
    - It is unanimously recognised that the passenger can not expect the same level of internet service onboard as in fixed situations (office, home of fixed hot-spot access); the passengers are aware of this; the train operators have not yet produced any "indication" accessible to passengers with regards to the level of the service, no guarantee, since yet no charge for the service is proposed.

- The access from on-board follows a standard system, based on Wi-Fi hot-spot in the coach, access to an on-board portal via login-password; the number of the maximum users to get a "normal" internet service strongly depends on the bandwidth of the train-ground communication to be shared among the users. It is acceptable that a "normal" minimum level of the internet service should be characterised by: maximum 30 s of delay from launch of a query until the response from distant server and 30 s "time of access" including the time for "read" of the distant answer.
- The prioritisation of access shall be solved according to the standard IP protocols available and set up in the normal commercial internet services; no specific priorities have yet been implemented in the on-board server policy.

- Services broadcast from on-board; such as video-on-demand, video-clips, games, generic information: this category of services is broadcasted via the train WLAN; the capacity of access is decided by the nature of the broadcast (image, sound...) and shall be shared within the maximum capacity of a standard Wi-Fi service:
    - This service does not need a specific train-ground communication capacity; the contents of the on-board "stable" service can be pre-loaded during the stations of the train in service places (end stations, depots...).
    - The authoring rights need specific solutions which may differ from country to country; the legal aspects need a specific relation of the train operator with the authorities; there is no basic involvement of the telecom provider in this relation.
    - Choice of such services to be offered is based on each Train Operator Company marketing studies.

- Broadcast from on-board of TV news, weather forecasts, fresh tourist information, newspapers and other similar. This service is characterised by the need of train-ground communication to download the news; the query is initiated by the crew and the download is tolerant to interruptions and discontinuity. In the case of this service the following problems have been identified:
    - Need for authoring rights harmonisation;
    - Access of the users via the on-board portal.

The experience of SNCF shows that to reach such requirements, multiple technologies could be used, like for instance satellite communications combined with WiFI spots, in points where the satellite losses the visibility. In the same time for some multimedia services, like the ones described previously, WiFi or Wi Max spots, where a big quantity of data is downloaded in a short term seems to be the solution.

5.3.1 Overall observations with regards to the level of services:

a) The Internet service is tolerant to interruptions until 2 minutes but 30 seconds is an acceptable latency value for the connection to a distant server and response to queries;

b) The coverage should be assured on the whole train route;

c) No prioritisation among users or among the specific type of internet access shall be specifically exercised; the solutions for priorities are the standard solutions for users inside a standard WLAN.

The experience of SNCF and DB indicates that the availability of 1 Mbps bandwidth for down-link enables a "decent" service for 20 – 30 simultaneous users (max. 30 s delays acceptable for access to distant server);

In this stage where the on-board internet is still in an experimentation phase any recommendation for a minimum level of service can only be indicative.

There is no precise time limit for ending the experimentation phase, at least in case of SNCF and DB.

In any case, the minimum level of service should be set up periodically and following the evolution of the technology and on the techniques available.

It is requested that the discussion and the set up of the harmonised minimum condition and level of services to passengers shall be led by the UIC and this shall precede any inclusion in a future possible TSI.

6 Technology state of the art

6.1 *The reference architecture for multimodal global mobile broadband communication (MOWGLY)*

The objectives of the EC project MOWGLY (Mobile Wideband Global Link System) were to solve the most significant and critical technical issues prerequisite to development, deployment and evolution of the broadband access satellite architecture for collective mobile users with the target to offer a quality of service similar to the traditional terrestrial networks for users in situation of mobility.

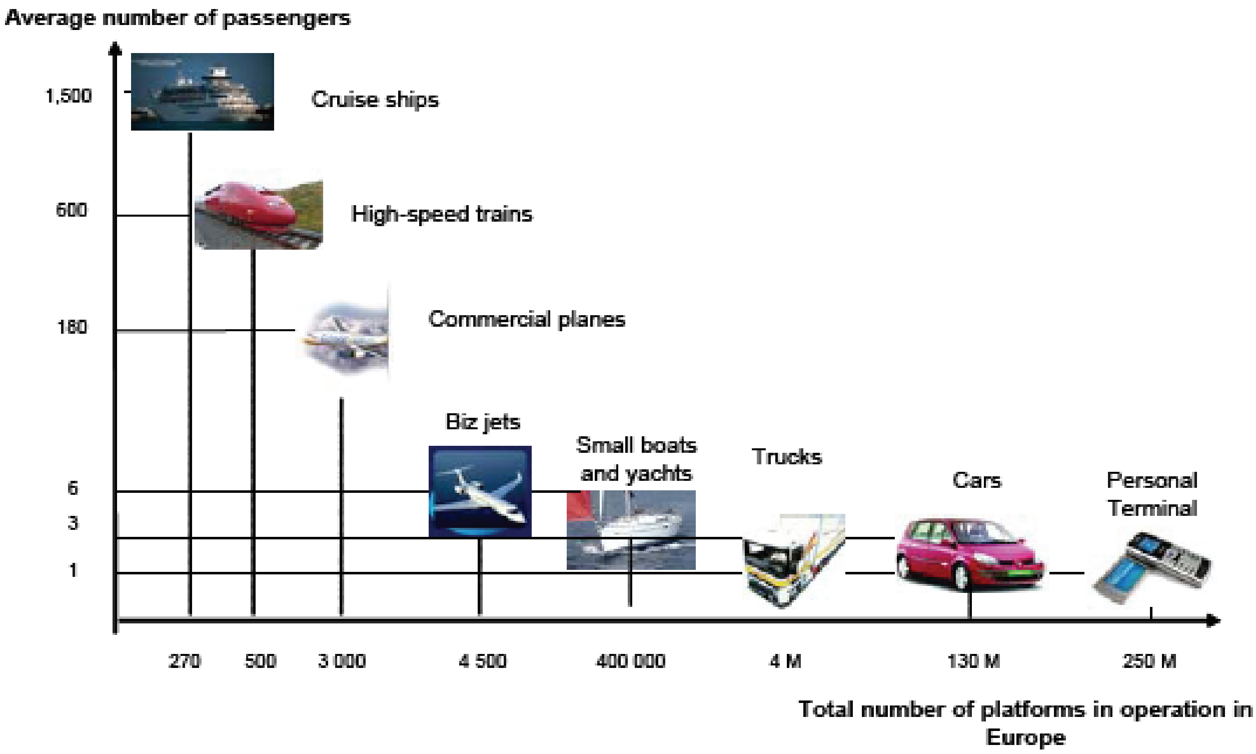

Figure 6 : Potential market of mobile users of satellite communication

The project has started from the conclusion that there is an important market potential which could benefit from a common core technology.

One fundamental objective was to optimize the cost of the core system at the maximum possible extent. When referring to the connectivity domain, the main cost drivers are:

• The total cost of the installation of the equipment on the mobile vehicle,

• The cost of the satellite segment,

• The cost of the ground segment.

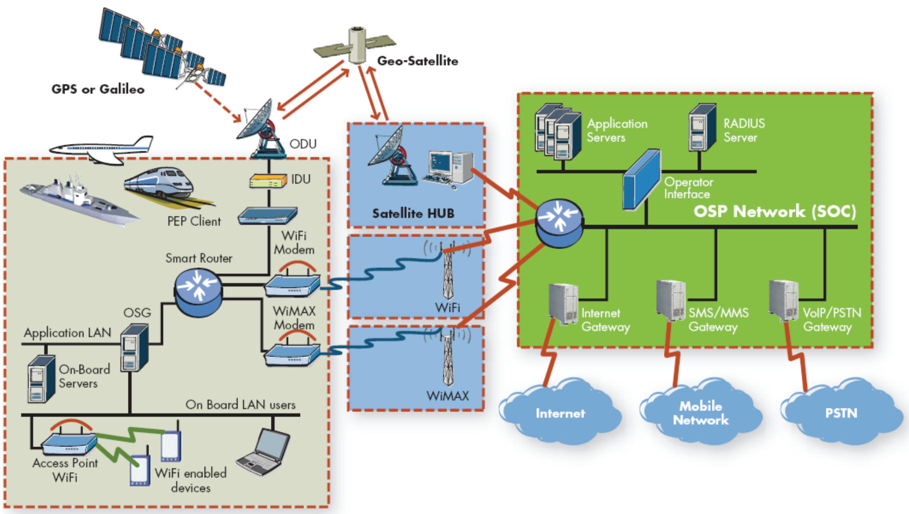

Figure 7 : Reference architecture for the broadband mobile multimodal communication

The specific solution recommended for trains supposes the availability of a terrestrial infrastructure which allows for the use of terrestrial (even if wireless) links, such as GPRS or WiFi. Even if some of these links are narrowband, they can be used as return channel in an asymmetric traffic flow, where broadband is received by satellite. However, the train presents different problems (such as temporary link loss due to tunnels, or obstacles in the satellite line-of-sight; interference from the power lines; vibrations) that must be overcome.

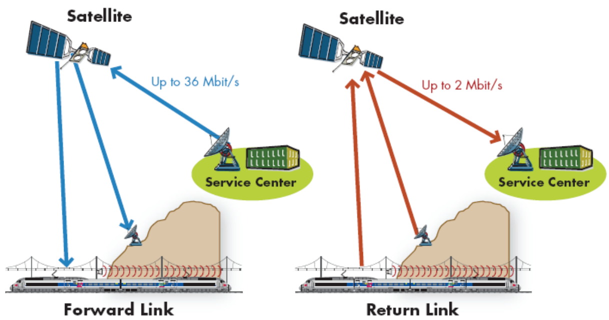

Figure 8 : Principle of asymmetrical forward / downlink for moving trains

Satellite-based systems seem to be particularly suited to providing broadband connectivity to passengers' trains. In principle, trains can be served using terrestrial wireless technology. For example, existing GPRS or UMTS networks can be used, but the connection speed can hardly be considered broadband when shared among a large number of users. Or, technologies such as WiFi and, more recently, WiMax have been proposed; in this case, the costs of deployment of an ad-hoc network are very high, except for short lines (e.g. commuter trains near a big city).A better solution is to integrate satellite and terrestrial wireless in a hybrid system that can take the advantage of both technologies. Ku-band satellite can offer broadband almost everywhere in the countryside, and terrestrial wireless networks can complement satellite coverage in shadowed zones (tunnels, stations, urban zones, or areas shadowed by trees or hills). The functional scheme is shown in the figure 8. The system functions involve the cooperation of the satellite telecommunication, the mobile internal communication and access system and the ground system. It can be added a secondary wireless communication segment which value is to complement the onboard mobile service network in railway stations and other such environments.

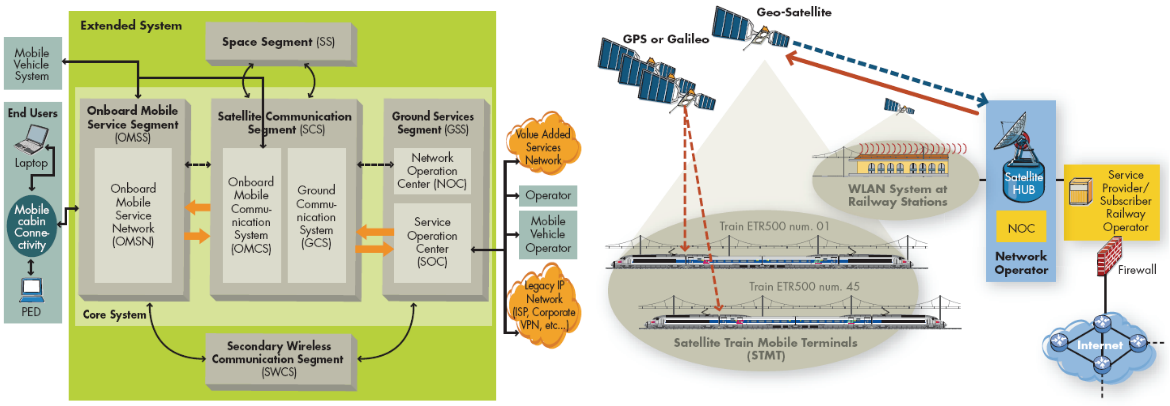

Figure 9 : The functional scheme of the mobile communication

The onboard equipment shall implement a 'multipath-routing' technology capable of:

• Selecting, with the appropriate advance, the most appropriate communication link. This selection can be done based on a-priori knowledge of the availability of the links, on real-time monitoring of link quality, on economic considerations (required bandwidth and associated cost).

• Switching the data flow from a link to another. The switch should, as far as possible, be transparent to the end user, so at least preserve the active TCP sessions. This switching can be between two different types of link (vertical handover) or between two cells of a cellular network (horizontal handover).

The routing technology above is a key point for the final quality of service as perceived by the end user. A number of companies have proposed solutions to this problem that are currently under trial or operation. Some solutions are based on the use of GPS localization of the train, coupled with a geographical database constantly updated, which allows the router, for example, to take appropriate measures way before the train enters into a tunnel.

An implementation of this switching functionality is the "Smart Router", whose logical decomposition is shown in Figure 8, developed by Rockwell Collins France and MBI within the MOWGLY European project.

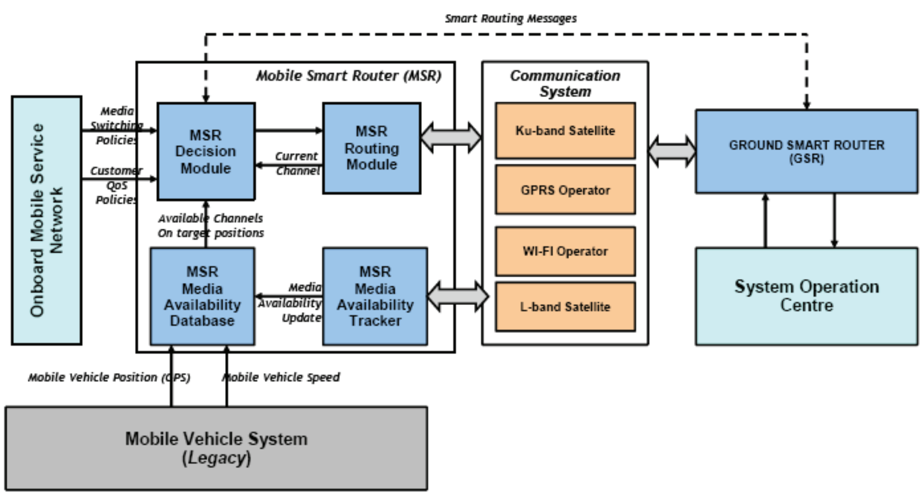

Figure 10 : Logic de-composition of the smart router (courtesy of Rockwell Collins Francs / MBI)

6.2 Application on Thalys HS trains

The relevant application of this technology is the broadband internet for trains developed in cooperation by Nokia Siemens, the UK company 21NET and Telenet and installed on HS trains Thalys, TGV East and some TER at SNCF railways.

The application integrates the newest technology for compression and acceleration of the VPN channel established between the mobile and the satellite or a ground based access point.

The UDgateway® application is an all-in-one WOC (Wide Area Networks Optimization Controller) designed for broadband satellite and WiMAX, to achieve LAN-like performance and security and to reduce the amount of bandwidth required. The core technology provides an enhanced end-user experience and great bandwidth savings with TCP acceleration, QoS-based traffic differentiation, HTTP pre-fetching, web and DNS caching, CIFS acceleration and the UD cast WAN compress technology.

The applied architecture is the reference architecture proposed by the project MOWGLY where the multi-system communication is enabled by the smart router and the use of the acceleration of data throughput and compression technologies in the on-board router.

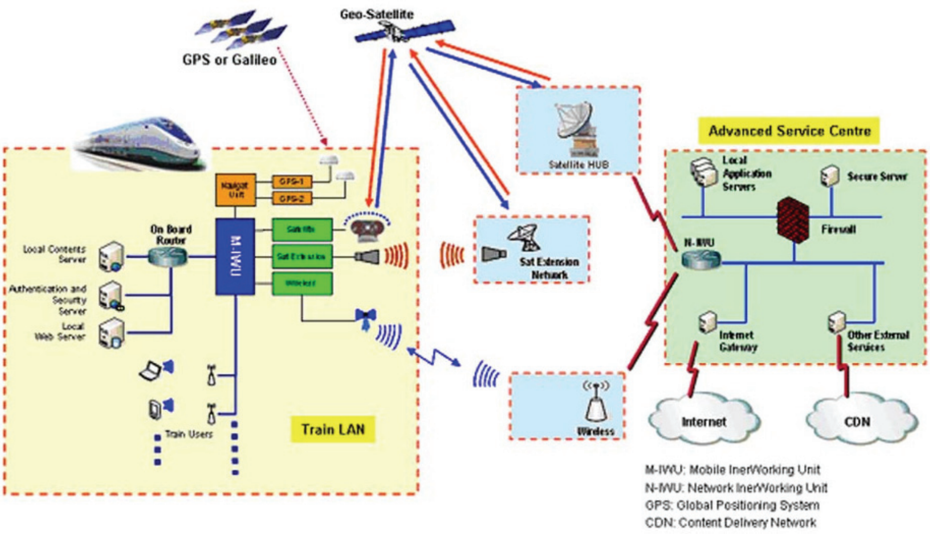

Figure 11 : Multi-system reference communication architecture for moving trains

Outside of the train the main communication device is the satellite terminal, which antenna is covered by a protective radom.

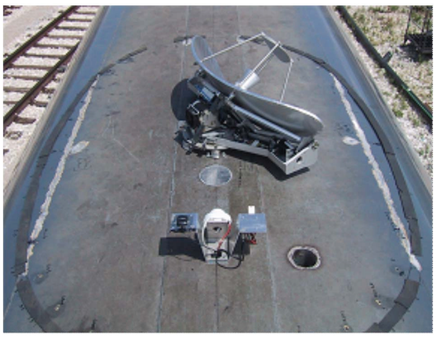

Figure 12 : Roof antenna and radom mounted on a Thalys train

The arrangement in the coaches' interior corresponds to the WiFi application as shown in the figures 1 and 2.

The satellite connection is utilised most of the time and as a priority to provide Internet connectivity on the train. The high speed bi-directional satellite connectivity operates via a small earth station (parabolic antenna) installed on the roofs of Thalys trains. This provides the link to the Hispasat satellite located 36,000 kms above the Atlantic Ocean as Thalys trains cover the four European countries that they serve. The other end of the satellite communications link is at Hispasat's Satellite Base Station located at Arganda near Madrid. A VPN (Virtual Private Network) tunnel interface connects the satellite link to the public Internet network at ThalysNet's NOC (Network Operations Centre) established in Belgium in Nokia Siemens Networks premises at Herentals.

The internet connectivity is possible throughout the duration of the voyage. The switchover process from satellite to UMTS and WiFi is a process that undergoes continuous examination by the central server, the latter determining access availability and opting for the best link. As the central server switches from one technology to another, it is possible that a very short interruption of services may occur. This barely impacts on the passenger's connectivity experience as only a delay of a few extra seconds during a download may be noticeable.

The Network Operations Centre's mission is the real time monitoring of services and equipment on board Thalys trains. In order to minimise intervention on board trains in cases of major equipment failure most of the software interventions can be undertaken at a distance from the Network Operation Centre. This facility also allows customers to be authenticated when they log on to the portal when on board the train as well as manages the external public access Internet connection; passengers can therefore access the Internet just as they would if they were in their office or at home. Connectivity quality is guaranteed by bandwidth adjustment on uplink/downlink. Tests carried out by the Consortium during the pilot phase with fifty simultaneous users determined that even if there are more than 50 users, all the available bandwidth will not be utilised. During the peak usage of the service on a daily basis it is envisaged to share between trains the uplink bandwidth going from the train to the Internet, and the downlink going from the Internet to the train. Bandwidths can be adjusted at any time in order to ensure continuous availability of the WiFi service to passengers. This uplink and downlink adjustment is similar to a fixed WiFi terminal. The access is authenticated and passing through the TalysNet portal.

Figure 13 : WiFi zone mark inside the Thalys coaches

Once connected, the passenger needs to open an Internet browser (Internet Explorer orFirefox in most cases) and is automatically directed to the portal for access to ThalysNet. The first time this happens, the internet user is invited to log on the portal's home page to access the WiFi internet service. Besides Internet access, the portal offers free access to information sections regarding the service, Thalys.com and Cybelys.com websites, as well as real time news updates. An interactive card allows users to check out real time train itineraries on the Thalys network. Access to the portal is free to all passengers. Access to the Internet via the portal is free for customers travelling in Comfort 1. For those travelling in Comfort 2, there is no free access to the ThalysNet portal but there is a charge for Internet access

Internet users access to the same functions offered by traditional internet connectivity:

- surfing the Internet,
- instantaneous online messaging,
- downloading files,
- sending and receiving of emails,
- transmission and reception of attachments,
- use of IP-based voice services (Skype, Wengo, etc),
- any other internet service.

According to the Thalys press release (13 January 2009), more than 60.000 Thalys passengers have used the broadband Internet connection while traveling at 300 km/hr across four European countries – Belgium, The Netherlands, France, and Germany. Nine out of ten interviewed ThalysNet users have evaluated the service as “good” or “very good”.

It is also a reality that the internet on board is an attractive factor for travellers to use the Thalys trains.

6.3 The Japanese application

A similar application technology is used in Japan to connect on broadband the new generation of HS trains Shinkansen N700. Because of the line profile with long portions of the route in tunnels, the broadband connection with the train is realised via a leakage cable suspended trackside, on the electrification masts.

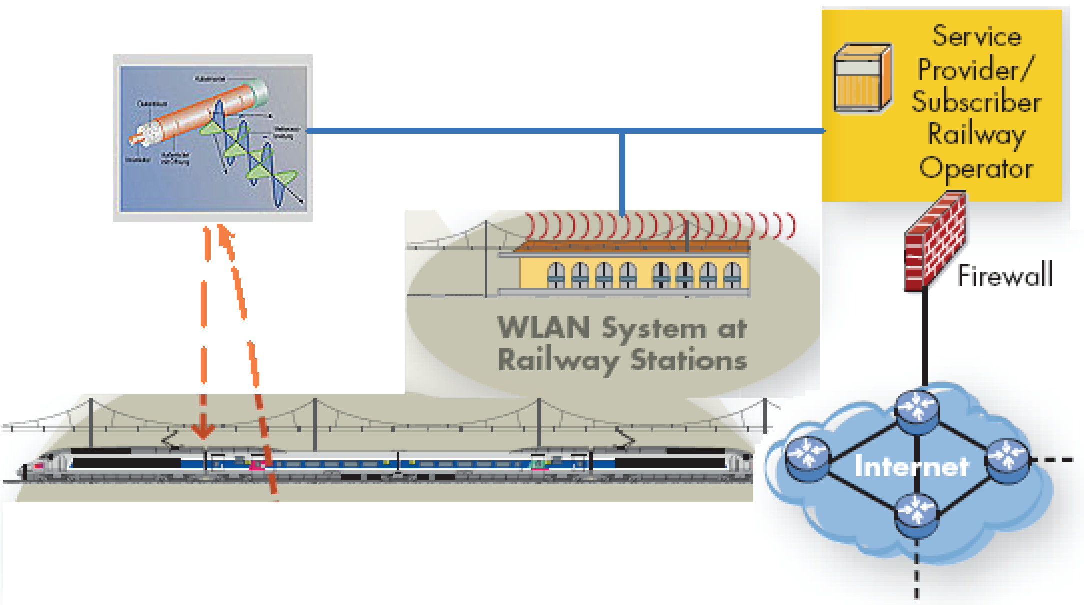

Figure 14 : Broadband train ground connection via the leakage cable

The whole network is a WiFi network to which the train is coupled. The same service is available in the 17 stations of the Shinkansen line.

The application is in commercial service starting from March 2009. The users have 2 Mbps bandwidth all over the time in a stable and seamless connectivity along the trains’ trajectory.

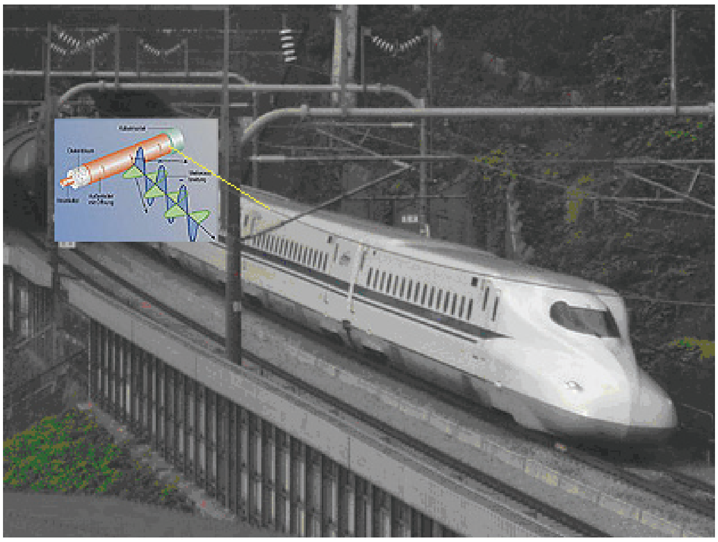

Figure 15 : The Shinkansen route is provided with leakage cable for broadband connectivity

The coaxial leakage cable is used as an ultra-high frequency waveguide which radiates with controlled directivity and power a part of the radiowave travelling along the cable in the direction of the train. The train has a simple antenna, directed laterally and can receive and transmit from and to the cable.

6.4 The INTEGRAIL ICOM (Intelligent COMmunication) approach to a global multi-user connectivity

The Project INTEGRAIL aims to create a holistic, coherent information system, integrating the major railway sub-systems, in order to achieve higher levels of performance of the railway system in terms of capacity, average speed and punctuality and the optimised usage of resources. The telecommunication needs and proposed solutions addressed in INTEGRAIL are based on the investigations carried out in the project but moreover on the leading technology and results achieved by previous projects. INTEGRAIL proposes new intelligent procedures for enhanced telecommunication opportunities in a multi-user framework which include the railway undertakings, railway customers, third party companies and other transport entities involved in the railway business.

ICOM provides a framework for advanced system communication covering the complex physical distribution of railway systems in trains and over ground infrastructure. ICOM communication framework is maximising the use of technology in the railway context, where heterogeneous railway networks are integrated starting from applications defined QoS.

Railway operators exchanging information include both Railway Undertakings (RU) that own, operate and maintain trains and Infrastructure Managers (IM) that manage train tracks and all related fixed infrastructure:

- Each of these companies relies on its own core networks to host its applications and databases;
- In order to link with the mobile trains, a railway operator may deploy its own private access networks, use access networks of another railway operator and/or resort to the access networks offered by public telecom operators;
- An IM operator also relies on wayside networks deployed throughout its zone of operation for remote control and operation of its infrastructure.

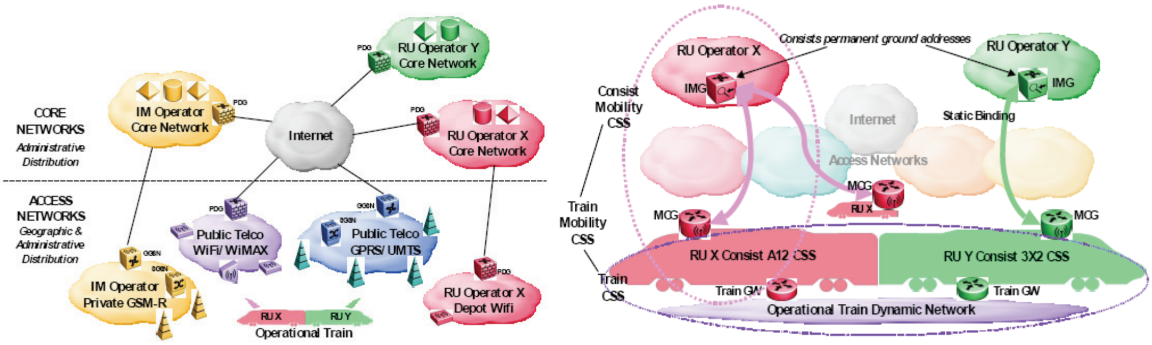

Figure 16 : The railway networks distribution and the ICOM train mobility concept

ICOM central point technology is the internet which flexibility of applications and high degree of standardisation are the guarantee for the future oriented applications.

The train mobility CSS (Consist Mobility) is defined as the composition of the dynamic train CSS and of the consist mobility CSSs of the consists that are currently part of the train. It evolves dynamically like its underlying train CSS. Many InteGRail users and applications are primarily focused on the operational train, and do not know or care about the consists that compose it. They will interact with the train as a whole through the train mobility CSS. This powerful abstraction is instantiated through dynamically established translation tables that associate functional train addresses to the static consist addresses managed by the IMGs (ICOM Mobility Gateway). This opens the path to extended accesses to the train, making the best of ground to consists and train-wide connectivity.

The consist mobility CSS concept can be mapped directly on single wireless technology approaches already in use in the railway world. Yet, by exploiting the diverse properties of each wireless technology and the numerous access networks being deployed over Europe by various actors, a dramatic improvement of train to ground connectivity is achievable.

To allow such optimum use of wireless technologies available to the train, ICOM introduces in the MCG (Mobile Communication Gateway) and the IMG a network selection function. The idea is to determine automatically the wireless network best adapted to each information exchange session, making compromises between QoS properties, current and estimated network availability and factors like costs or other business considerations. In response to evolutions of the communication conditions, the network selectors will trigger vertical handovers to more adapted wireless networks. The network selection algorithms take into account the end to end communication properties of the session as defined by its ICOM traffic class as well as resource status information from the wireless links (building on standardisation efforts like Media Independent Handover). To improve selection results, the algorithms may also take advantage of knowledge of train position and existing radio coverage along its route.

Public telecom operators are also quite active in integrating heterogeneous wireless technologies to improve the services they offer, but they tend to concentrate additional complexity in the network. To the opposite, ICOM that is pushing for an opportunist user approach manages the new features from the end points of the wireless trunk.

Except the use of the ICOM principles to the demonstration of the extended connectivity a a range of business oriented decisional scenarios of railway undertakings and infrastructure managers, until now no commercial application of ICOM is available.

7 The future developments of broad-band communication and info-mobility

7.1 The conclusions of the ITU study on long term evolution of mobile communications

The International Telecommunication Union (ITU) has dedicated in 2008 an important study to the future developments of the information mobility and the telecommunication using broadband. The conclusions of this study show that:

- The communication service market recently moved rapidly from voice-centred service to data-centred service. Fast and high-quality IP based multimedia service is expected to build the common base in the future.
- There is a need for a universal super high-speed portable Internet service that provides high mobility and network speeds of several Mbit/s capable of transmitting multimedia content at a low price.
- For the future wireless access market the existing cellular network will become critical to a certain degree to assuring lower price and enhanced speed using, and assuring mobility. Currently, the standardization of this bandwidth has not yet been established. The focus on the LTE (Long Term Evolution) migration is ongoing, so the technologies of systems companies are being examined to derive standards. The railway broadband communication requirements are not yet taken into consideration in the LTE standardisation process.
- QoS (Quality of Service) must be considered the leading element in terms of cost, complexity, and capacity. Several basic QoS functions can be already accommodated in the Internet. IP QoS mechanisms like transmission control protocol (TCP), explicit congestion notification (ECN) and real time protocol (RTP) that are commonly used on the Internet, follow mostly end-to-end mechanisms and may be exploited to produce improvements on the networking technologies.
- There is a definite movement towards integration and convergence of heterogeneous wireless access networks. This trend not only includes cellular network but also emerging systems, such as WLAN, WPAN, wireless sensor networks (WSN), mobile ad-hoc networks, digital broadcasting networks, and the Internet, which will complement or expand current and next-generation networks.

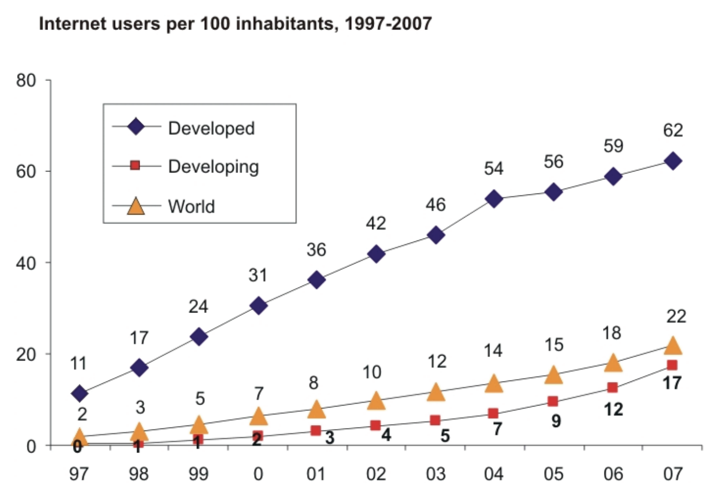

Figure 17 : Development of the internet users

Europe leads the world in terms of mobile penetration, with over 570 million subscribers and a mobile penetration of over 70 %. This compared with 9 % mobile penetration in Africa, 42 % in the Americas, and 19 % in Asia Pacific.

The satisfaction of the future needs obliges to rapid realisation of global mobility concepts capable of unifying under a single umbrella the segment developments. Such a concept is justified in the ITU study under the "Mobile Convergence Network".

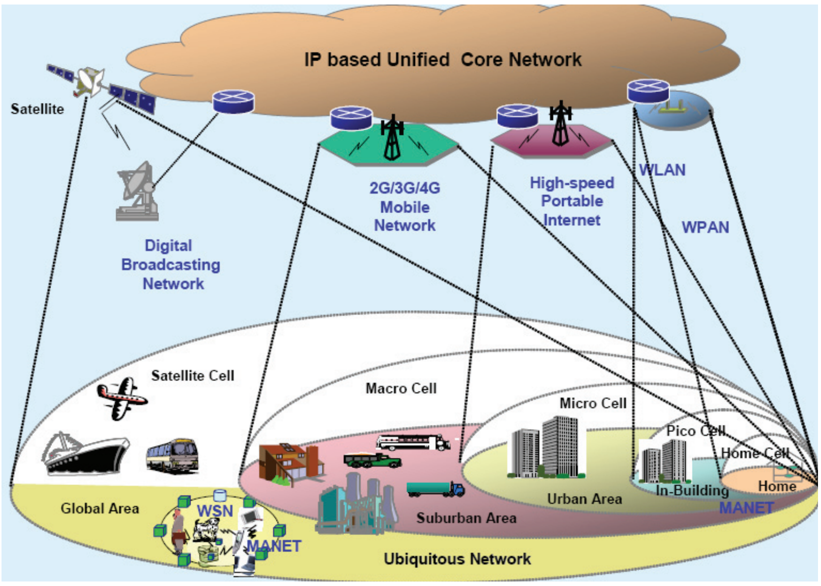

Figure 18 : The ITU concept of mobile convergence network

Convergence may be defined as an integrated or coupled phenomena associated with diverse networks, services and providers. In terms of the business value chain, convergence is considered from the perspectives of services, networks and terminals. Network convergence enables wired and wireless services to be provided using the same infrastructure and highlights the importance of interoperating networks and internetworking.

In this way, future broadband mobile communications may involve a mix of concepts and technologies in the making. Some can be recognized as deriving from 3G, and are called evolutionary, while others involve new approaches to mobile wireless, and are sometimes labelled revolutionary. What is important, though, is the common understanding that technologies beyond 3G are of fundamental relevance in the movement towards a converged world. In particular, the major drivers toward ubiquitous communications and services will provide a new paradigm for a generation of convergence communications with value-added features.

ALL-IP networking and IP multimedia services are the major trends in the wired and wireless network. The concept of the next-generation convergence network (NGcN) incorporates the provision of a common, unified, and flexible service architecture that can support multiple types of services and management applications over multiple types of transport. There are essential attributes of this next-generation service architecture such as layered architecture, open service interface, and distributed network intelligence.

The new generation of mobile multimedia applications will be developed in IP environments guaranteeing optimal synergy between the ever-growing mobile world and the Internet. In the IP environments, mobile networks will benefit directly not only from all the existing Internet applications, but also from the huge momentum behind the Internet in terms of the development and introduction of new services. It is important to stress that these evolutions are independent of each other and can also be deployed in a fully independent way. This means that the operator can make an independent yes or no decision for each of these evolutions.

7.2 The impact of the long term evolution on the broad-band mobility on trains

Although submitted to some particularities (e.g. route through tunnels and zones with no sky visibility and high speed – 350 km/h) the train<>ground telecommunication is obviously following up the large market developments and trends.

It would be an illusion to consider that the future mobile telecommunication systems used for the railways will be “made for railways”.

The railways shall apply the market technology. Adjustments and adaptations will be necessary to comply with specific requirements of the environment but also for enhanced availability and reliability of the communication. But, the market technology will lead and the railways will have no opportunity (and even no reason) to deviate from this market.

A few very important conclusions on the migration path of the telecommunication systems may need to be seriously considered in a future vision of the railway train-ground telecommunication:

- ALL-IP networking and IP multimedia services are the major trends in the wired and wireless network.
- There is a definite movement towards integration and convergence of heterogeneous wireless access networks. This trend not only includes cellular network but also emerging systems, such as WLAN, WPAN, wireless sensor networks (WSN), mobile ad-hoc networks, digital broadcasting networks, and the Internet.
- In terms of the business value chain, convergence is considered from the perspectives of services, networks and terminals.
- Network convergence enables wired and wireless services to be provided using the same infrastructure and highlights the importance of interoperating networks and internetworking.
- QoS (Quality of Service) must be considered the leading element in terms of cost, complexity, and capacity. IP QoS mechanisms follow mostly the end-to-end mechanisms and may be exploited to produce improvements on the networking technologies.

For the future railway mobile telecommunications this evolution may determine important options to be evaluated and decisions adopted.

1. All services shall be included in a single “Mobile convergence network”.
2. Such services should be based on the future oriented holistic view of the train-ground communication needs which should include the safety related communication, the train and traffic monitoring, the crew and train management information and the passenger information and access to the systems and networks outside from the moving train.

3. When analysing the development trends it is obvious that the existing situation (more than one performing telecom systems inside and for the train – ground communication) shall migrate to a single convergent networking system capable of satisfying the different requirements. Such requirements should be expressed in terms of the priorities and quality of service (QoS), when services will be mapped and differentiated.
4. It is obvious that clear distinction will be made between the Qos for the transmission of safety relevant information and the other information categories.
5. As pointed in the evolution trends, it will be the QoS which will generate the application of mechanisms on an end-to-end approach for each service category.
6. The modern trains (communicating trains) should include a standard on-train area network, wired (for the train control,, diagnosis, monitoring and signalling purposes) but also wireless for providing the selective and protected access of passengers and crew to the IT and telecom services.
7. In comparison with the other transportation systems the train has the advantage of a guided route, where broadband telecommunication systems can be specifically arranged and available. The combination of satellite, ground WLANs and gap-fills (as shown in the example of Japanese experience) may lead to converging networking based on stable and soundly migrating mass technologies.
8. The business justification of convergent networking applications on trains shall be based on the examination of a holistic approach of the telecom needs of the moving trains. The current technologies and trends do enable the scalability and flexible use of the basic systems.
9. Technical interoperability may be the natural consequence of the converging networking.

7.3 Economic considerations

With regards to the point 8 above, the ESA initiative "Broadband for trains" has enabled the highlight of the major cost positions and of the elements relevant for technical and business options. The economic analysis applied on optimised architectures has shown that at the current stage the internet for passengers in the trains is not per se a business case.

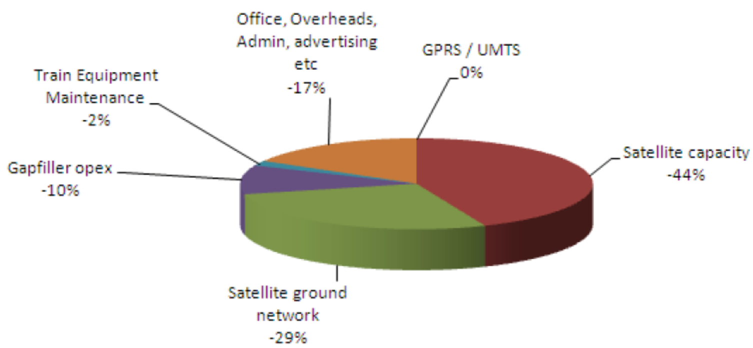

Figure 19 : Cost percentages on a typical international HS route (Paris – Stuttgart)

In the solution of satellite communication, the cost of the satellite capacity use and the cost of the satellite ground network used for the application represent about 3 / 4 (73 %) from the total application cost. The economic analysis has been carried out on a generic model shown in figure 20 (DLR team, ESA-ARTES-1 project “Broadband for trains”).

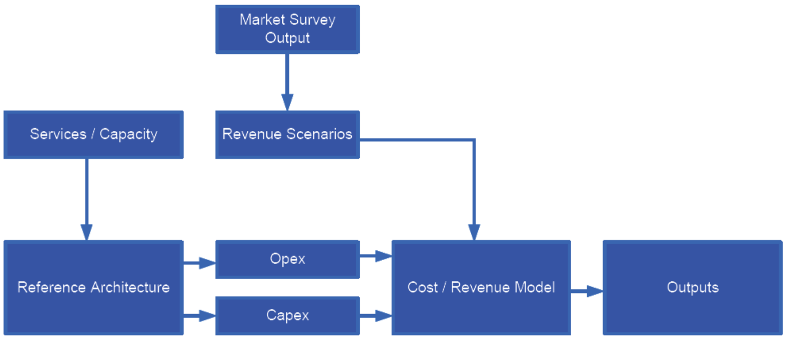

Figure 20 : Model for economic evaluation applied to the reference architecture based on the combinations of satellite and gap-fillers in tunnels (e.g. HS route Paris –Stuttgart)

The conclusions derived from the current practice show that:

- The offer of internet on train is an important attraction for passengers. The internet for free may generate an increase of the passengers number, especially on the routes Paris-London, Paris – Brussels, Paris – Cologne. This can generate a HS service revenue augmentation of 10 – 18 % in the period 2009 – 2012.
- Currently the users of the internet services on trains could not expect the same service level as in the case of fixed locations. This is a consequence of the limited bandwidth which can be accessible on an affordable cost.
- The offer of entertainment services (such as films, TV programs) can be an increased attraction factor, but the authoring rights are still a problem in the international traffic. The solution of the authoring rights needs specific legal accords.
- BW capacity per train can become insufficient in case of long trains or more multiple units coupled on the same onboard server.

8 Conclusions and steps forward

The needs for info-mobility of citizen can be satisfied during their trip on trains. Such info-mobility is strongly centred on the access to internet / multimedia internet where broadband communication is a sine-qua non facility for the internet use at a decent quality of service.

Nevertheless, at this stage of applications, the internet on trains do not have the same performance as in the case of fix hot-spots.

The access of the passenger to internet inside of the train is realised in the WiFi technology and is passing via the train operator internet portal. At the portal, the passenger can select between the services from on board (e.g. trip information, connexions, other operator's legacy information) and the connexion to a distant internet server. Different business models have been discussed and this is an open item, to be decided by the train operator.

The available technologies enable the realisation of broadband communication with moving trains, including the HS trains running with 300 Km / h. The currently reported best practice combine for the train-ground communication link the satellite telecommunication and the ground based communication, eventually completed with gap-fillers for assurance of communication continuity in tunnels.

The data and voice communications to serve the train operation performance (e.g. train monitoring, diagnosis, assistance for the crew, tele-detection, tele-medicine, electronic seat reservation … other similar utilities) have been analysed in EC projects (such as INTEGRAIL) but have been not practically applied in the context of the broadband communication with moving trains. The train operators have opted for the commercial opportunity and priority to serve the passengers needs for info-mobility. It has been demonstrated that the offer of internet on board is increasing the attraction for the train.

The current technical state of the art and the existing practice do not yet enable the harmonisation of the QoS for the passengers' services. Some of the parameters (such as the latency time for connectivity or data transfer) have been tested based on the bandwidth accessible for the up- and downlink on satellite connectivity. The up- and downlink are asymmetrically served by the dynamically allocated bandwidth. Nevertheless it is recognised that this harmonisation is necessary and will be driving factor to mapping of services and interoperability in international traffic.

The major tendencies and the next expected performances of the mobile communication technology do justify joining together the passengers' broadband communication and the train operational data communication under the same technologic system. From a business perspective, the separation of the two data streams is possible and affordable.

The "network convergence" in the vision of the LTE (long term evolution) forecasts the non-contested orientation towards the IP unified core networking which has full advantages for all applications – including the safety related train-ground communications.

It would be therefore justified to consider the future broadband communication with trains together with the LTE options for the GRM-R migration strategies, to finally have a single system.

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