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Defining an Adaptable Communications System for all railways

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Abstract

Within Innovation Program 2 (IP2) of the European Shift2Rail Joint Undertaking, a Technology Demonstrator (TD) “adaptable communications for all railways” activity was created to bring together key stakeholders, to investigate the future communication needs, define and specify key functions and finally develop prototypes to prove the feasibility and capabilities of an adaptable communication subsystem for railways.

A key aspect of the future adaptable communication system will be the support of multiple access technologies, including but not limited to LTE, 5G, Wi-Fi or SatCom, combined with bearer independence to address availability, resiliency, performance, capacity, security, safety and maintainability requirements of existing and new railway applications.

The first project within IP2 is named X2Rail-1 and it has already started to

- collect, assess and qualify user and system requirements from users and stakeholders, including railway operators, infrastructure managers, regulatory groups and related associations;
- undertake business model analysis with the aim to explore new operating and deployment models ranging from dedicated and hybrid networks to “network-as-a-service” approaches;
- specify the architecture, subsystems and functions needed to enable an adaptable communication system and
- assess key criteria and create guidelines for the selection of appropriate communication technologies or radio network candidates.

The paper will outline the key findings and will provide an outlook of the prototype developments planned in upcoming X2Rail projects. It will also explain the expected improvements and benefits of the future adaptable communication systems for the different railway domains to support the goals of the Shift2Rail Joint Undertaking.

Keywords: Shift2Rail, X2Rail-1, adaptable communication system, GSM-R, LTE, 5G, radio technology,

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Acronyms

3GPP	3rd Generation Partnership Project
ASCI	Advanced speech call items
CAPEX	Capital Expenditure
CBTC	Communication-Based Train Control
CCA	Cross cutting activities
EIRENE	European Integrated Railway Radio Enhanced Network
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETSI	European Telecommunications Standard Institute
FRMCS	Future Rail Mobile Communications System
GSM-R	GSM for Railways
IP	Innovation Program
IM	Infrastructure Manager
JU	Joint Undertaking
MORANE	Mobile Radio for Railways Networks in Europe
MVNO	Mobile Virtual Network Operator
NGTC	Next Generation Train Control
OPEX	Operational Expenditure
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
S2R	Shift2Rail
SERA	Single European Railway Area
SLA	Service Level Agreement
TCMS	Train Control & Management System
TETRA	Terrestrial Trunked Radio
UIC	Union Internationale des Chemins de Fer

1. Introduction

The European Commission's 2011 Transport White Paper “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system” [1] has set out a number of key goals to strengthen the railway sector in the transport system, given rail's inherent advantages in terms of environmental performance, land use, energy consumption and safety. The white paper points out that the creation of a Single European Railway Area (SERA) will be crucial to achieving a modal shift from road towards more sustainable modes of transport such as rail, as this could serve to dramatically cut the costs of running passenger and freight trains by providing a common framework of rules and regulations for rail operators in all EU countries.

In addition to the adoption of the Fourth Railway Package in January 2013 the European Commission identified the need for an increase in research and innovation efforts to support the competitiveness and attractiveness of the rail sector, while encouraging innovative approaches to business models, use of technology and products. In consequence, the EU research and innovation programme Horizon 2020 was leveraged to form a Public-Private-Partnership (PPP) project called Shift2Rail (S2R) Joint Undertaking (JU), formally established by Council Regulation (EU) No 642/2014 [2].

The S2R JU is a Public-Private Partnership (PPP), providing a platform for the actors of the European rail system to work together with a view to drive innovation in the years to come by implementing a comprehensive and co-ordinated research and innovation strategy. The Members of the Joint Undertaking are the European Union plus eight founding members and nineteen associated members, which represent Europe’s rail sector, including manufacturers of railway equipment, infrastructure managers, railway undertakings, metro, tram and light rail operators, and other rail-related companies, as well as SMEs, research organisations, universities and actors from outside the traditional rail sector.

A series of member projects will address the five different Innovation Programmes (IP) and additional Cross Cutting Activities (CA) in line with the Shift2Rail Master Plan [3] and cover applied research activities, i.e. Technology Readiness Levels (TRL) 1 to 3, to the development of technology demonstrators (TRL 4 to 7).

Innovation Programme 2 (IP2) addresses the challenges of the command, control and communication systems of the future. It aims at enriching control and safe separation of trains and become a flexible, real-time, intelligent traffic management decision support system among others. Today's European Rail Traffic Management System (ERTMS) is the leading solution for railway signalling and control systems and consists of the communication system, train control system and traffic management layer. However it does not fully take advantage of new, emerging technologies and practices, including use of satellite positioning technologies, high-speed, high-capacity data and voice communications systems, automation, as well as innovative real-time data collection, processing and communication systems. It is expected that the future advanced traffic management and control systems will contribute to the overall goals of the programme in delivering improved capacity, decreasing traction energy consumption and carbon emissions, reducing operational costs, and providing enhanced safety and security, and better customer information.

The Shift2Rail Multi Annual Action Plan (MAAP) [4] has defined a set of technology demonstrators to assess and define the system needs and requirements, create a comprehensive set of specifications and work on the implementation of prototypes and demonstrators to enable the integration of functional subsystems into an Advanced Traffic Management and Control System.

The X2Rail-1 member project aims to research and develop key technologies relating to several technology demonstrators defined in IP2. One of them is the adaptable communication system (TD2.1), which is addressed by the work package 3 (WP3) in the project.

This paper provides an overview of the initial work planned for adaptable communication in the X2Rail-1 project, the findings and challenges identified in the first 12 months and an outlook to future X2Rail activities continuing the work done in X2Rail-1.

2. Adaptable communication system in the X2Rail-1 project

The Shift2Rail IP2 technology demonstrator adaptable communication for all railways aims to analyse, specify and implement a number of prototypes. These prototypes will demonstrate key features of an adaptable train-to-ground IP communication system with enhanced throughput, safety and security functionalities that will take advantage of new technologies, support the current and future needs of voice and data services including signalling and train control systems. At the same time backward compatibility to existing ERTMS deployments needs to be ensured.

The overall objectives of the TD2.1 "Adaptable communications system for all railways" are documented in the Shift2Rail Multi-Annual Action plan and cover the following:

- Definition, development and test of prototypes of a train-to-ground radio system answering to the current specification of European Train Control System (ETCS) and Communications Based Train Control (CBTC) systems, including voice services but also added requirements to support enhancements of the signalling system foreseen by other TDs to improve the quality of services for users or reduce the costs (as for example communication with wayside object controllers or for TCMS)
- Design a "technology independent" system, avoiding as far as possible any specific railway solution to reduce initial cost. Allow future evolutions of the radio bearer without impact on the reliability of the signalling system(s), to keep the cost of the system as low as possible and improving efficiency over the time
- Address convergence of metro and railway (GSM-R/EIRENE) voice services, standardization of function and services with a technology independent approach to share cost and allow interoperability
- Encompass new business model definitions supporting the shift from "network as an asset" to "network as a service" model vision. Demonstrate in which conditions it could be possible to use public networks instead of dedicated networks

The X2Rail-1 project does address the first activities of the adaptable communications technology demonstrator for all railways in a single work package, which is structured in the following set of tasks.

- Technical Coordination and System Integration – covers the work coordination and management of member contributions in the technical tasks combined with the alignment with other work packages in X2Rail-1, especially the X2Rail technical management work package to ensure coherence on a system level
- User & System Requirements - The objective of this task is to capture and define the end user requirements from railway undertakings covering the predominant railway transport categories (Urban/Mass Transit, Suburban/Commuters, Freight and Regional/Main Lines) as well as requirements from existing and future applications and services. At the same time requirements around the communication layer from other Shift2Rail projects and X2Rail work packages should be incorporated. System requirements capture the quantitative boundaries (e.g. data rate, latency, QoS, etc.) of the communication system relevant to the

identified applications. They are derived from the user requirements and provide substantive input to subsequent system specification, design and validation activities.

- Business Model – The aim of this task is to define candidate business models aimed at reducing the cost of the communication system while leveraging alternative operating models. Sharing radio resources, infrastructure domains, operations or even embracing a Mobile Virtual Network Operator (MVNO) approach has the potential to reduce the financial burden, but needs to be balanced with the operational requirements around service quality, availability, reliability and security.
- Specification of the Communication System - This task defines the technical specifications of the communication system including end-to end architecture, functional domains, definition of interfaces between domains and user applications. In addition QoS and traffic prioritization, security, selection or specification of protocols and of the principles for operation and supervision of the communication system, and dimensioning rules using traffic models shall be covered.
- Guideline for choice of Technology – In this activity guidelines to assess and finally select one or more suitable radio access technologies are defined. These guidelines will take into consideration the existing knowledge of the urban and mainline railway environment, traffic model requirements, interoperability with other radio technologies and direct or indirect cost implication to create a list of key selection criteria and Key Performance Indicators (KPIs).
- Definition and development of selected prototypes - The objective of this task is to define the scope of the prototypes which will be used for the demonstrators in future X2Rail projects. A number of prototypes are planned covering different aspects of the communication system and railway environment, including the integration of different cellular radio bearers, heterogeneous networks including satellite communication system, critical voice services and the usage of advanced technologies, such as cognitive and software defined radios (SDR).
- Definition of test strategy – This task represents the preparation of the lab test activity for subsequent X2Rail projects which mainly covers the creation of a high level test and validation strategy.

In addition to the tasks in the adaptable communication work package the Shift2Rail JU has initiated a complementary action and issued an open call linked to the business model task of X2Rail-1. The open call "S2R-OC-IP2-03-2015: Technical specifications for a new Adaptable Communication system for all Railways" [5] addresses the definition of new business model scenarios for the use of more advanced radio technologies in the railways domain, as identified in Next Generation Train Control [6], to support the shift from the "network as an asset" to the "network as a service" vision. It also covers the analysis and definition of conditions in which the use of public radio communication network instead of dedicated networks could be possible. This open call project should collaborate with the X2Rail-1 project and provide its view and experiences in the business model, including the context of legacy upgrading.

3. Overview of communication systems in railways

The communication subsystem is a substantial component of the Command, Control and Signalling system (CCS) defined by the Technical Specifications for Interoperability [7]. The subsystem supports the communication between onboard, trackside and adjacent or central system. Today ERTMS relies on communication system which is based on GSM technology, called GSM-R, enhanced with Advanced Speech Call Items (ASCI) and railway specific functionality, defined in MORANE and EIRENE [8].

GSM-R technology is predominately deployed on highspeed and mainline tracks across Europe to enable communication interoperability mandated by the TSI. At the same time infrastructure managers in some countries are still relying on alternative communication systems based on analogue radio, such as Private Mobile Radio (PMR) or public mobile operator services for tracks in rural or remote areas. In areas with high user density or significant traffic demand some operators also use alternative radio system like PMR to overcome radio resource shortage imposed by GSM-R. The urban rail domain is usually not concerned with interoperability regulations and therefore has implemented networks based on TETRA for voice requirements and the Wi-Fi variant IEEE802.11p for data applications, including the support of the urban rail train control system CBTC.

Railways are currently using dedicated systems in dedicated spectrum, in order to manage the network and the subscribers in a fully independent way. Railways require a strict control over the subscriber base, the entitlements of each user and over the level of coverage and service availability in all the geographical extension of the railway lines supported by the system. This is key to ensure the fulfilment of their operational needs. Since there already is a large GSM-R infrastructure in place, and railway life cycle in the range of 15 - 50 years, the successor system will coexist during a period of time of approximately 10 years with the existing GSM-R. This implies that in addition to migration considerations the requirement for coexistence becomes pivotal to ensure a smooth transition towards the successor communication system.

It becomes obvious that the railway communication system has become a complex patchwork of networks and radio technologies with limited interworking and inter-system handover capabilities. As a result delivering consistent communication services for voice and data applications has evolved into one of the main technology challenges for railway undertakings these days.

In the light of risk of obsolescence of deployed technologies and the development of new applications, railway stakeholders have identified the need for a new communication system and started different initiatives and project to define the future communication system for railways.

4. The UIC FRMCS Project

In 2012 the UIC set up a project, called Future Rail Mobile Communications System [9] to work on the necessary steps to define a future communication system and enable the introduction of a technology successor for GSM-R. At the beginning the UIC evaluated the current situation and launched several studies on users' needs which resulted in the collection of requirements captured in the "User Requirements Specification" document.

The scope of the FRMCS project covers the assessment of the current functional requirements specification (EIRENE FRS) [10] , with the aim to support an equivalent capability set, but removing obsolete requirements and including future needs and potential new functions. In addition the FRMCS project is working on the architectural analysis, the definition of functional interfaces, migration strategy, technical impact and spectrum needs. Finally the FRMCS project will initiate studies around improvements and opportunities in the areas of infrastructure and radio resource sharing. The User Requirements Specification URS document version 2.0 [11] was published March 29th, 2016 and describes the functional requirements and service characteristics of communication and support applications. The services have been categorized into critical, performance and business related services. It is currently used as basis for standardization work in the Rail Telecommunications Technical Committee of the European Telecommunications Standard Institute (ETSI TC-RT) [12] and the 3rd Generation Partnership Project (3GPP) working group SA1 (system architecture – functional) [13].

In August 2016 the 3GPP SA plenary approved a study item to investigate the requirements for a new railway communication system as successor to GSM-R. Meanwhile, using the User Requirements Specification the UIC FRMCS project and the ETSI TC RT working group created a set of use cases and submitted a number of contributions into 3GPP SA1 for Release 15, which resulted into the technical specification document TS 22.289 "Mobile communication system for railways" [14] and change requests to the mission critical specifications TS 22.179 [15] and TS 22.280 [16] . These specification documents act as a basis for the downstream work for stage 2 and stage 3 by other 3GPP working groups, especially the system architecture working group for critical applications (SA6).

So far the FRMCS project is mainly concerned with requirements from the highspeed and mainline domains, which are typically served by GSM-R radio systems. From that perspective, FRMCS is primarily analysing a successor system for GSM-R.

It becomes evident that the FRMCS project, ETSI TC RT work and the activities in X2Rail projects for the adaptable communication system overlap in several areas and complement in others. Thus collaboration between the groups and initiatives is desirable to avoid diverging approaches and align on the system principles and architecture for the future telecommunication system for all railways.

5. Preliminary findings for the adaptable communications system

The X2Rail-1 project formally started in September 2016, and at the time of writing this paper, has been working on the adaptable communications system for almost twelve months. The main focus for the first phase of the project was the user and system requirements analysis and collection. The requirements capture methodology has been to initially adopt, verify and adapt the FRMCS User Requirements Specification as a benchmark, whilst focusing on the requirement of 'adaptability' and considering all segments of rail transport, including metro and urban rail, for incorporation into the final solution. It has taken a technology and solution agnostic approach.

Adaptability is recognized as one of the main added values of the new communication system and incorporates scalability as a means of guaranteeing technological and economic sustainability, as well as being able to address the heterogeneous needs of a wide range of present and future applications in all railway domains. Similarly flexibility has also been defined in terms of technological requirements in order to achieve the vision for of a bearer agnostic, multi-access and adaptable communication system able to cope with the wide range of present and future radio access technologies and networks.

5.1. User and System requirements

User requirements (UR) have been ascertained by means of conducting guided conversations with a wide range of railway telecommunication user, stakeholder representatives and have aimed at being as comprehensive as possible. The final requirements have emerged through harmonisation of the FRMCS User Requirements Specification in that:

- a number of additional applications have been identified;
- additional functional and non-functional attributes have been incorporated;
- detailed needs and constraints have been identified.

Five key URs have been distilled, and all the URs have been translated into System Requirements (SRs), i.e., technical performance expectations have been attributed to the qualitative URs and specify the system behaviour and performance level each attribute should achieve for a particular application.

Precedence has been given to requirements covering the primary uses cases for signalling, critical voice, critical video, critical data and passenger connectivity. Key system requirements cover network security risk, mean downtime and availability and encompass mainline, regional, freight and metro & urban rail. The top level system boundary and interfaces have been determined. It is recognized that the boundary is complex to define in detail because it is dependent on the application the telecommunications system is interfacing with.

The System Requirements will be used to guide the architecture and design of the resulting telecommunication system and used as a benchmark for system validation and verification activities.

5.1.1. Key User Requirements

1. The system will be adaptable in terms of radio access technology support, bearer selection and configuration as required by prevailing QoS demand and availability, and scale in terms of performance, reach and number of users.
2. The network will provide a convenient means for migration, upgrade and maintainability, co-existence and backward compatibility when required.
3. The network will be able to support safety critical communication for railway applications, and be able to provide connectivity to selected third party users, such as primary emergency services.
4. The system will be resilient to service disruption through equipment failure, malicious events, interference etc.
5. The system requirements should allow for the design of a system that lowers energy and environmental impacts when compared to existing solutions.

The following diagram (Fig. 2) depicts the concept of the envisaged adaptable communications system and has been developed based on the Key User Requirements and identified applications. It includes contextual aspects such as: use of train control and traffic management, user types and railway scenarios. The figure incorporates mainline, freight, regional/rural and urban/metro railway operating scenarios, as well as a range of services requiring telecommunications for effective operations. These services are: passenger information; on-board systems; passenger connectivity; passenger data; driver voice; train crew connectivity; safety and security; CCTV; signalling; autonomous and remote vehicle operation; maintenance staff connectivity; electronic signage; wayside objects and sensors; level crossings; and virtual coupling.

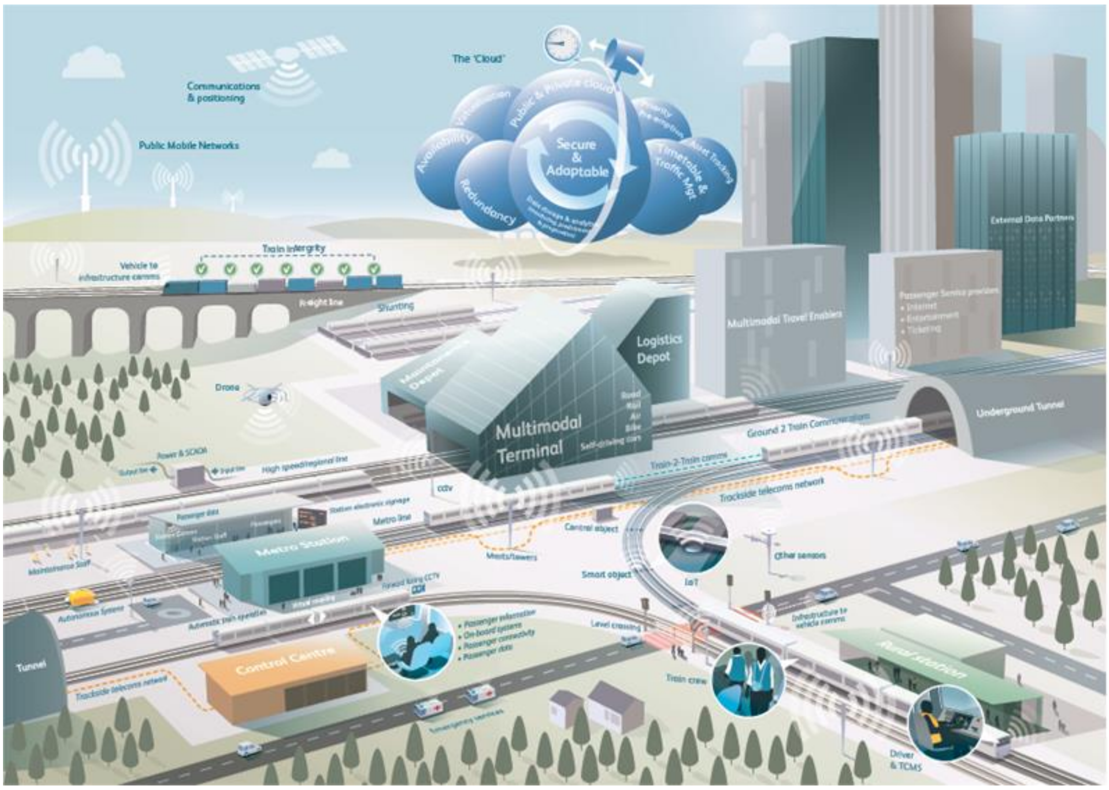

Fig. 2 - high level architecture of the adaptable communication system

The telecommunications core functionality is depicted as a ‘cloud’, which represents the adaptability of the communication system, in that it can adapt to prevailing and predicted circumstances and may consist of a fabric of telecommunications technologies connecting railway services. The cloud identifies and allocates appropriate telecoms resources to provide the required services at a given time. It would be able to dynamically divert resources as demanded and network circumstances require. It would also connect data warehouses and provide network security.

Migration, co-existence and backward compatibility are implied in the figure in that no particular telecommunication system has been specified. Consequently, it should be able to support migration, co-existence and backward compatibility between technologies.

Support for safety critical applications is depicted in the figure through the presence of emergency services, a level crossing, driver connectivity and on-train signalling. Maintainability and resilience are implied through the use of a ‘cloud-centric’ network that supports adaptability, redundancy and a software-centric network that eases maintenance requirements. Lower energy and environmental impacts are implied through the use of a single adaptable network that supports a range of services, compared to the use of multiple independent ‘stove-piped’ networks requiring bespoke and sub-optimal infrastructure.

5.2. Business Model

The business model task investigates potential cost reductions for the future communication system by exploring alternative operating models that include sharing radio resources, infrastructure domains, or operations. For all candidate models it has to be ensured that service quality, availability, reliability and security are sufficient for the operational needs of railways.

In the course of this task the following five business models have been identified:

- *Dedicated Mobile Network* - For this scenario, the entire network is under full ownership and control of the Railway Infrastructure Manager (IM), as is the case for current GSM-R deployments. Thus, the IM can design the network according to the operational requirements. Capital Expenditure (CAPEX) savings can be expected in the case that a base station infrastructure is already in place as costly sites (including masts or non-transmission related infrastructure) can be re-used. However, this model will most likely not be suitable for applications with very high data rate needs, as the radio spectrum currently available for railways (2x3 MHz UIC spectrum) is not sufficient to fulfil such requirements.

- *Dedicated Network with Supplementary Public Network* - Frequency scarcity can be mitigated by using a supplementary network operated by a Public Network Operator (PNO) on top of the dedicated railway network operated by the IM. Mission critical services would still be made available via the dedicated network, while the supplementary public network could be used for traffic offloading, especially for non-critical services that require higher data rates e.g., passenger connectivity or real-time video applications. Another business model that relies on a supplementary public network is the use of public Satellite Communication networks to increase coverage and availability in low-traffic regional areas, where the implementation of a cellular network is not always economically viable.
- *Dedicated Network, RAN Sharing with Public Network* - Sharing the Radio Access Network (RAN) could possibly result in a reduction of costs, as the RAN is the most expensive part of a mobile network. Usually, RAN sharing encompasses the joint use of sites, masts, antennas, and power supply, but can also include transmission-related equipment. The usage of both dedicated rail spectrum as well as public spectrum owned by the PNO is possible, thus making applications with higher data rates feasible. Given an appropriate agreement between the IM and PNO, the IM retains control over the network and the user management. The Core Network (CN) remains under the ownership of the IM.
- *Public Network, IM as MVNO* - In this scenario, the IM does not operate its own dedicated wireless communication infrastructure anymore, but acts as a Mobile Virtual Network Operator (MVNO) who uses an existing public infrastructure to provide its services. Benefits include potential cost savings (CAPEX and potentially OPEX), the possibility for higher data rate applications, as well as an increased resilience in the case of multiple public networks being used. The MVNO retains control over the management and authentication of users. However, coverage and availability depend on the PNO. Furthermore, Service Level Agreements (SLAs) need to be in place to ensure a sufficient level of service quality and prioritization of mission-critical traffic. Finally, rail-specific voice services are not per se supported by a PNO and would require additional agreements.
- *Public Network* - In this final operational model, the IM does neither own, nor operate a dedicated network anymore and instead relies solely on the services of a PNO. In general, benefits and disadvantages are similar to the MVNO model. Since the entire network operation is under the purview of the PNO, a further reduction of OPEX might be realized in case moderate price margins are imposed. Availability and QoS depend entirely on the PNO, which results in strict SLAs to allow for the critical operation of trains. Furthermore, security issues have to be taken into account as the IM rescinds control of user network authentication to the PNO as well.

The different business models will be evaluated for four different rail market domains. Even though the different rail market segments have the potential for alignment, their specific characteristics cannot be ignored. The rail market segments under consideration in this task are high-speed/mainline, urban/metro, regional, and freight. All four segments represent railway operating scenarios relevant to Shift2Rail. For each rail segment, traffic parameters including, e.g., number of passengers, maximum & average train speed and number of communication users, have been collected, which are in line with previous findings in [17].

5.3. Choice of technology

The aim of the “Choice of technology” activity is to aide and consult Railway Infrastructure Managers with identifying the right radio technology for their use case and particular domain requirements. Guidelines for the assessment of suitable radio access technologies will include a list of key selection criteria, which can be divided into four main categories:

- *System Requirements* - Technological candidates should be able to fulfil virtually all system requirements as captured in the “user and system requirements” activity (see Section 5.1). Generic requirements such as latency, data rate, reliability, availability, and adaptability are included, as well as specific functional requirements such as those for voice and voice group calls.
- *Traffic Model* - A communication traffic model will be developed to determine the necessary data rates to fulfil the needs of all railway applications as defined in the “user and system requirements” activity (see Section 5.1). Traffic calculation will not only distinguish between the four types of railway domains, i.e. high-speed, metro, regional and freight, but also include a generic high traffic station with shunting area. The model will also account for a future telecommunication traffic increase that is anticipated through large scale deployment of IoT sensor, wayside object networks or improved passenger connectivity.
- *Radio Link Characteristics* - The guidelines will take into consideration different mechanisms to ensure sufficient signal coverage, reliability and low latency. This includes the discussion of suitable railway network topologies as well as radio link propagation models for high speed mobility.

- *Coexistence and Interoperability* - The guidelines will take into consideration the coexistence and interoperability with legacy GSM-R systems, and specifically managing interference of GSM-R and its successor in case both are operating in adjacent or identical frequency bands. Furthermore, interference with rail-unrelated services in neighbouring frequency bands has to be taken into account.

For the remainder of this task, all key selection criteria outlined above will be refined and elaborated in more detail. Finally, all criteria will be linked to existing and emerging radio technologies including LTE, 5G, Wi-Fi and Satellite Communications. It has to be noted that this assessment will not result in the choice of a single technological candidate, but it will merely provide a guideline to aid the assessment and selection of both available and emerging radio technologies.

5.4. Specification of the communication system

The focus of this task is on the architectural analysis and definition of system principles guided by the user and system requirements. The first step in this activity led to a list of principles and further investigation areas, which include but are not limited to:

- Support of multiple access networks
- Enable concurrent use of access network for increased logical link reliability, higher aggregated throughput and traffic segregation based on application profiles
- Support of service hand-over between access networks without interfering, interruption or impacting the applications
- Transparent access network usage while hiding access details and characteristics and expose only necessary bearer information to the application
- Superior service availability for applications, users and devices in comparison to legacy systems
- Identification of common functions such as network security, identity management and policy control across different access networks
- Definition of criteria for selecting the radio access network based on application requirements, user equipment coverage, traffic profile in the areas etc.
- Handling of prioritize traffic and service pre-emption
- No single point of failure
- Support of end-to-end application security
- Coherent and simple functional interface for applications

The functional architecture depicted in fig. 3 for the adaptable communication system can be segregated into three layers, the onboard system, the access layer which consists of one or more access domains and the network layer.

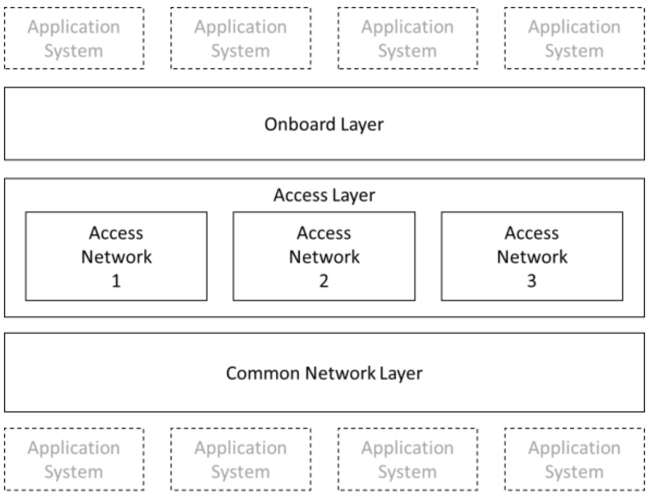

Fig. 3 - High level architecture of the adaptable communication system.

The onboard system provides the interface to a range of onboard applications and acts as a gateway to the network by connecting through available radio access networks. The access layer embodies the access networks based on cellular radio, Wi-Fi, satellite communication or other technology systems. The fixed network becomes also part of the access layer to connect fixed devices or equipment connected through ethernet, fibre or alternative links. The main attributes of access networks within the access layer towards the network can be circumscribed as packet based and capable of QoS management and control. The network layer will act as an umbrella covering all of the access networks in the access layer whilst ensuring adaptability, flexibility, availability and security are managed particularly when devices or equipment move from one coverage area into a neighbouring area or from one access network to another. During these handover scenarios the communication services shall be managed without interruption towards the application. The network layer will also provide a coherent interface towards applications and systems located trackside or adjacent to the trackside.

Going forward, this specification task will investigate the aforementioned principles and derive the system components which will form the adaptable communication architecture. One of the key questions to be answered is which technical basis should be used. The 3GPP project has issued a set of specifications, which are able to address the majority of the user and system requirements. The functional architecture defined for mission critical applications is able to support voice requirements including point-to-point and group communication as well as mission critical video services and data services. In addition, the 3GPP project already includes a close integration of non-3GPP access such as Wi-Fi by supporting handover of data sessions and voice calls between Wi-Fi and LTE. In comparison, an alternative approach might follow the over-the-top principle, which relies on an IP pipe and minimizes the interaction between applications and control mechanism of the communication system. The main advantage can be identified by looking at a single application, which has limited interaction with the communication system. From a single application perspective this over-the-top approach addresses all functional requirements, but becomes complex coordination challenge when a set of applications require communication channels with different characteristics and raises the demand for limited resources. In contrast, a centralized coordination and orchestration function in line with 3GPP specifications is capable to balance the application requests and providing direct feedback to the applications in case the communication requirements cannot be supported. It should be noted that the reference to 3GPP for the aforementioned functions does not imply a tight link to 3GPP access technologies. Most if the functions, for example 3GPP MCPTT, can be implemented without strong dependencies to the underlying systems or close integration with the access layer.

The common network layer provides a coherent communication interface to the application layer and hides the specific network or radio access details from the applications. In addition, common functionality and capabilities across all access networks are consolidated and unified, which include authentication, admission control, user profile management, policy control, routing, secure transport and hand-over. The upcoming work in the specification task will focus on the functional split of the communication system, the relation between system components and the definition of quantitative and qualitative capabilities linked to inter radio access network hand-over, pre-emption handling and traffic prioritization. Furthermore, the activity will identify and refer to existing standards and specifications including functional frameworks, which will act as basis of the adaptable communication system, as well as highlighting the areas, which require further elaboration, enhancements and potentially the creation of new standards.

6. Summary and outlook

The definition and specification of the adaptable communication system within the Innovation Program 2 shall contribute to the overall Shift2Rail goals of cutting life-cycle costs by 50%, doubling railway capacity and increase reliability and punctuality as much as 50%. These goals in the light of the broad and diverse user and system telecommunication requirements represent a complexity, which is addressed by a number of tasks in the adaptable communication work package. The different railway domains have common requirements as well as specific needs, which have to be mapped into a common functional architecture without constraining the target characteristics of the system including integral adaptability, flexibility, scalability, upgradability and security.

An imminent step towards realizing this vision is to define how adaptability will be embedded into the telecommunication system. In this paper, it has been considered as a means of dynamically selecting available network resources to best satisfy demand by the applications whilst decoupling the application from the underlaying radio and core network. This could assume a local decision made by an onboard unit, or a global decision made by a centralized network controller. It may assume a level of cognition and even forward prediction of resources, demand, allowable latency and economic factors.

The activity and findings within the first 12 months provided valuable insights and background information, which will guide the upcoming collaboration towards a solution with addresses all requirements and enables a new set of advanced traffic management and train control applications, which will ultimately make the rail transport more competitive.

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