Working Principles and Use Cases of Railway Mobile Communication System towards 5G & Beyond

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Introduction:
Railway mobile communication system

- Railway infrastructure and networks requires robust telecommunication system internationally.
- Railway infrastructure managers and railway undertakings currently use an interoperable radio communications network, **GSM-R (Global System for Mobile Communications – Rail)**, for operational voice communications and to provide the data bearer for ETCS (European Train Control System).
- It is widely used in Europe and China for **security and train tracking applications** through the secure transmission of voice and data, and also provides the communications that allow ETCS (European train control systems) to function.

Introduction:
GSM-R

- Both GSM-R and ETCS are part of the **ERTMS (European rail traffic management system) standard**, which is defined by the International Union of Railways (UIC) and is designed to allow interoperability between cross-border traffic.

- **GSM-R supports**:
  - voice group call,
  - voice broadcast call and
  - prioritization of these services.

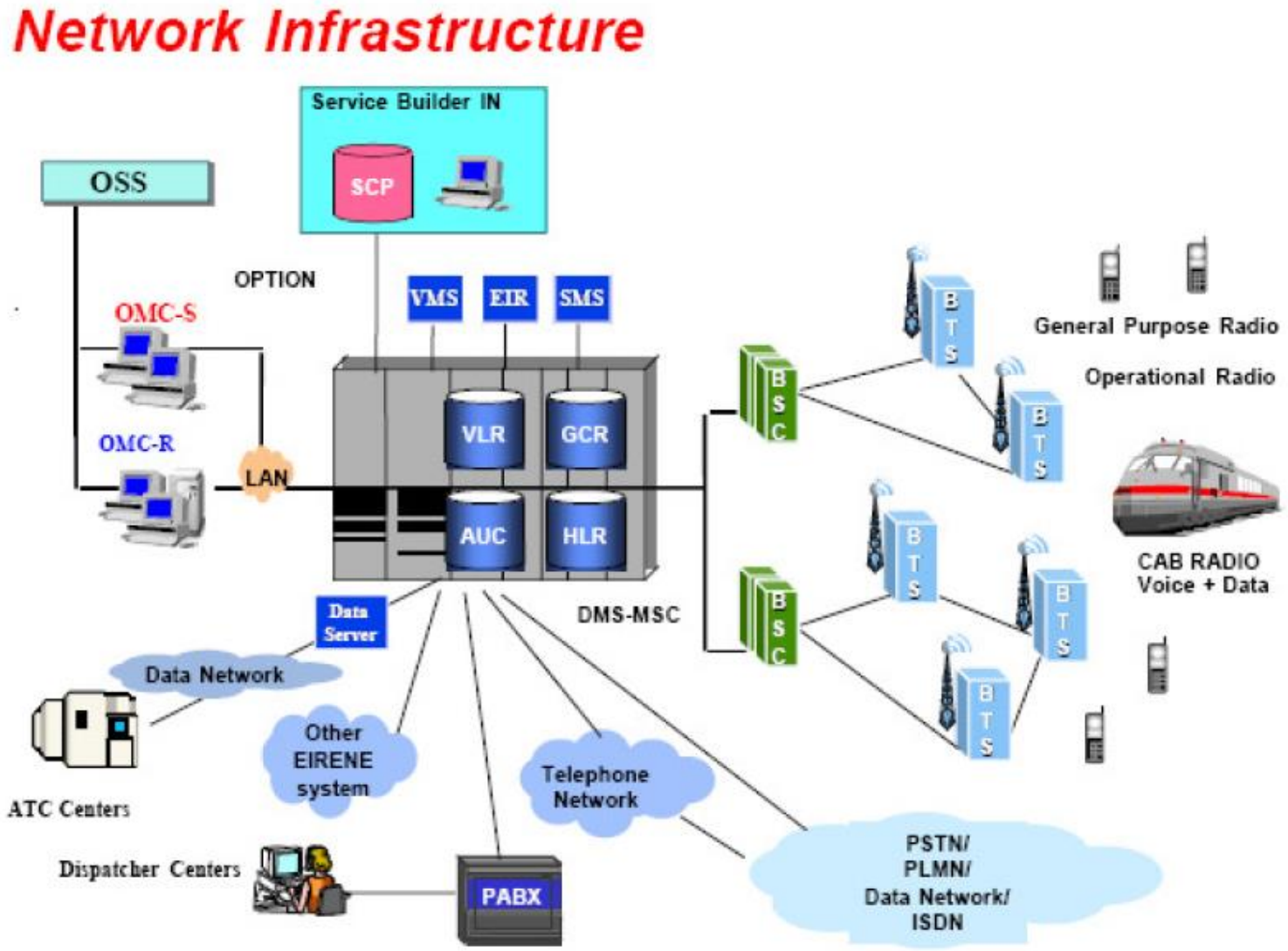
Introduction: GSM-R Architecture

The GSM-R system is based on GSM and EIRENE (European Integrated Radio Enhanced Network) – MORANE specifications

The architecture of GSM-R is divided Switching Sub-system (NSS) and Ope

GSM-R is one part of ERTMS (European Rail Traffic Management System) which is composed of:

- ETCS (European Train Control System -ETCS, signalling)
- **GSM-R (communication)**
- **ETML (European Traffic Management Layer-ETML, payload management)**
- **EOR (European Operating Rules)**



Introduction:
ERTMS

ERTMS comprises of two systems :

ETCS (European Train Control System), a train control standard, based on:

- onboard equipment for **supervising train movements** at all times and to stop the train if it moves beyond the permitted stopping point.
- Monitoring of driver's response (if necessary, ETCS takes control and activates the emergency brakes).

GSM-R, the European radio communications standard for railway operations.

- Based on GSM radio technology, GSM-R uses exclusive frequency bands for communications between the train and traffic control centres and the trackside devices (Radio Block Centres [RBCs]).

Introduction:
GSM-R Frequency band

E-GSM (900 MHz-GSM) or DCS 1800 (1,800 MHz-GSM)

- **Europe** (4MHz wide range)
  - Uplink (UL): 876–880 MHz used for data transmission
  - Downlink (DL): 921–925 MHz used for data reception
- **China (**4 MHz wide range)
  - Uplink: 885–889 MHz
  - Downlink: 930–934 MHz
- **India (**1.6 MHz wide range)
  - Uplink: 907.8–909.4 MHz
  - Downlink: 952.8–954.4 MHz
- **Australia**
  - UL: 1,770–1,785 MHz
  - DL: 1,865–1,880 MHz

Future Railway Communications

Railways telecommunication networks should offer:

- Support Operational needs of Infrastructure Managers:
  - Trains circulation,
  - ETCS signaling,
  - supervision of line energy,
  - Track maintenance.
- Support Services requirements of Railway Undertakings:
  - Administrative Telephony,
  - Supervision of railways installations,
  - passengers information,
  - ticketing etc.

UIC (International union of Railway) defined Future Rail mobile communication Systems (FRMCS) and described user's requirements specifications (URS)

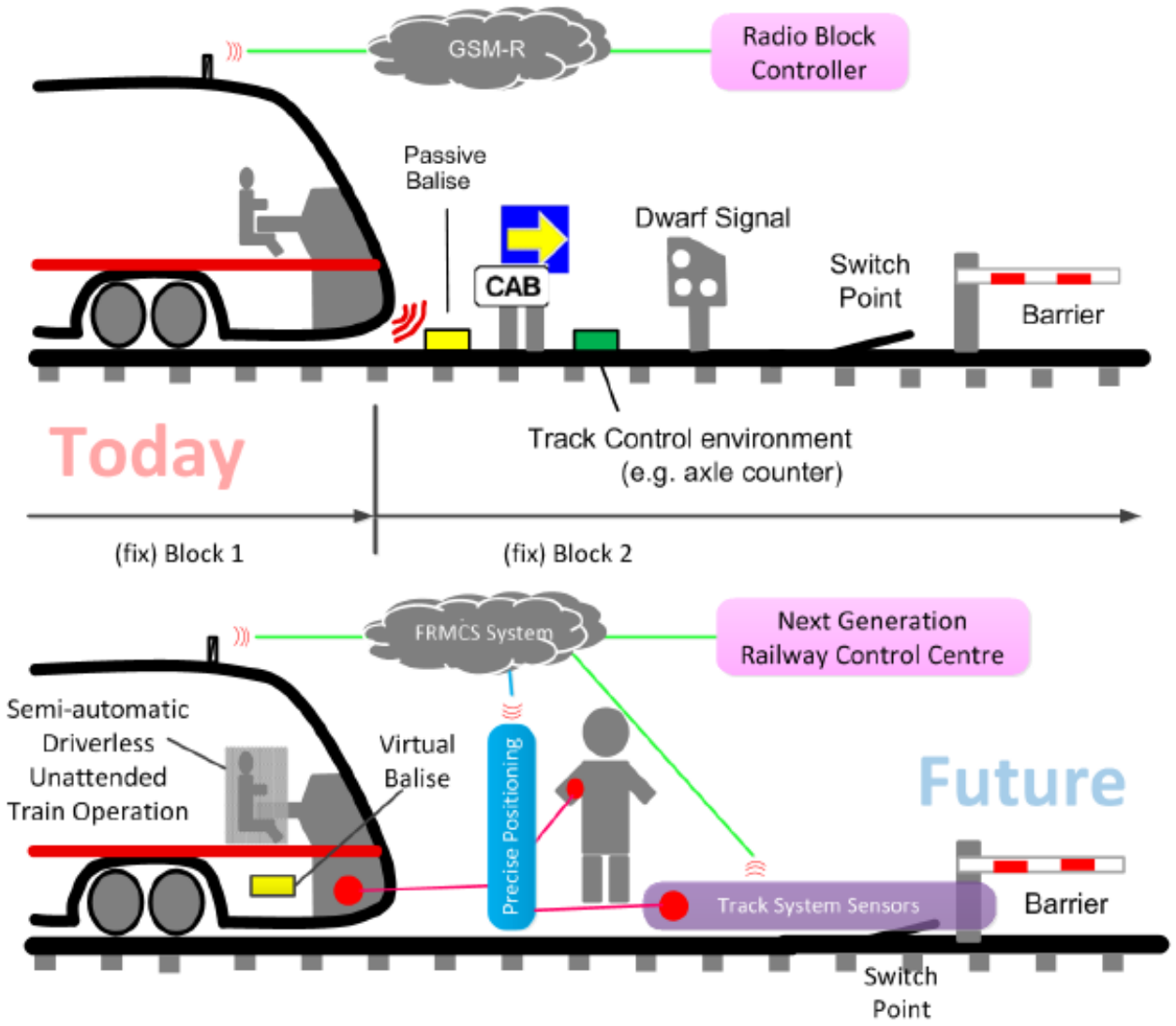
Users in FRMCS refer to: (few example)

- Driver(s)
- Controller(s)
- Train staff:
  - -Train conductor(s)
  - -Catering staff
  - -Security staff
- Trackside staff:
  - -Trackside maintenance personnel
  - -Shunting team member(s)
- Railway staff (excl. all of above):
  - -Engine scheduler(s)
  - -RU operator(s)
  - -Catering scheduler(s)
  - -Engineering personnel
  - -Station manager(s), etc.
- Member of the public:
  - -Passengers (on trains, on platforms, at stations, etc.)
  - -Other persons (on platforms, at level crossings, etc.)
- Systems:
  - -ATC on-board system
  - -ATO on-board system
  - -On-board system
  - -Ground system
  - -Trackside system
  - -Sensors along trackside
  - -Applications (such as, for example, those for monitoring lone workers, for remote controlling of elements)
- Network operator
- Public emergency operator

What are the railway targets ?

Railway targets

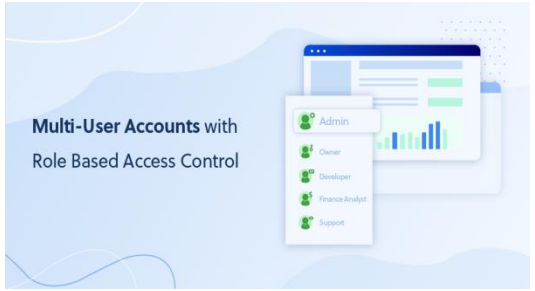
- Improve punctuality
- Increase line utilisation (more trains per hour)
- Reduce system costs (track, rolling stock)
- Lower the amount of interfaces and complexity
- Automation of processes
- Accuracy in positioning (rolling stock, track system)



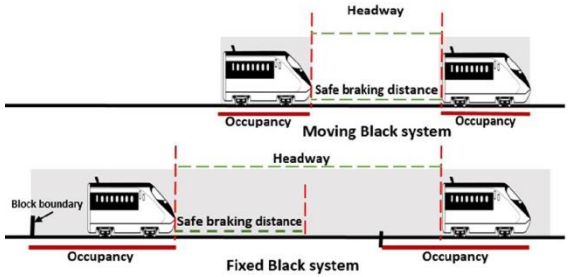
Requirements for the Future Railway Mobile Communication System

URS deals with major six classes of applications:

Emergency communications, Automatic Train Control, shunting …

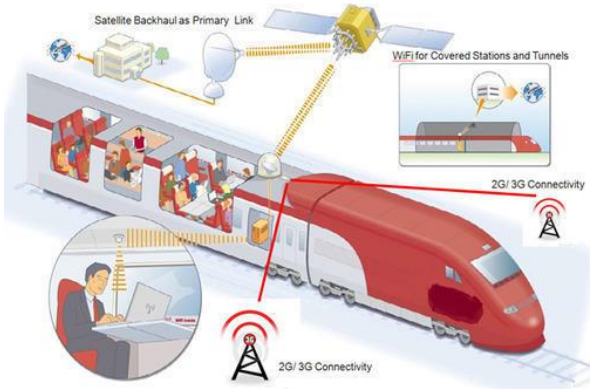


Critical support applications (e.g. role management and presence, multi user talker control…

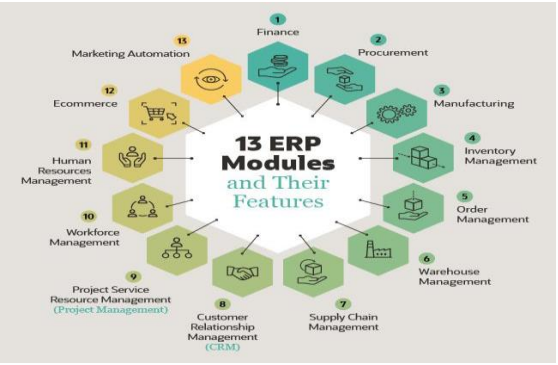


Performance communication applications (e.g. lineside telephony, public address …)

Performance support applications

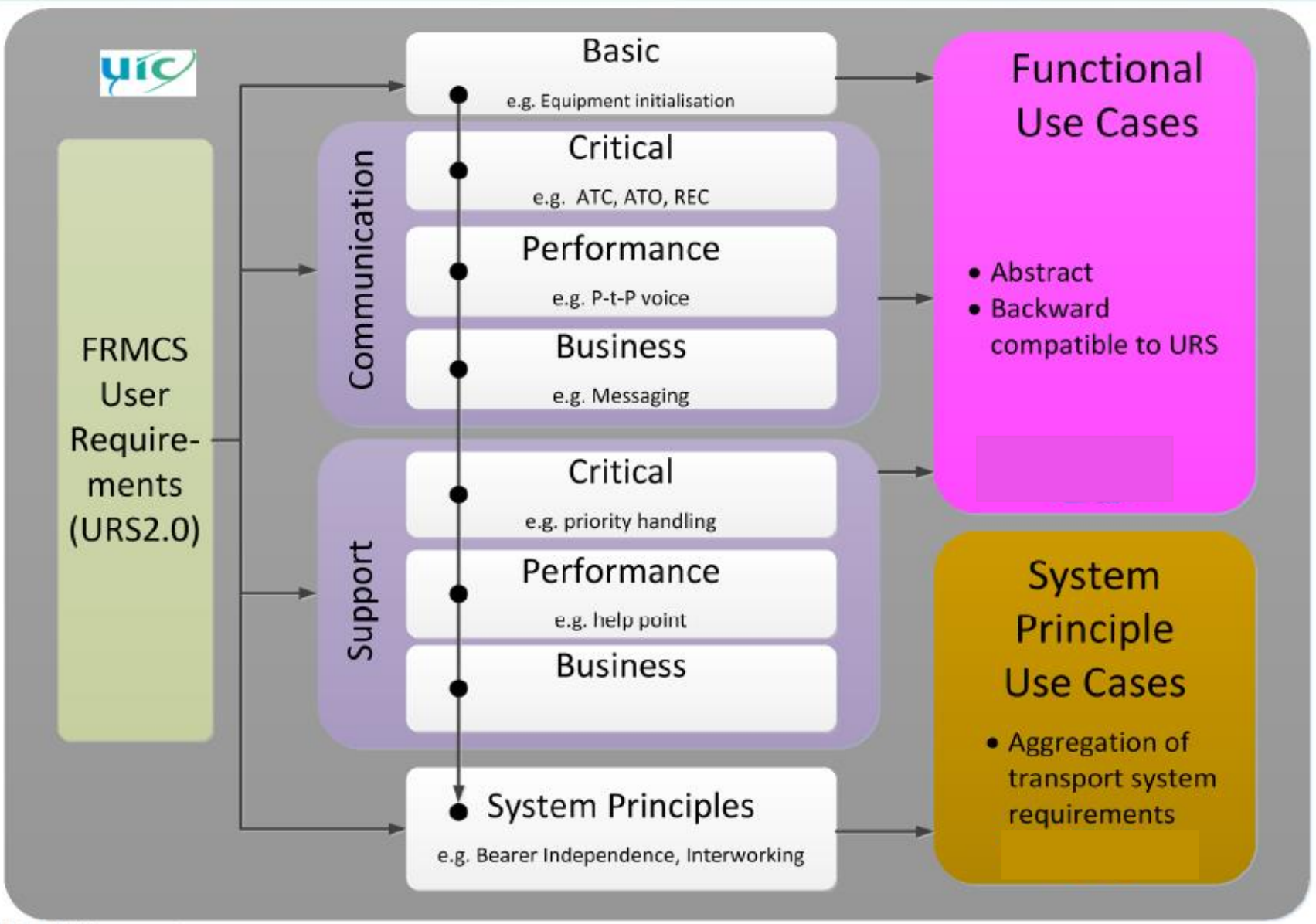


Business communication applications (e.g. wireless internet on-train for passengers …)



Business support applications (e.g. billing information …)

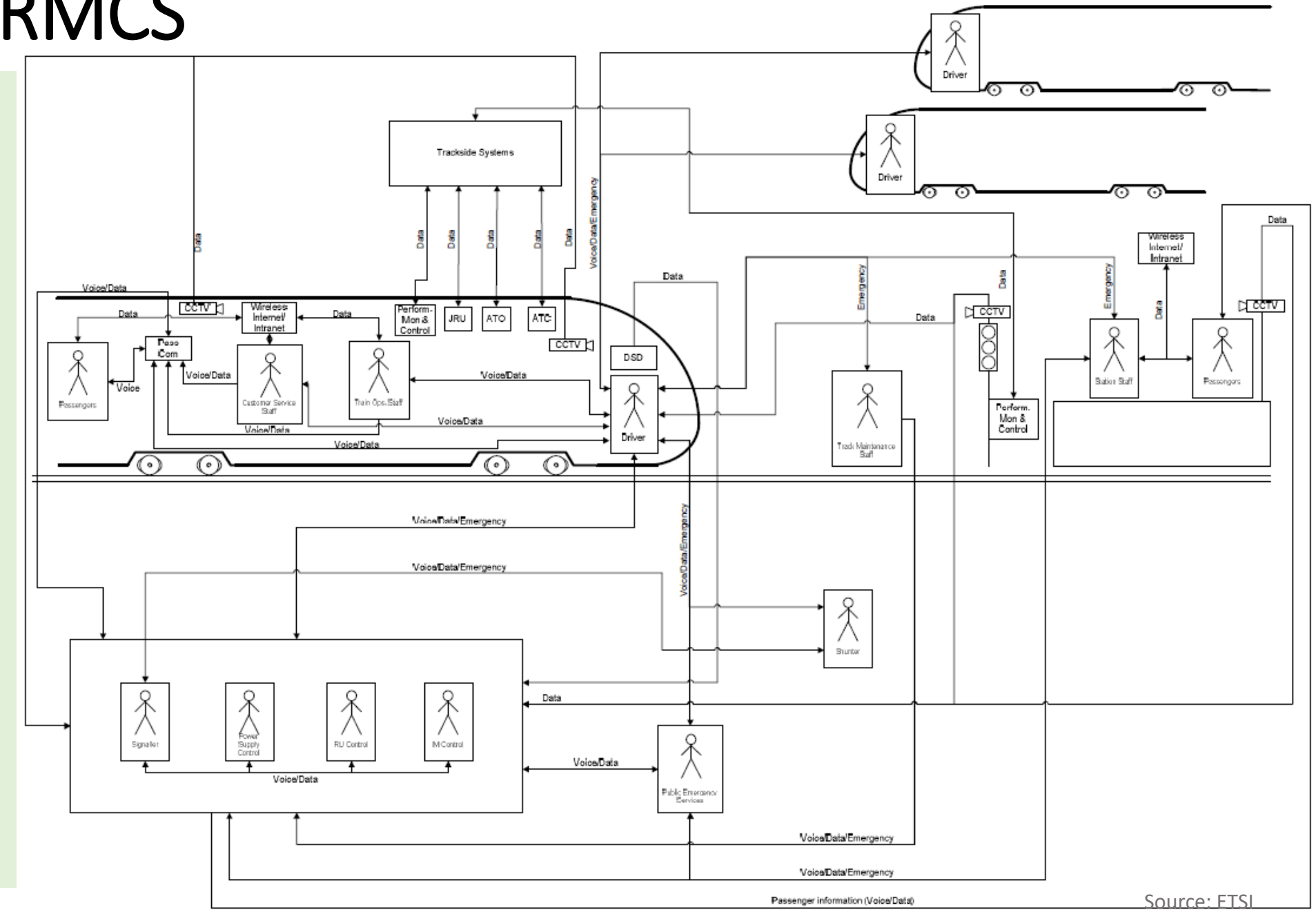
User requirements and Use cases



Scope of FRMCS

Fig. illustrates from the **perspective of the user**.

It shows the **complexity of the communication needs** in the railway environment, and illustrates only a certain number of relationships between the human users and equipment (trackside and on-board) or between equipment without human interaction.



Source: ETSI

Fundamental Principles in Development

Fundamental principles that shall be considered throughout the development of voice and data applications for FRMCS:

Satisfy the Communication needs of the Railway Operation.

- Operation includes normal, degraded and emergency operating conditions.
- Characteristics of theroute, for example maximum permissible line speed, headway between
- trains, complexity of route (single, double, multiple track layout), low/ medium/high density routes, climatic environment, volume of train journey commencing.
- Capacity, reliability, availability, maintainability, quality of service.

Support the **applications independently of the used FRMCS networks** and radio access technologies by any of the users.

- Transition of a user to or from other FRMCS networks or radio access technologies shall
- not lead to interruption of the usage of the applications.
- Provide voice and data communication.
- Provide all basic telephony features and supplementary services as commonly used (for example Call forwarding, call transfer, etc.
- FRMCS networks shall be able to interconnect/interwork with GSM-R or and/other networks

The FRMCS shall **place the human being at the centre of the design.**

- Human-Machine Interfaces shall be intuitive.
- Human-Machine Interfaces shall be standardized where possible.
- Functionality/application shall remain consistent across all devices used.
- For voice communication, the system will allow the user to switch between different modes of using the microphone and loudspeaker (e.g. handset, headset, hands-free, etc.) based on the operational needs.

Support the **exchange of information and performance of actions without the manual assistance of humans** (machine to machine communication) both for operational and maintenance purposes.

- Automatic and remote monitoring of the characteristics of the railway assets has to be supported.
- Maintenance of on-board and infrastructure assets have to be automated.

Shall mitigate the risk of miscommunication.

Shall be cost effective.

Provide precautionary measures to prevent unauthorized access.

FRMCS/5G support for Railway Applications

Use Cases

Allocation and isolation of FRMCS communication resources (was End-to-End Network Slicing for FRMCS)

Bearer Flexibility: 5G expands the use of heterogeneous network allowing a common core to control both 3GPP and non-3GPP access. It will support a harmonized QoS and policy framework that applies to multiple accesses.

System Security Framework: Primary authentication: Network and device mutual authentication in 5G is based on primary authentication. In railway this would be particularly useful for trains roaming onto another railway network. Primary authentication is radio access technology independent, thus it can run over non-3GPP technology such as IEEE 802.11 WLANs. This would allow authentication to be consistent across the various flexible bearers. Secondary authentication: in 5G it is meant for authentication with data networks outside the mobile operator domain

Roaming: Railway Industry could add its own universally recognized Network/Slice service types to fulfill FRMCS requirements. Mission critical service (MCX) users who roam onto a visiting network would roam onto the visiting MCX server. The visiting network server would query the home network MCX server.

Maintainability: FRMCS on-board gateway will contain SIM cards to support multiple frequency bands

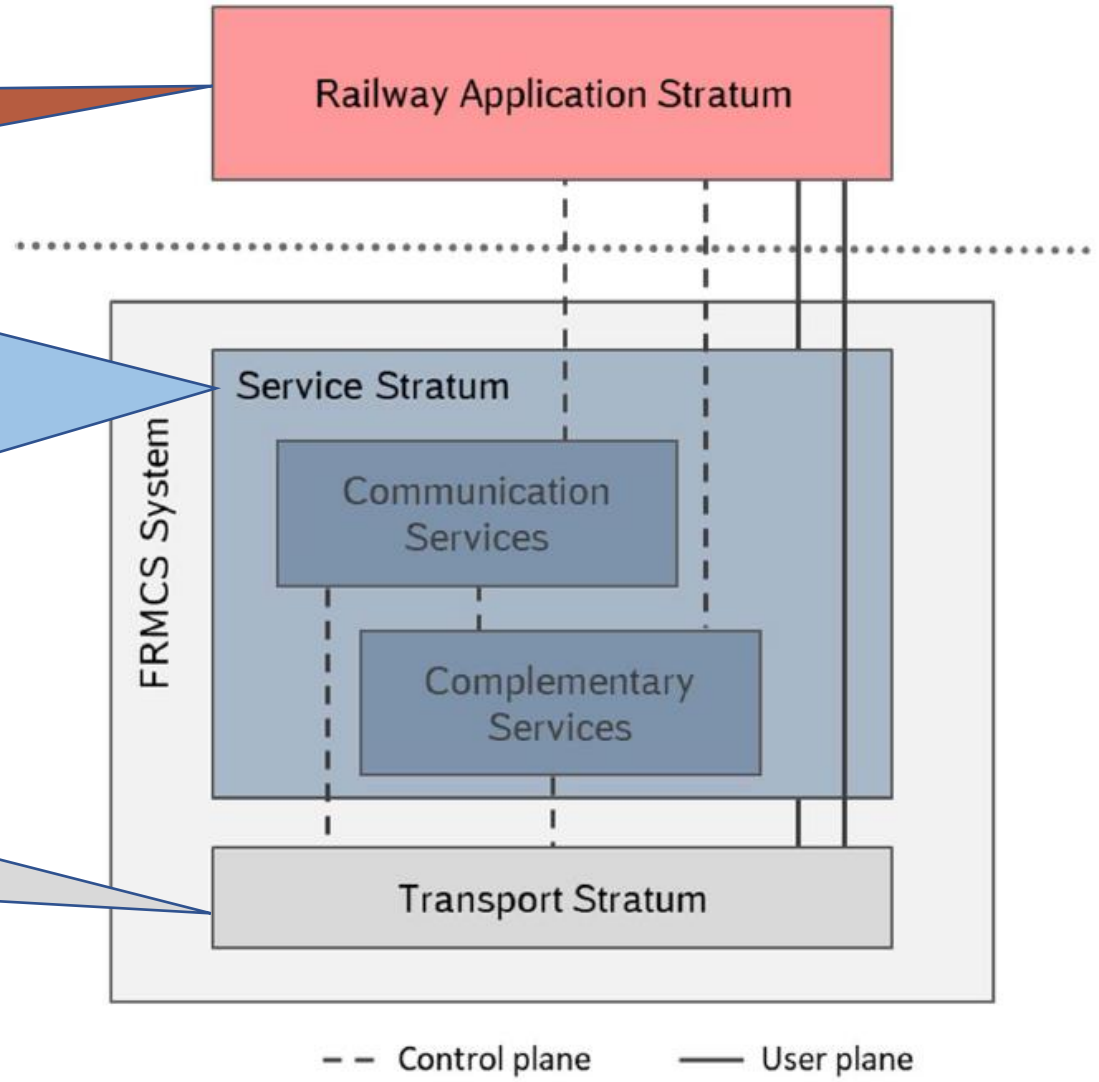
FRMCS Equipment capabilities for multiple FRMCS Users: The UE would manage a separate IP address for each FRMCS user managed by the UE.

High Level Architecture: FRMCS

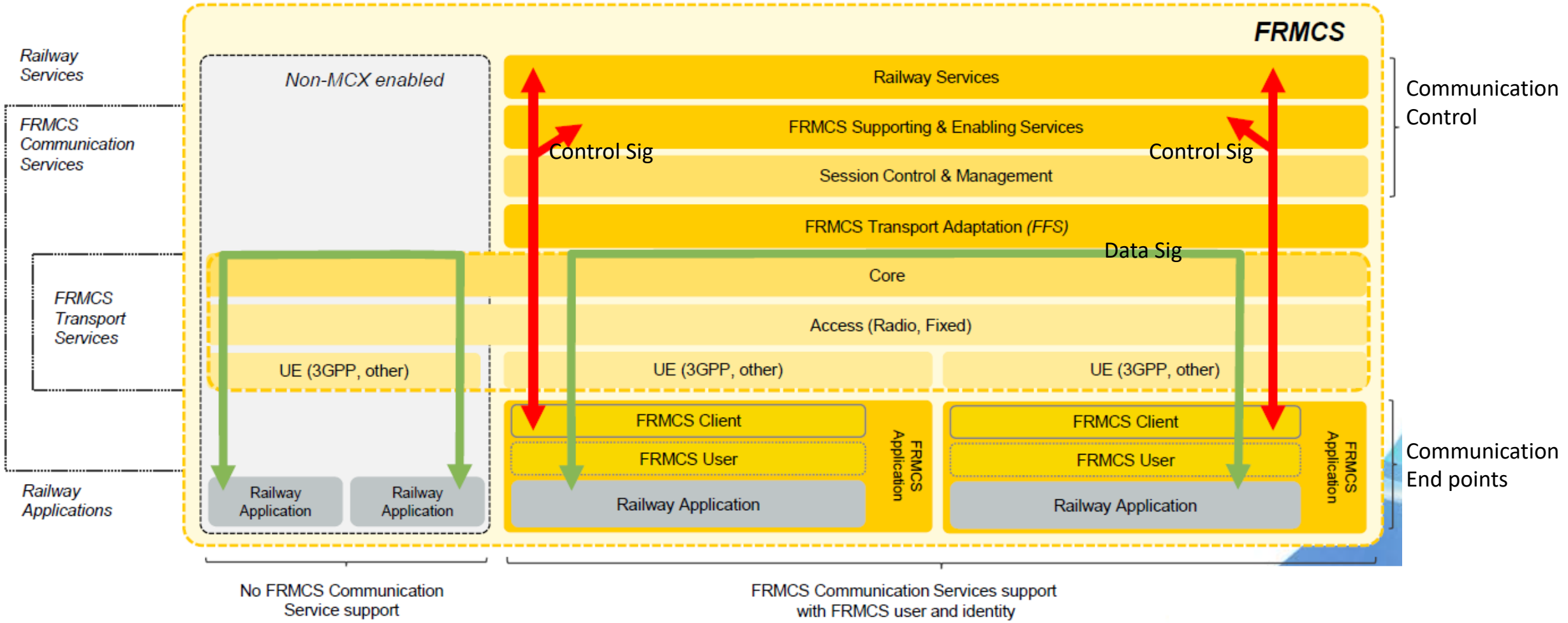
The **Railway Application Stratum** provides railway-specific functionalities using services offered by the service stratum.

The **Service Stratum** comprises Communication services and Complementary Services:
- **Communication Services** are services enabling the exchange of information between two or more service users.
- **Complementary Services** are ancillary services, e.g. providing and/or utilizing the location of the service user, supporting Communication Services and the Railway Application Stratum.

The **Transport Stratum** comprises the set of access and corresponding core functions applicable for the FRMCS system.

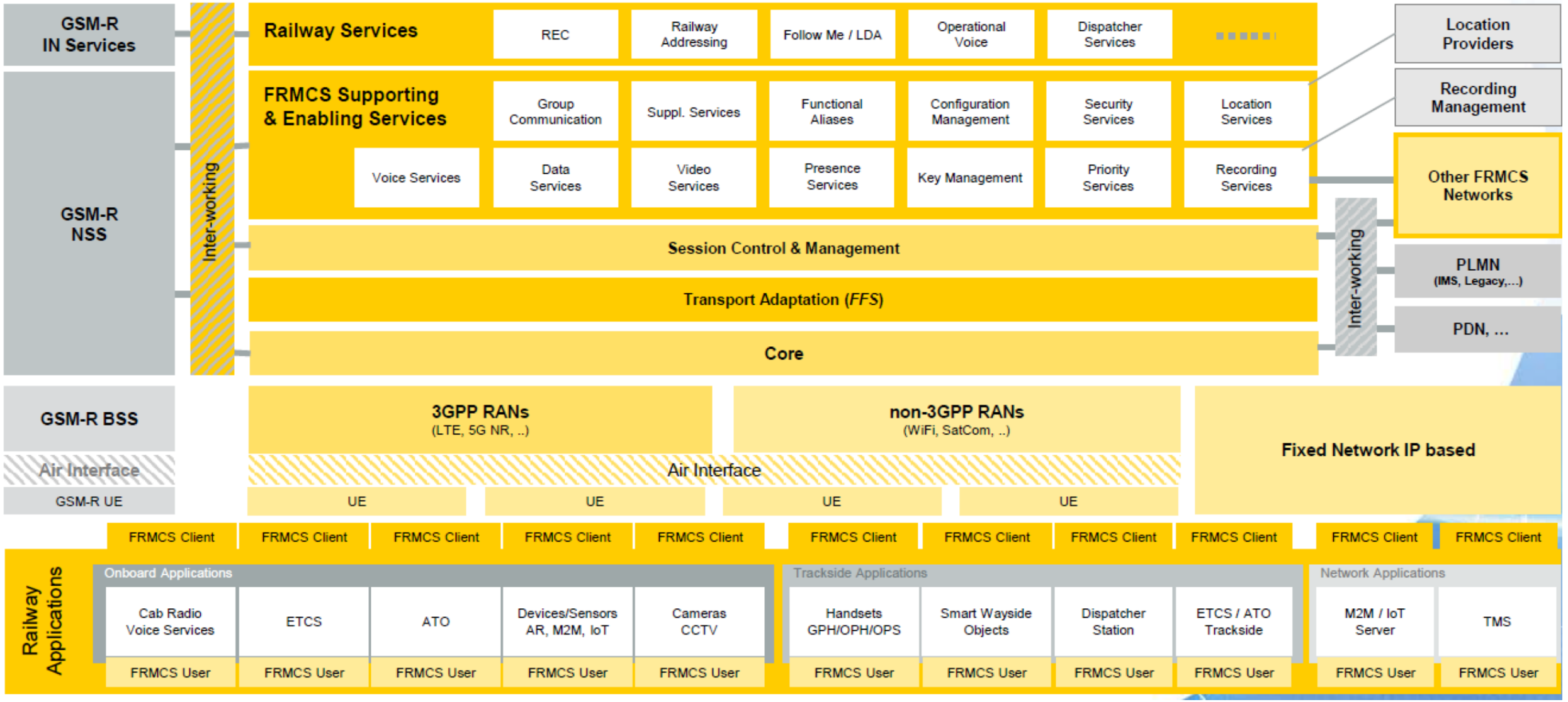


FRMCS System: Reference model



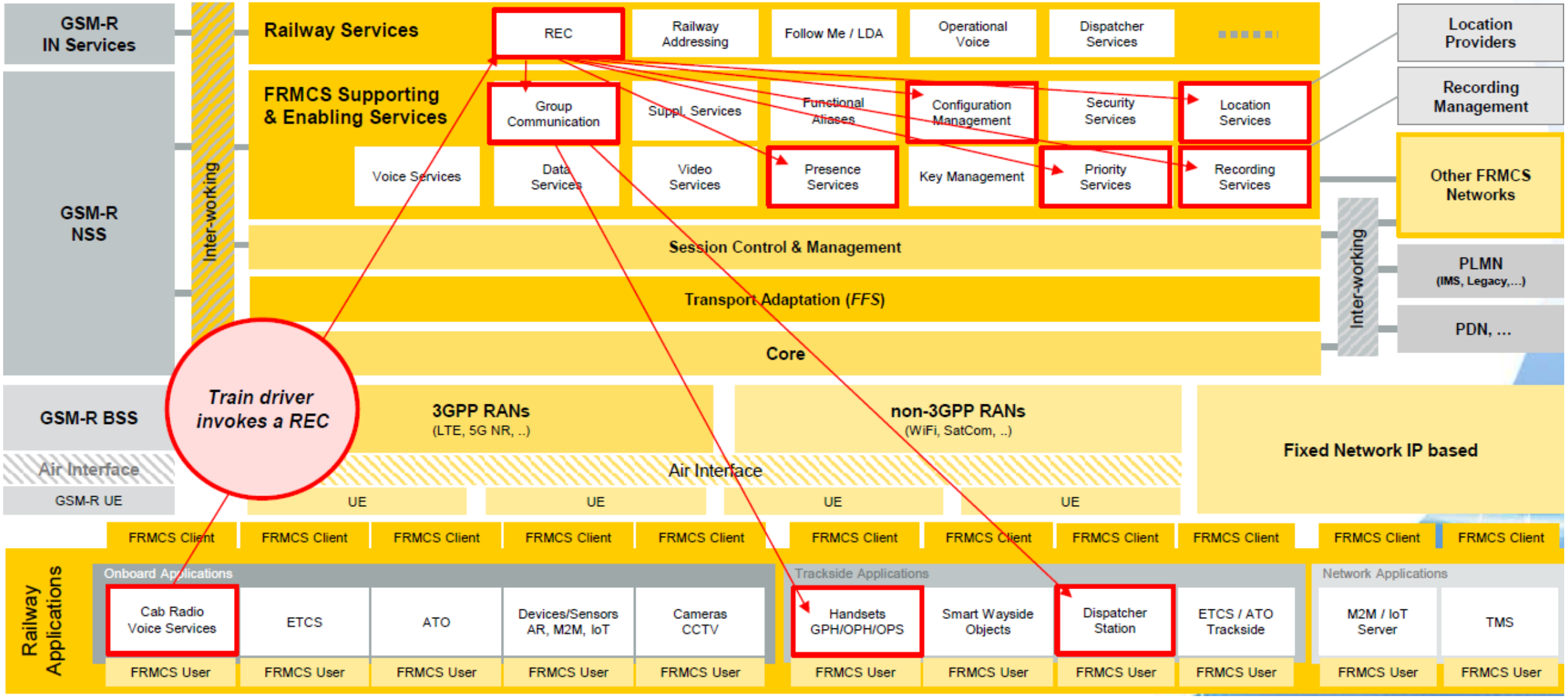
Source: 3GPP

FRMCS: Functional Architecture



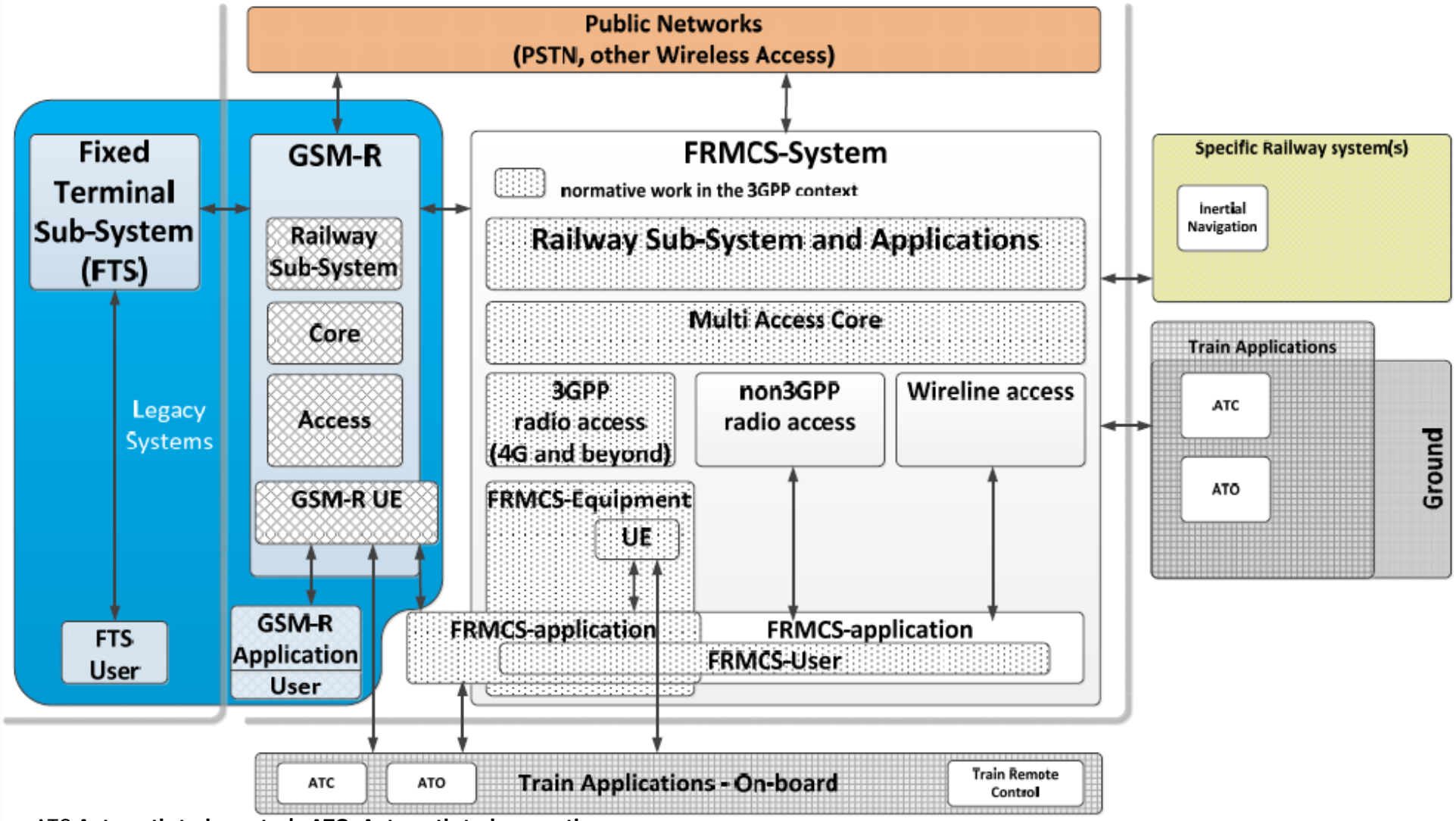
Source: 3GPP

Example: Railway Emergency Call



Source: 3GPP

FRMCS: General architecture



ATC-**Automatic train control; ATO- Automatic train operation**

3GPP Rel 15

Functional Use Cases:

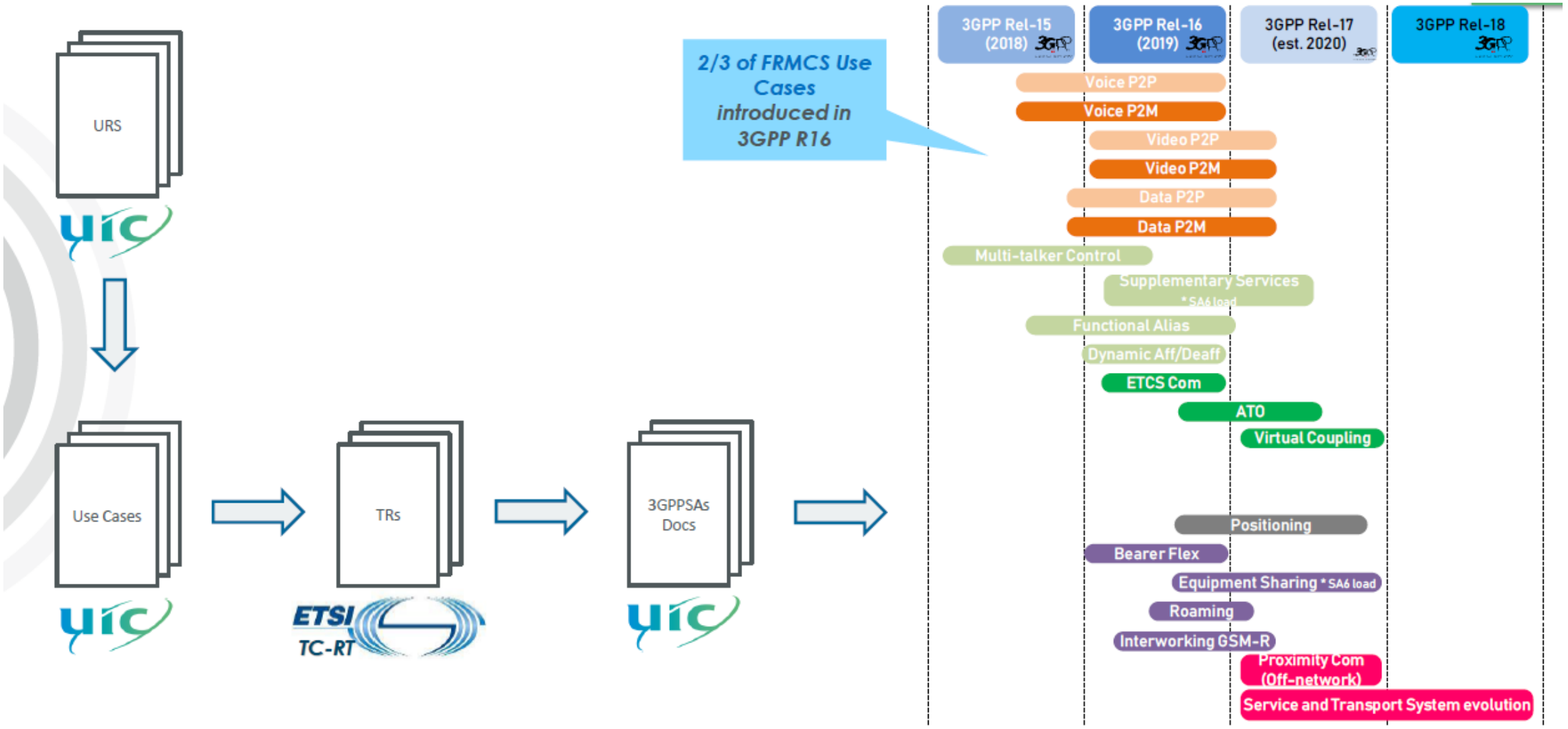
- Role Management
- Power Up and Initialization
- Location Management
- Prioritization end-to-end
- Communication
- Voice communication
- Train safety applications

System Principle Use Cases

- High reliability communication
- Interworking to GSM-R
- Accuracy in positioning
- Security
- Availability and Maintainability

Source: 3GPP

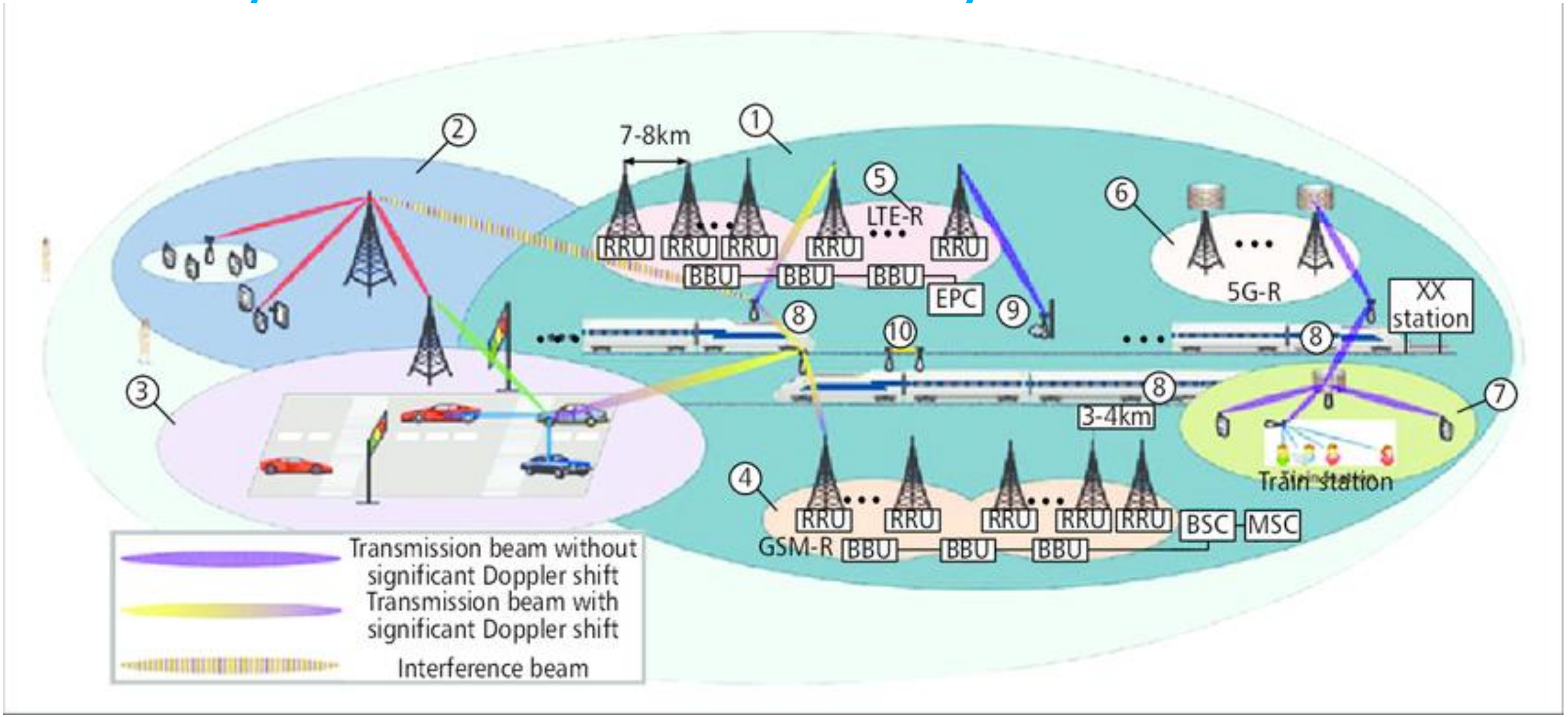
Rel 16-17 activities



Maximize Functions in 3GPP Release 16 & 17

Some of the additional research works:

Railway Mobile Communication Systems



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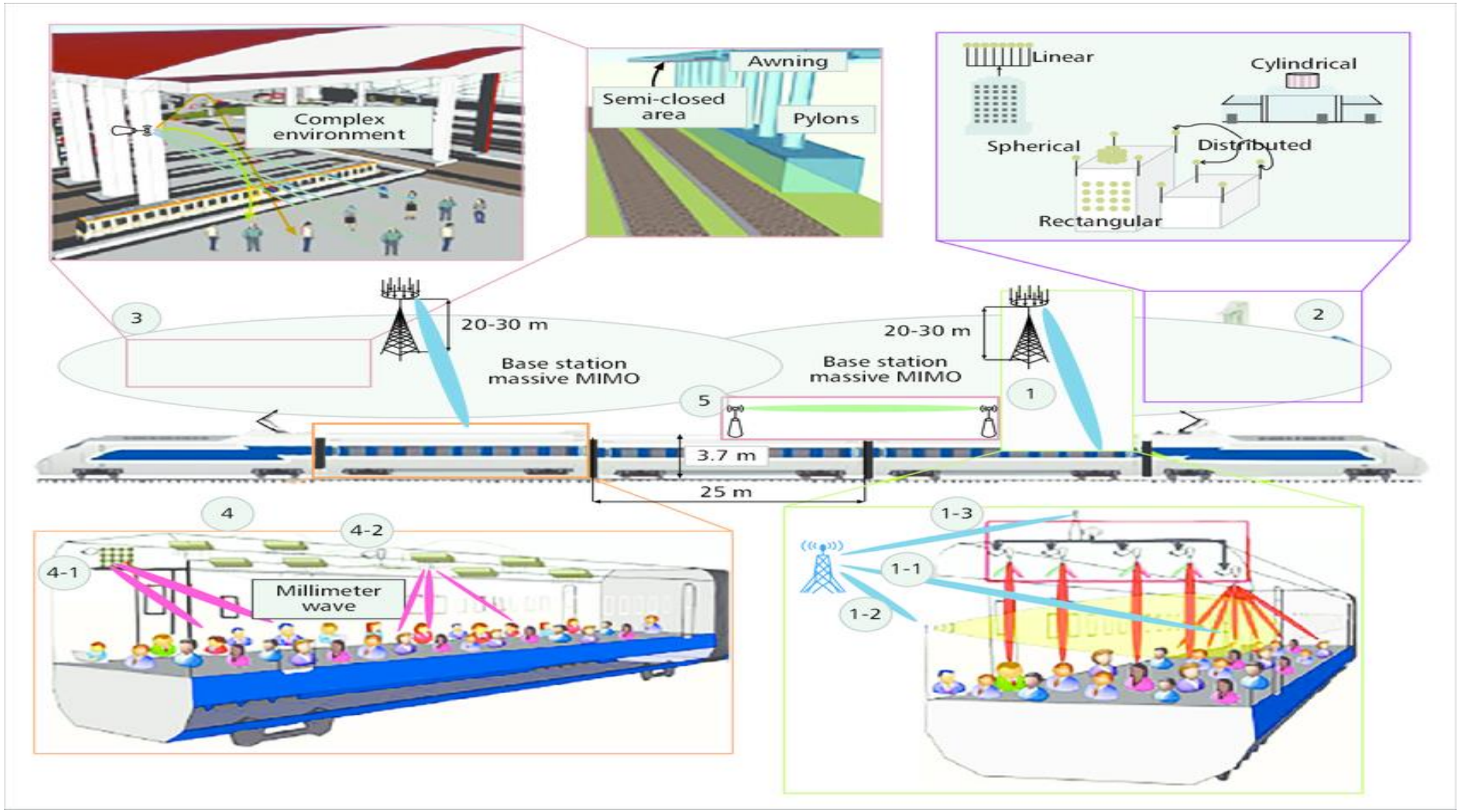
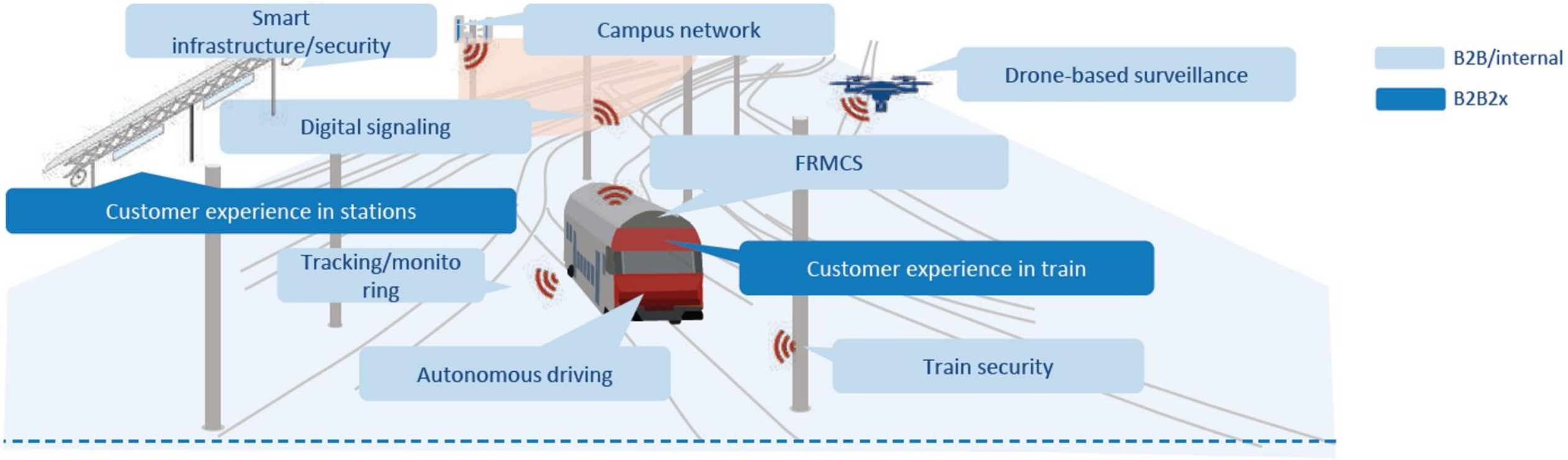


Summary:

FRMCS Development is on-going activity

Opportunities and challenges lie in Every layer: Service, applications and transports/infrastructure



धन्यवाद


danke
謝謝
ngiyabonga
teşekkür ederim
спасибо
dank je
gracias
thank you
tapadh leat
mochchakkeram
dziękuje
go raibh maith agat
obrigado
sukriya
kop khun krap
arigatō
dakujem
terima kasih
merci