Network Sharing and Slicing For Railway
European Railway Spectrum challenge

- Challenge: Harmonized LTE spectrum to replace GSM-R in Europe
  - GSM-R 921-925 DL and 876-880 UL
- Candidate Bands under analysis at PT 1
  - 918.3 – 921 DL and 874.3 – 876 UL
    - **Pros:** Adjacent to GSM-R with feasibility to reuse existing GSM-R sites
    - **Cons:** PT 1 may recommend power restriction on DL due to risk of desensitizing B8 UL
      - Germany and Belgium plan to extend GSM-R in this band to provide sufficient traffic channels for ETCS Level 2 train control
      - New device chipset ecosystem to support/3GPP standardization needed for new band
- 1900-1910 TDD (Band 33 A)
  - **Pros:** Already a standard 3GPP band
  - **Cons:** CEPT report 39 recommends power restrictions on 1905-1910 to protect B1
    - Railways would need to double the amount of cell sites
    - Ecosystem limited to Chinese devices
Network sharing 4G Ran Architectures

Gateway Core Network (GWCN)
- Radio Sector, eNodeB and MME shared between MNO and railway

Multi-Operator Core Network (MOCN)
- Radio Sector and eNodeB shared between MNO and railway

Multi-Operator RAN (MORAN)
- Radio shared between MNO and railway
4G Radio Slicing Techniques

— Radio Resource Partitioning (using ENodeB special scheduler based on UE Subscriber Profile ID)
— QCI prioritizations within a partition
— Access Class Barring – for congestion scenarios
— ARP – Allocation and Retention Policy - for congestion scenarios
RAN Network Slicing

- RAN slicing enables network operators to guarantee a defined Radio network resource share.

- A RAN slice:
  - will provide a minimum network capacity at high load
  - can use all available capacity at low load

![Graph showing resource usage over time for two slices, Slice A - Railway and Slice B - Mobile Network Operator.]
A UE's non-GBR bearers are mapped to a particular resource partitioning based on PLMN ID or on SPID value for the UE.

Up to 6 resource partitions (slices) per cell.

QoS settings and QCI usage within a slice does not impact other slices.
Core selection mechanisms

- **PLMN**
  - CN #1: MNO
  - PLMN #1
  - CN #2 Rail
  - PLMN #2

- **APN**
  - CN #1: MNO
  - APN 1
  - CN #2 Rail
  - APN 2

- **DECOR**
  - CN #1: MNO
  - APN 1
  - CN #2 Rail
  - APN 2

- **eDECOR**
  - CN #1: MNO
  - DCN-ID#1
  - CN #2 Rail
  - DCN-ID#2

- **5G Slicing**
  - CN #1: MNO
  - S-NSSAI #1
  - CN #2 Rail
  - S-NSSAI #2

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- CN selection by RAN using PLMN ID’s
  - Requires RAN and Core support
  - All device types supported

- Separate APNs for isolating UP sessions
  - Requires CN support
  - All device types supported

- CN selection using HSS info (UE Usage Type)
  - Requires CN and RAN support
  - All device types supported

- CN selection by RAN using UE info (DCN-ID)
  - Requires UE, CN and RAN support
  - Enhancement of DECOR - backward compatible

- UE Usage Type 1 & 2

- Connectivity to multiple slices simultaneously

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DEDICATED CORE NETWORKS (DECOR) –

— Based on UE Usage Type (UUT) in subscription data, MME redirects the UE to a Dedicated Core Network (DCN) via Attach, TAU and HO procedures.

— DCN is reselected when UUT is changed or MME configuration is changed, causing UE not to be served by the current DCN.

Benefit

— Enables multiple Core Network Segments in one PLMN, for operator services differentiation. e.g., Rail, MVNO and enterprises.
NG-RAN (5G) supporting E-UTRA

- gNB provides NR user plane and control plane protocol terminations towards the UE
- ng-eNB, provides E-UTRA user plane and control plane protocol terminations towards the UE.
Network slicing: the basis
Railway use cases have a large span of characteristics

- LOW DATA VOLUMES
- HIGH DATA VOLUMES
- LOW LATENCY
- HIGH LATENCY
- LOW/NO MOBILITY
- HIGH MOBILITY
NETWORK SLICING FOR RAIL
Mapping railway use case characteristics

LOW DATA VOLUMES

HIGH DATA VOLUMES

HIGH MOBILITY

LOW/NO MOBILITY

Mission Critical Push to Talk

Low Latency

High Latency

Train Control

Passenger Surveillance

Remote Control Shunting

Train Health Monitoring

Wayside Monitoring

Virtual Coupling

Train Control

Mission Critical Push to Talk

Low Data Volumes

High Data Volumes

High Mobility

Low/No Mobility

Platform Monitor
Network slice is a logical network serving a defined business purpose, consisting of all required network resources configured together. It is created, changed and removed by management functions.

- "End to end" within a provider
- Enabler for services, not a service
- Mobile and fixed
- Resources may be physical or virtual, dedicated or shared
- Independent/"Isolated" but may share resources
- May integrate services from other providers, facilitating e.g. aggregation and roaming
Network Slicing – Rail Examples

- **Train Control**
  - Very high availability
  - Very high reliability
  - Very low latency

- **MCPTT**
  - High availability
  - High reliability
  - Low latency

- **Passenger Connectivity**
  - Wide area coverage
  - Internet access
  - Operator services

- **Massive IoT/TCMS**
  - Low cost
  - Low energy
  - Massive numbers
Railway Network Slices

- Passenger Services
  - WAYSIDE AND ON-BOARD IOT SENSORS
  - TRAIN HEALTH MONITORING
  - WAYSIDE MONITORING
  - TRAIN HEALTH MONITORING
  - Enhanced MBB
  - Mission Critical Push to Talk
  - Automatic Train Control
  - Train Control
  - Remote Control Shunting
  - Passenger Surveillance
  - Video

- Enhanced MBB
- Train Control
- Automatic Train Control MCPTT
5G Federated Network Slicing

Train Roaming to a foreign railway while retaining slice

Home Rail Operator

NW Slice

Roaming Rail Operator

VNF

NW Slice for hosted service

Train Roaming to an MNO while retaining slice

Rail Operator

NW Slice

Service Providing Operator

VNF

NW Slice for hosted service

Train Roaming to a foreign railway while retaining slice

Home Rail Operator

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NW Slice for hosted service

Train Roaming to an MNO while retaining slice

Rail Operator

NW Slice

Service Providing Operator

VNF

NW Slice for hosted service
Railways Needs - MNO Provides

**Low Latency**
- Dedicated railway RAN Network Slice and Core

**Coverage**
- Railway may need to supplement coverage in unserved areas using MNO spectrum and site sharing mechanism

**Capacity**
- supplement capacity in rail yards using MNO spectrum
European rail corridors

Challenge of universal connectivity of freight and passenger trains across borders
Mission Critical Rail Services use multiple parallel connections for 100% availability
5G RAN-CN Connectivity options
Two architecture tracks in 3GPP rel15

- **5G EPC**
  - 3GPP target Q4 17
  - S1-based
  - Option 1
  - Option 3

- **5G Core**
  - 3GPP target Q2 18
  - N2/N3 (new interface)
  - Option 2
  - Option 4
  - Option 5
  - Option 7

- **LTE**
  - LTE/EPC
  - LTE/NR

- **NR**
  - NR/EPC
  - NR/5GC

- **LTE/5GC**
  - LTE/EPC
  - LTE/5GC
  - NR/5GC
5G STANDARDS PLAN

### ITU

- **2015**: IMT-2020 Requirements
- **2016**: IMT-2020 Proposals
- **2017**: IMT-2020 Evaluation
- **2018**: IMT-2020 Specs

### 3GPP

- **2015**: 5G Study Item
- **2016**: 5G Phase 1 (Rel-15)
- **2017**: 5G Phase 2 (Rel-16)

#### 3GPP Releases
- **Rel-13**: LTE evo
- **Rel-14**: LTE evo
- **Rel-15**: LTE evo
- **Rel-16**: LTE evo
- **Rel-17, ...**: 5G Evolution

#### 5G Study Items
- **Non Standalone 5G-NR**: LTE as Control Plane anchor - Option 3
  - Stage 3 Dec. 2017
  - ASN 1 Freeze March 2018
- **Standalone 5G-NR**: Options 2, 4, 5, 7
  - Stage 3 June 2018
  - ASN 1 Freeze Sept 2018
- **Stage 3 Dec 2019**: ASN 1 Freeze March 2020