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GSM-R Network Dimensioning, Design & Optimization

- Giorgio Ronchi, NOKIA

GSM-R Network Planning & Optimization

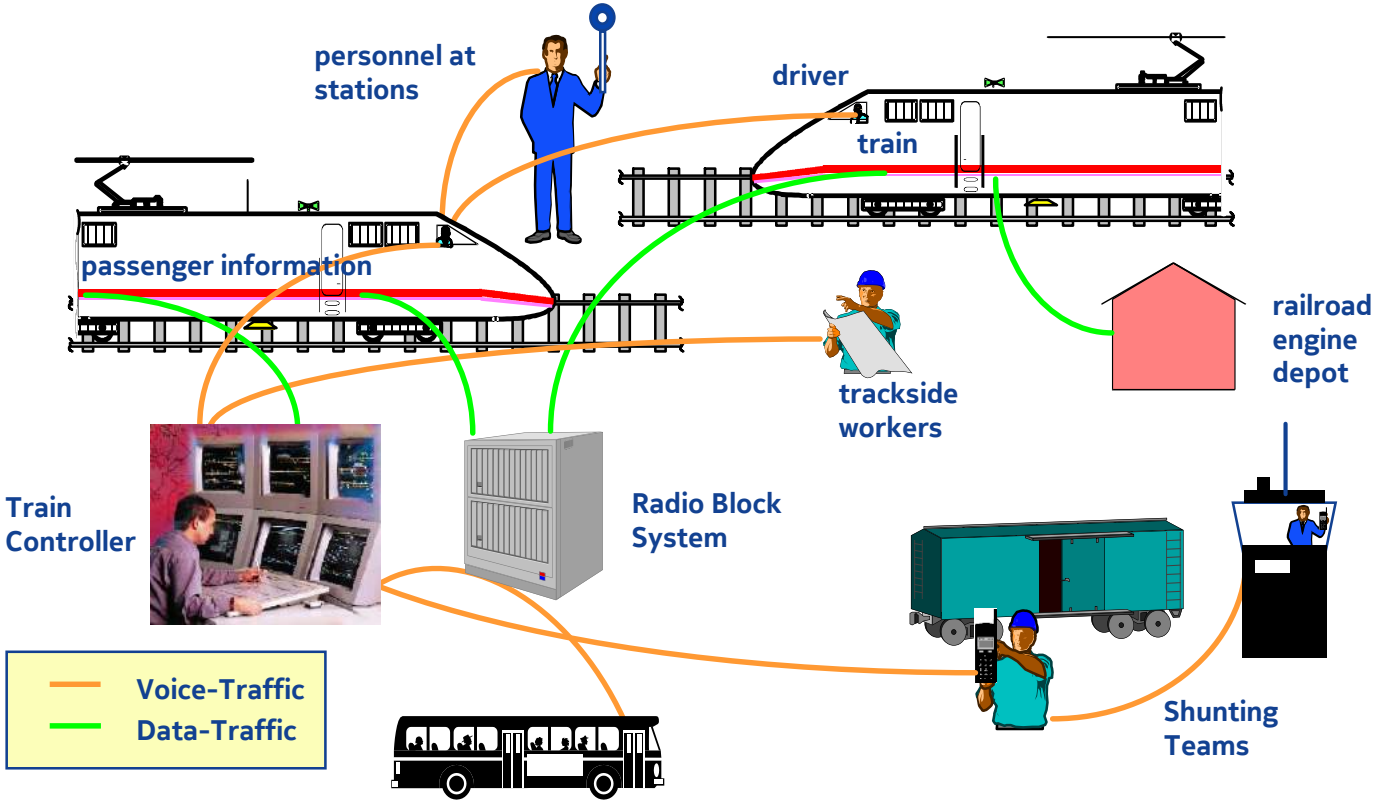
Agenda

- Network Dimensioning – Traffic Model
- Network Design
- Tunnel Coverage
- Planning for High-Speed Lines
- Tuning, Acceptance & Optimization.
- References.

GSM-R Dimensioning

- GSM-R Applications: ETCS tracks /VGCS.
- Subscribers: workers of the railway transportation company.
- Smaller traffic, however some connections (i.e. ETCS) need to be permanent.
- Limited number of frequencies available.
- Traffic is concentrated in certain areas i.e. in railway platforms and shunting platforms.

GSM-R Applications



Traffic types

Data/Voice:

- Point-to-point voice → standard calculation (MOC, MMC, MTC).
- Data circuit switched traffic (DCSS traffic) → (Goes to RBC).
- VGCS/VBCS voice → ASCI uses network resource differently.
- GPRS → Toward GGSN/SGSN.

Signalling:

- USSD (registration / deregistration for functional number).
- SMS.

The following penetration factors must also be identified:

- VMS (typical 0-15%).
- IN (typical 80-100% due to FN & part. LDA).

Traffic model

TRAFFIC MODEL												
Users involved in call	**Call Type**		**# users**	**# calls, per user, BH**	**# calls, total, BH**	**Call duration, mean time**	**BH traffic [Erl]**	**MOC %**	**MTC %**	**MTM %**	**Calls with fixed dispatcher %**	**Calls with mobile dispatcher %**
Driver - Traffic controller	Voice	Point-to-point		0.5	0	120	0	50	50	0	100	0
Driver - Driver	Voice	Point-to-point		0.01	0	60	0	0	0	100	0	0
Driver - Train Guard	Voice	Point-to-point		0.2	0	60	0	0	0	100	0	0
Driver - Station Controller	Voice	Point-to-point		0.2	0	60	0	15	15	70	30	70
Train Guard - Traffic Controller	Voice	Point-to-point		0.2	0	30	0	50	50	0	100	0
Train Guard - Station Controller	Voice	Point-to-point		0.3	0	200	0	40	30	30	70	30
Other calls between train functions	Voice	MPTY		0.01	0	120	0	0	0	100	0	0
REC in stations	Voice	VBS or VGCS		0.0001	0	120	0	15	15	70	30	70
REC along tracks	Voice	VBS or VGCS		0.0001	0	120	0	15	15	70	30	70
Maintenance teams	Voice	Point-to-point		3	0	180	0	10	10	80	20	30
Shunting teams in small - medium size stations	Voice	VBS or VGCS		1	0	3,600	0	15	15	70	30	70
Shunting teams in big stations	Voice	VBS or VGCS		0.5	0	3,600	0	50	50	0	100	0
Other GSM-R internal calls	Voice	Point-to-point		1	0	100	0	15	15	70	0	0
Other GSM-R internal calls	Data	Point-to-point		0.15	0	300	0	30	30	40	0	0
ERTMS	Data	Point-to-point		1	0	3,600	0	100 towards RBC	0	0	0	0
Other GSM-R external calls	Voice	Point-to-point		1	0	100	0	25	25	50	0	0

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Coverage Planning

Rules for a coverage and cost efficient planning

- Precise requirements defined at the start of the project (redundancy, signal levels, traffic, ETCS)
- Use standardized equipment as much as possible
- Minimum total amount of BTS is not necessarily the most cost efficient
- Careful frequency allocation
- Innovative and creative design

Maximum use of friendly sites

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Network Design Approach

Type of service	Coverage approach	Remarks
Voice & standard GSM services	Simple coverage, with safety margins	
GPRS & data services	Simple coverage, with safety margins	Interference control Frequency plan
ETCS L1, ASCI, other specific GSM-R services	Simple coverage, with safety margins	Traffic control data as input
ETCS L2	Double coverage	High system reliability

Tunnel coverage!

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GSM-R Network Design: the Railway environment

- **It is different from standard GSM networks environments and Nominal Network Design is based on a few basic requirements:**

Model Tuning

- A standard GSM propagation model is not suitable for GSM-R environment since it consider propagation beyond roof top heights.
- You need a GSM-R specific propagation model that considers the propagation along the “rail corridor”.
- Basically don’t care about what happens far from the railway tracks.

Terrain database

- A detailed description of railway line vector is a key-factor. Consider in deep detail cuttings, viaducts, tunnels.
- Height modification can help to better describe propagation.
- Clutter modification (“Rail Clutter”) allows to better evaluate and display coverage levels.

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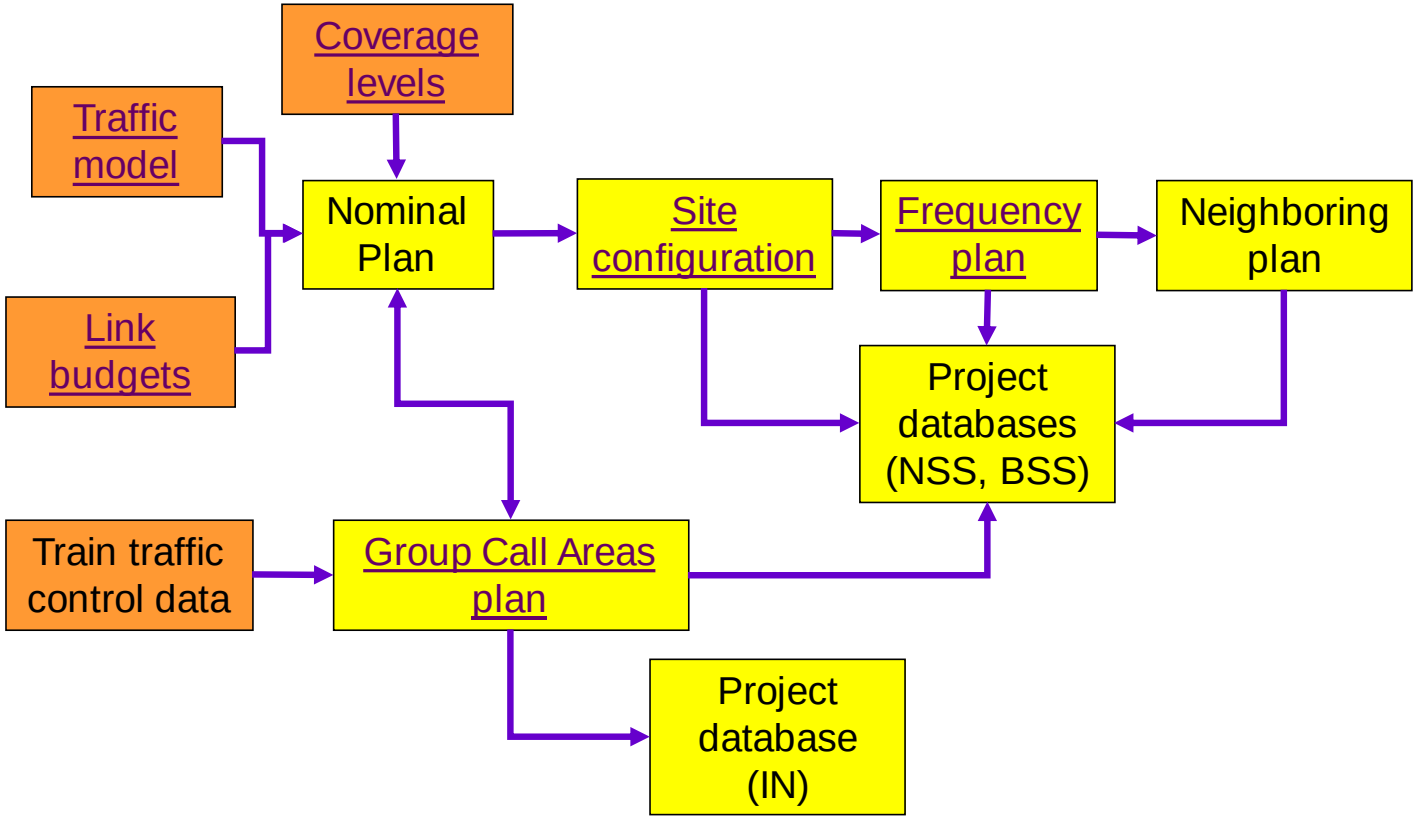
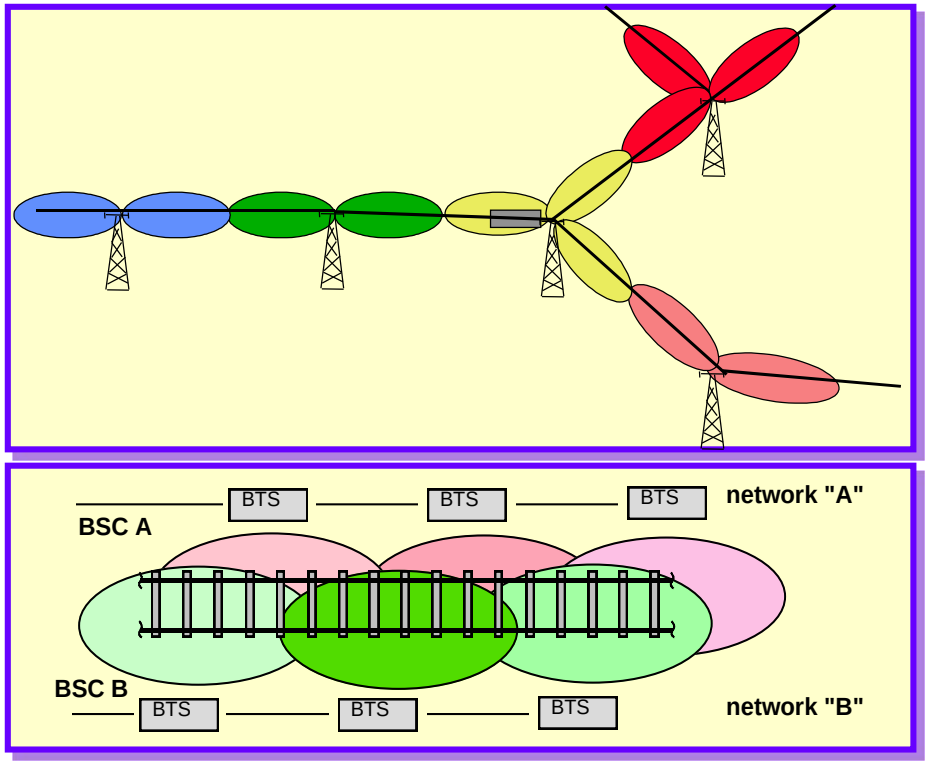
GSM-R Network Design: Nominal Plan



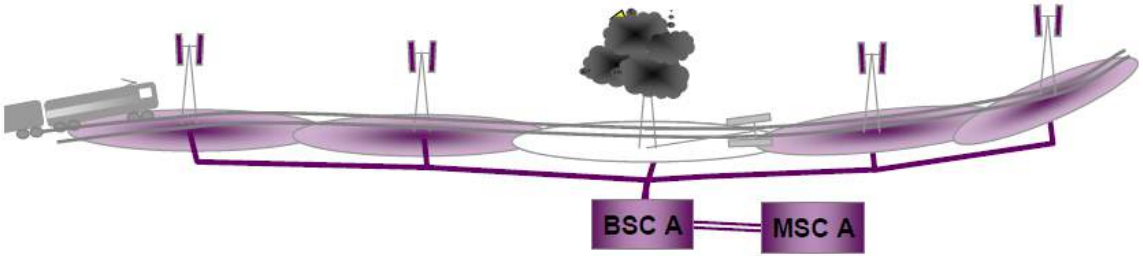
GSM-R Radio Planning Criteria and Strategies

- **Sites** to be placed along the railway tracks to use friendly sites.
  - **Reduce overall number of HO**, by combining cells.
  - **Antennae: 30°** beam width to better control interference and better fit the 2D coverage requirements.
  - **Frequency plan:** AFP tools are not suitable for GSM-R applications, better to perform frequency plan MANUALLY.
  - **Coverage redundancy** (opt): better with alternate site location. Single layer or double layer.

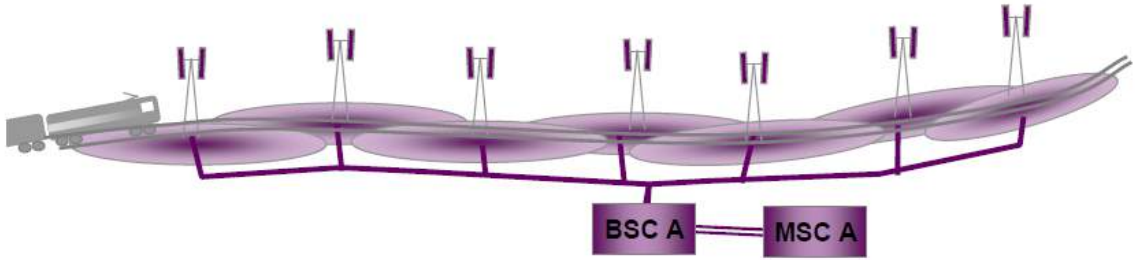


Coverage Planning - Single Coverage

Single layer no overlap

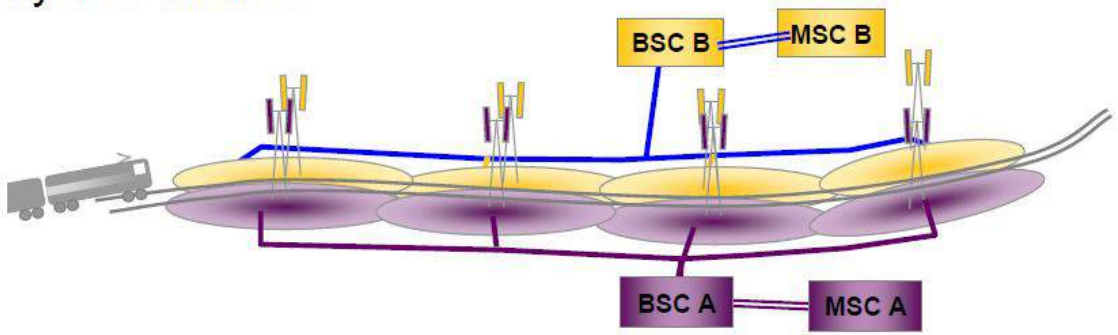


Single layer high overlap

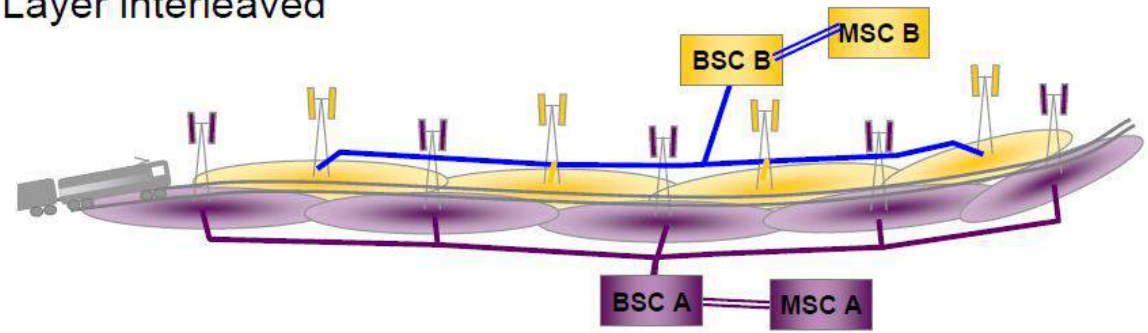


Coverage Planning – Double Coverage

Double Layer co-located



Double Layer interleaved



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Tunnel coverage

Most of railway lines have a great number of tunnels, some or them are very long

EIRENE does not have specific requirements for tunnels, but Railway Operators often require higher safety levels inside tunnels (i.e. Redundancy, in-train coverage, other MNO coverage).

- Tunnel coverage strategy depends on:

Coverage levels:	Out train or in train
Tunnel type:	Single or double, size and shape, …
Equipments:	BTS or Repeaters (off-air, F.O., other third-party).
Radiating system:	Antennas or leaky feeders.

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Tunnel coverage strategies

Equipment	PROS	CONS
BTS	✓High power ✓No new O&M system	✓Installation, especially inside tunnels
Repeater, other Third-Party	✓Easier Installation	✓New O&M required ✓Time delay on signal ✓Noise

Radiating system	PROS	CONS
Antenna 	✓ Easier Installation and maintenance ✓ Safety	✓ Wide dinamic range ✓ Fading ✓ Frequency band
Leaky cable 	✓ Thin dinamic range ✓ Application field ✓ Wide freq. band	✓ Installation and maintenance ✓ Reliability

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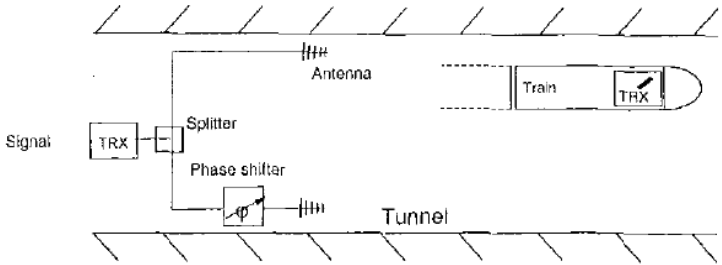
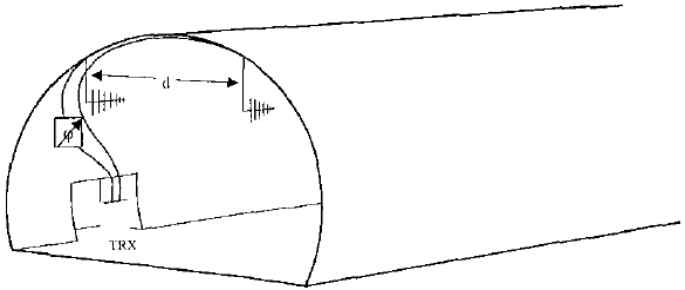
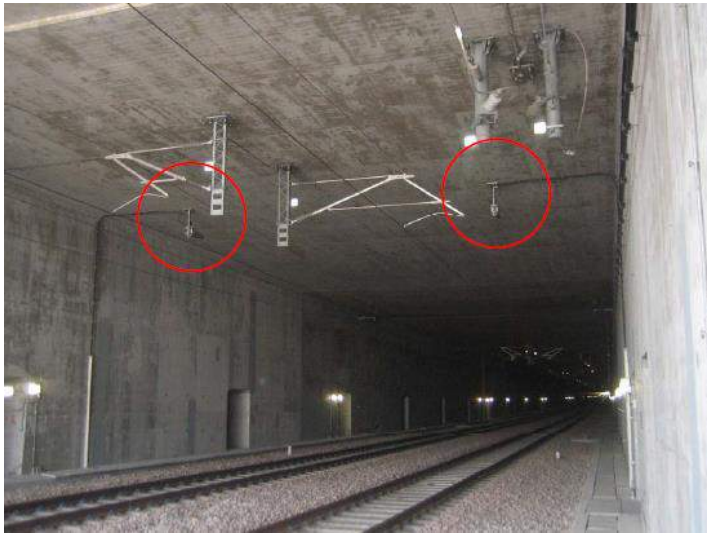
Phased array antenna system





Phased array antenna system is used in tunnels to improve the coverage and decrease the «fast fading» effect.

The system is composed by a pair of antennas and a variable phase shifter.



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Network Design for ETCS L2

- Coverage level: -92 dBm, 95%, redundant.
- Tuned propagation models:
  - For GSM-R urban area
  - For GSM-R open-area.
- Typical inter-site distance: 4 km (open area, 900 MHz).
- Urban area could be out-of-scope for ETCS L2.
- Track environment has great influence on Network Design
  - Environment
  - Presence of bridges and viaducts.
  - Presence of tunnels.

Traffic Model for HSL

- Traffic model is an important input:
  - Each train requires 1 TCH FR for ETCS L2.
  - 2 TCH FR are needed in RBC HO areas.
- Worst case: based on Block Lenght (*bl*).

$$Train_{track} = \frac{n \times L_{track}}{bl}$$

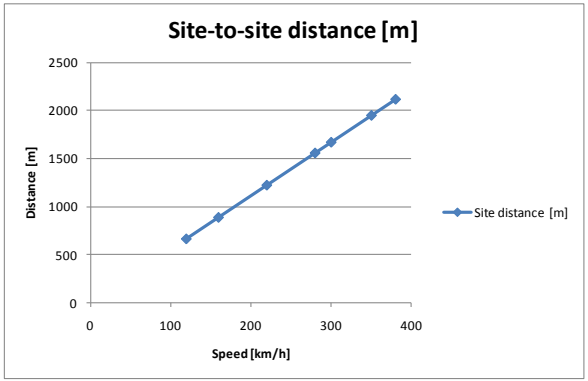
- Normal case: based on speed profile and rate.

$$Train_{track} = \frac{n \times L_{track}}{Speed_{track} \times T_{train}}$$

Handover Planning for HSL

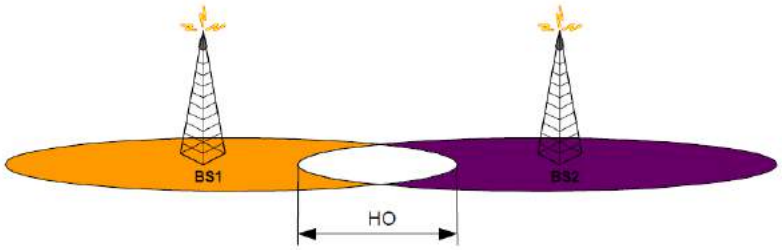
- Minimum site distance for TIR requirements!
  - Error-free-period (< 20 s, 95%)

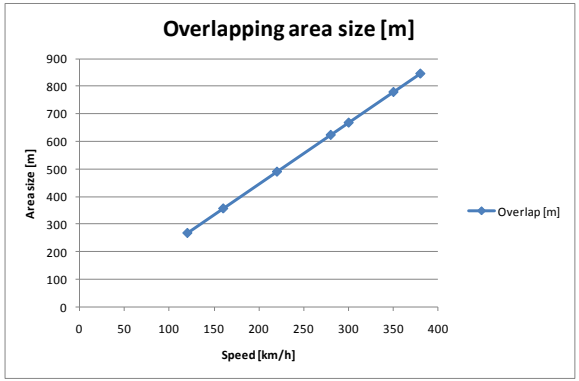
Speed [km/h]	Site distance [m]
120	666.7
160	888.9
200	1111.1
300	1666.7



- Overlapping area for HO execution.

$$ho_{min} = v_{max} * t_{ho} = 250\ km/h \times 8\ s = 555\ m$$





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GSM-R Network KPI

Special KPIs specified for railway networks spec. O-2475

Coverage ETCS:	-95 dBm @ 95% probability over area & time
HO success rate:	> 99,5%
Call setup success rate:	> 99%
HO execution time:	< 500 ms (95%)
Data connection establishment delay:	<8,5sec (95%), <10 sec (100%)
Data connection loss rate :	< 0,01/ hour connection time
Data transmission interference rate	
• Transmission interference period:	< 0,8 sec (95%), <1 sec (99%)
• Error free period	> 20 sec (95%), >7 sec (99%)

Require high amount of testing time and automatic test tools

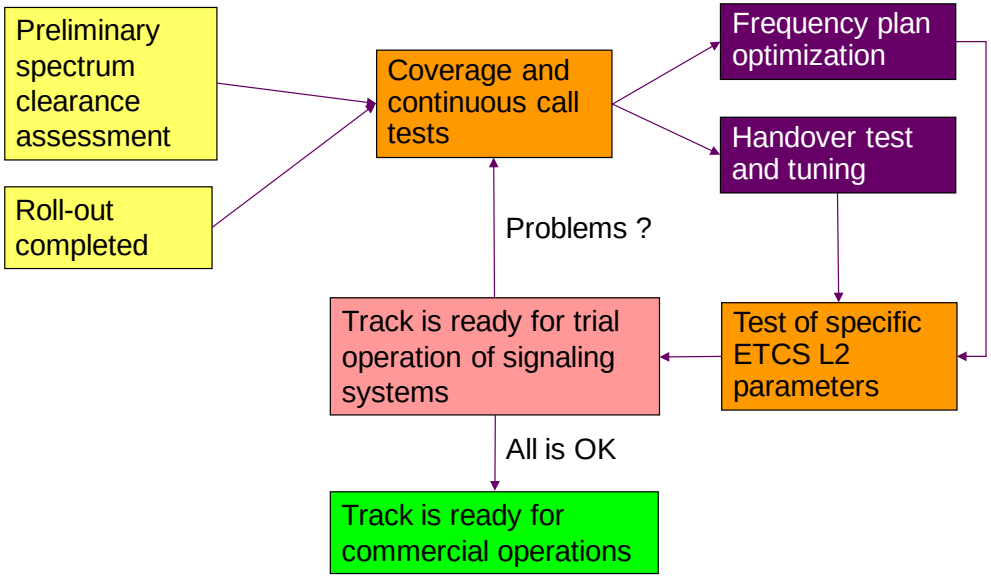
Tuning and optimization process

Drive Test: Is the starting point of GSM-R optimization

Target:

Is the railway track; track should be optimized for maximum speed

It is most important a detailed track database (tunnels, stations, …) with Km points, than GPS data.



Drive test equipments

Traditional drive test solution

Portable equipments – for single drive test, post-processing and tuning

Unattended data collection system

For traffic generation, load-stress and statistical KPI collection

Fixed installation in Train

A combination of previous options

Optimization process

- Tuning and optimazition is a critical phase during the realization of a GSM-R network.
- A big amount of drive-test is needed to collect all the necessary informations.
- Step 0 is the preliminar assessment of the environment, for the detection of external interferences.
- Step 1 is the coverage optimization with adjustements of antenna azimuts and tilts.
- Step 2 is the optimization of network performances with the setting of optimized database parameters for each cell.
- At the end of Step 2 network is fully ready for commercial operations.

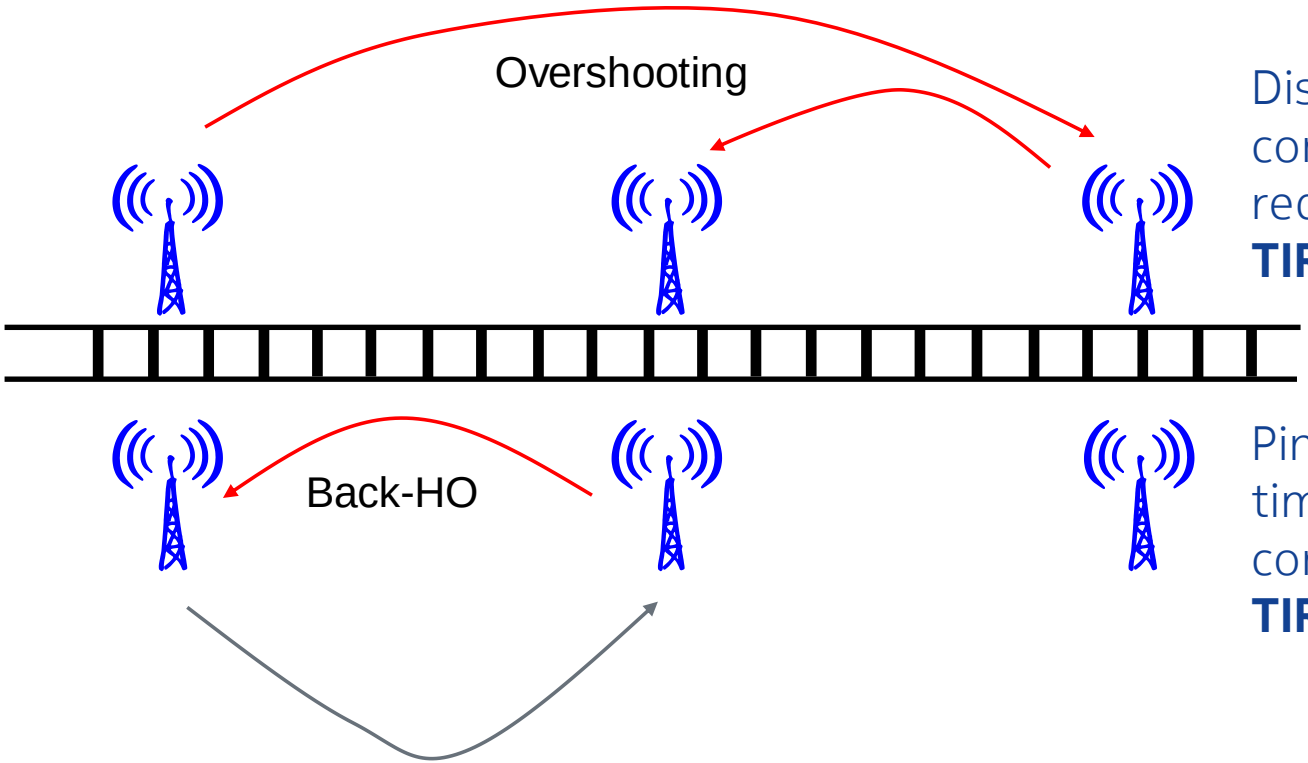
Coverage optimization

- During coverage assessment phase, some coverage problem COULD be detected and MUST be solved before proceeding.
- Possible coverage problems are:
  1. Lack of coverage (holes, fast-field-drop).
  2. Far cell camping.
- Possible solutions are:
  1. Check site installation, correct azimut.
  2. Add mechanical or electical downtilt.

Performances optimization

- The most critical performances are related to ETCS services (CSD calls).
- Typical problems are the violations of T_{TI} or T_{REC}.
- Possible causes are of 2 types:
  1. For both parameters: HO break time too long or interference.
  2. For T_{REC} violation, HO procedures: distance between HO too short or ping-pong/intracell HO.

HO optimization in live network



Distance between HO not controlled according to requirements.
TIR violations.

Ping-pong HO reduces time between consecutive HO.
TIR violations.

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About me …

- Giorgio Ronchi, PMP
- Degree in Telecommunication Engineering, Oct-1998.
- Working in Italtel/Siemens Group from Dec-1998, then Siemens, Nokia-Siemens and Nokia.
- Working on RFI/GSM-R Project from National Rollout tender phase, in 2002.
- Supporting GSM-R projects in Europe and worldwide: Denmark, Norway, Sweden, Poland, Romania, Greece, Saudi Arabia, China and more …


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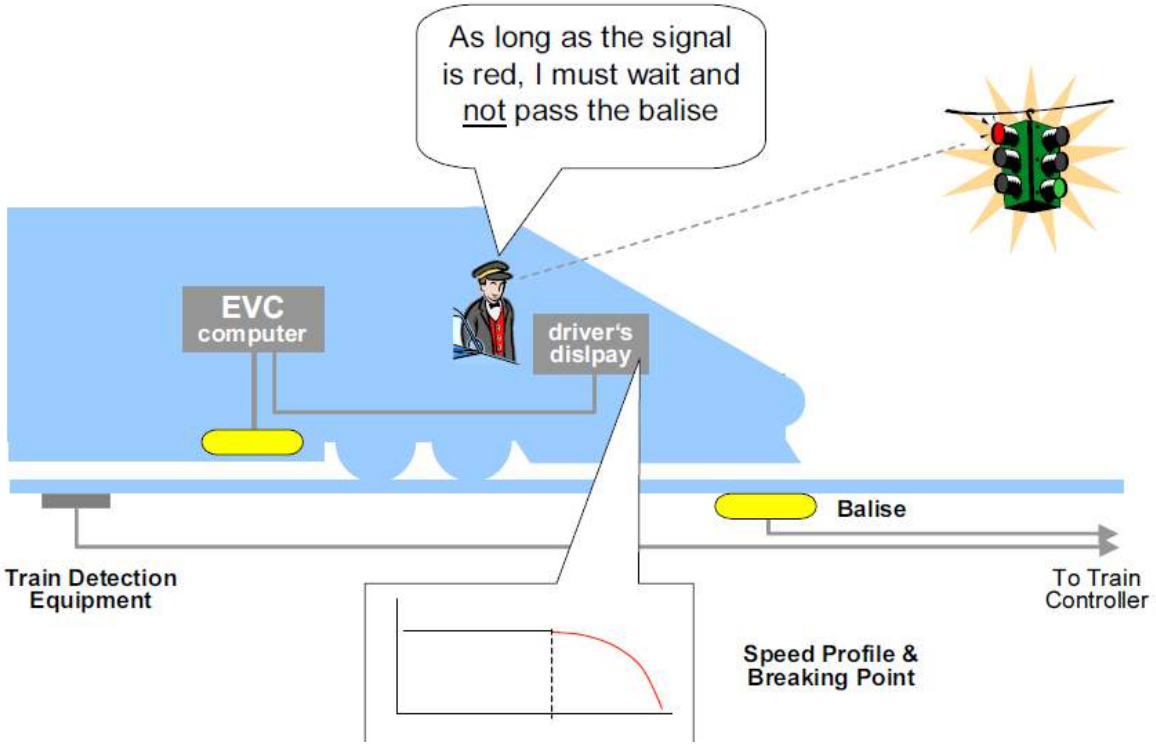
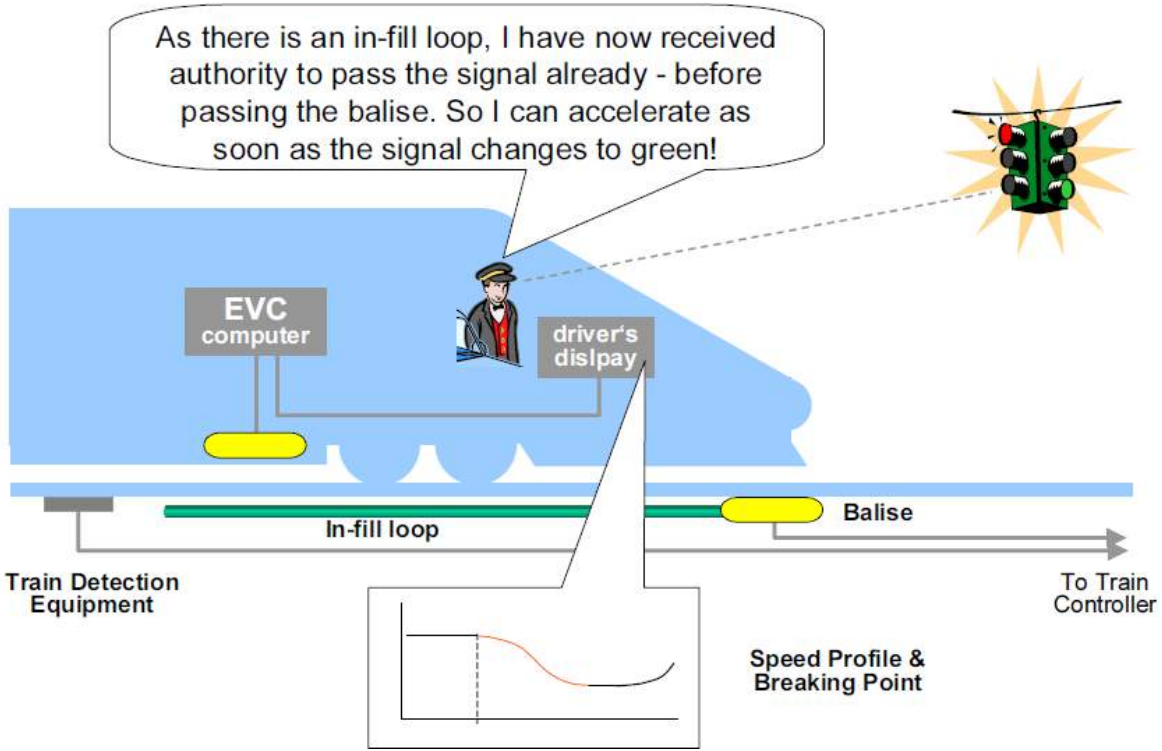
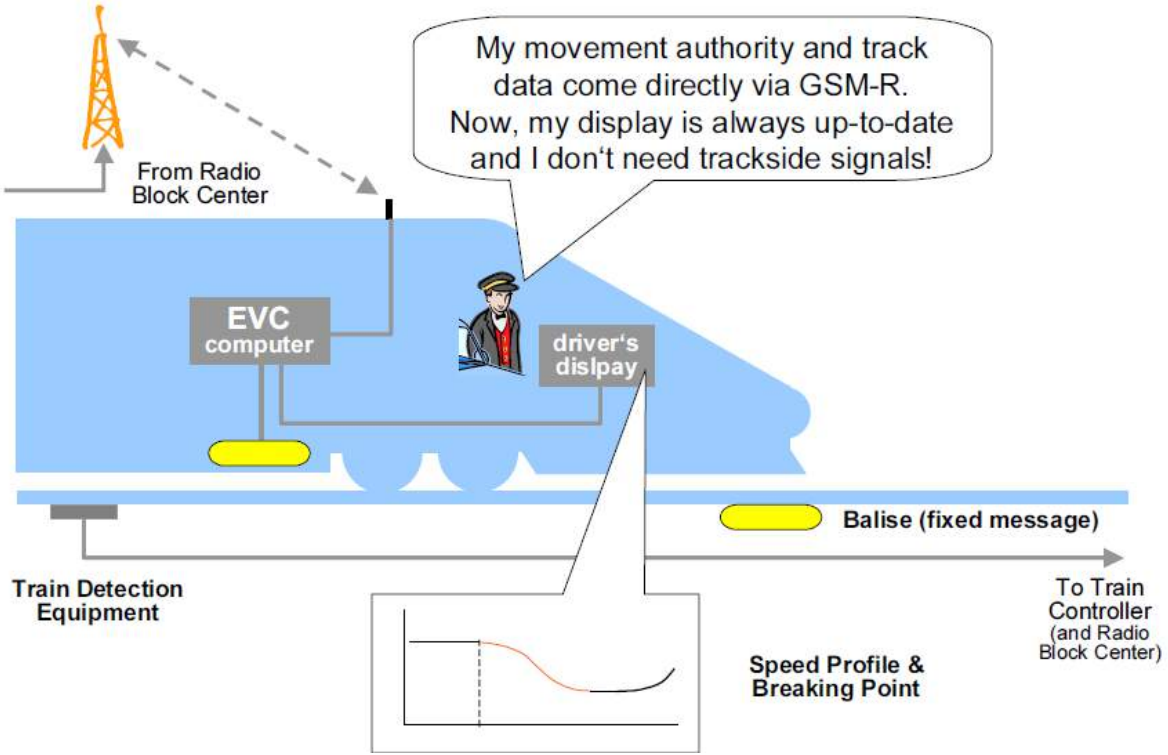
ETCS: Level 1



ETCS: Level 1



ETCS: Level 2



ETCS: Level 3