AUTO CONNESSE E A GUIDA AUTONOMA:
NUOVE SFIDE E D OPPORTUNITÀ PER I SISTEMI DI NAVIGAZIONE

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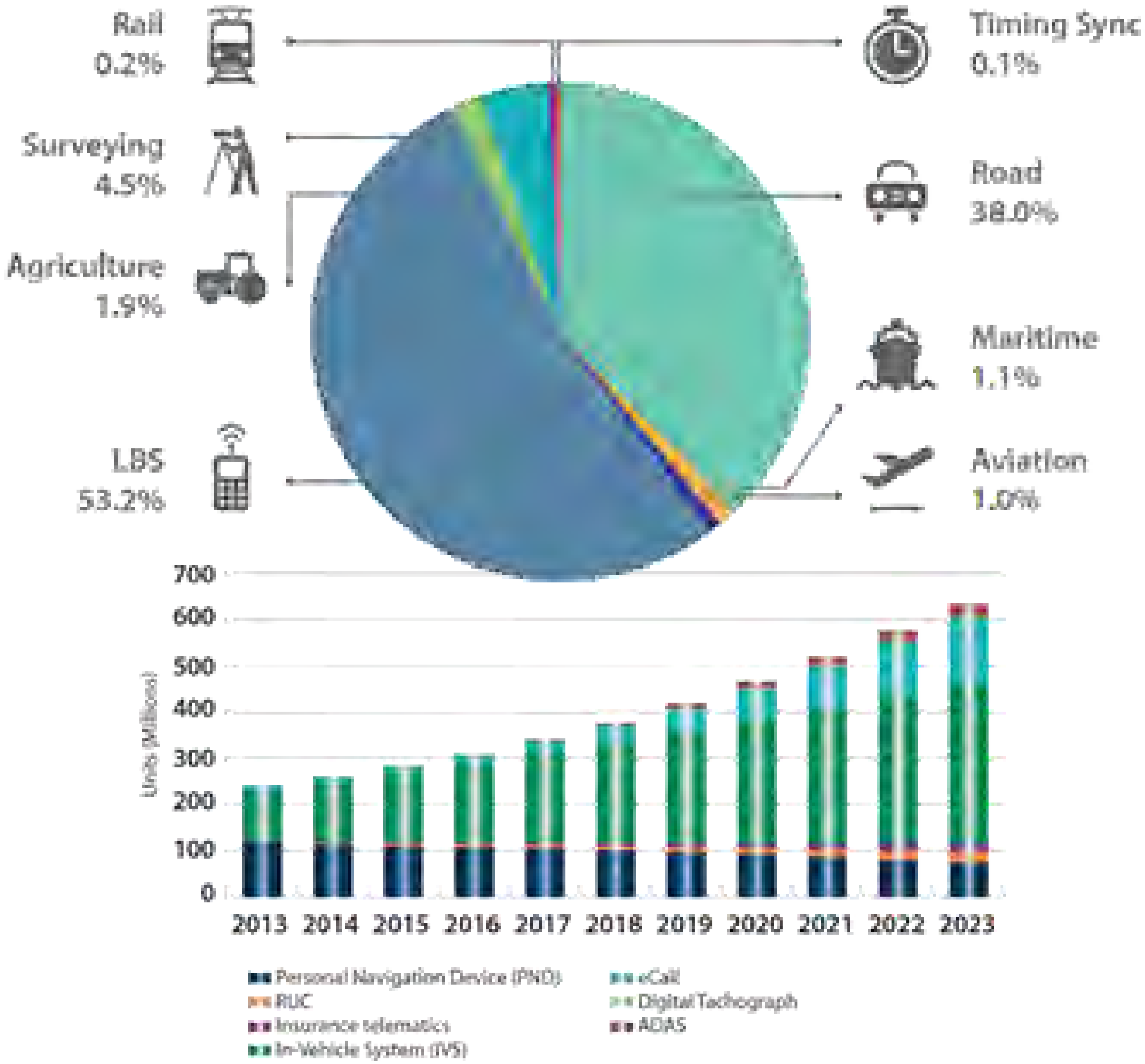
The Market



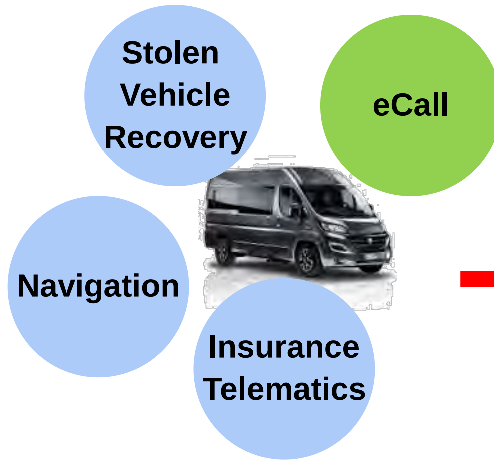
Rail
0.2%
Timing Sync
0.1%
Surveying
4.5%
Road
38.0%
Agriculture
1.9%
Maritime
1.1%
LBS
53.2%
Aviation
1.0%
700
600
500
400
300
200
100
0
Units (Millions)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Personal Navigation Device (PND)
RUC
Insurance telematics
In-Vehicle System (IVS)
eCall
Digital Tachograph
ADAS

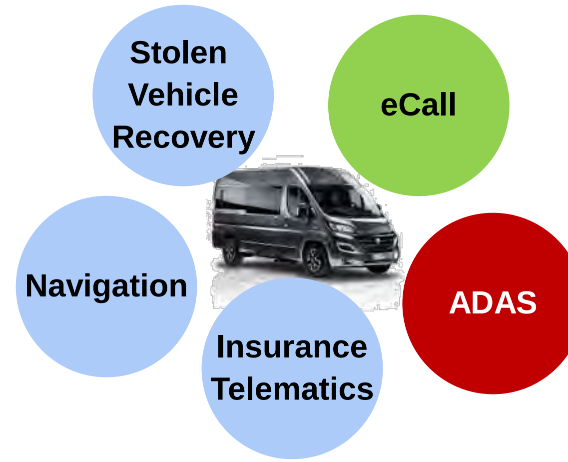
GNSS role in autonomous vehicles

Autonomous driving technology requires position and navigation

HIGH ACCURACY

HIGH INTEGRITY



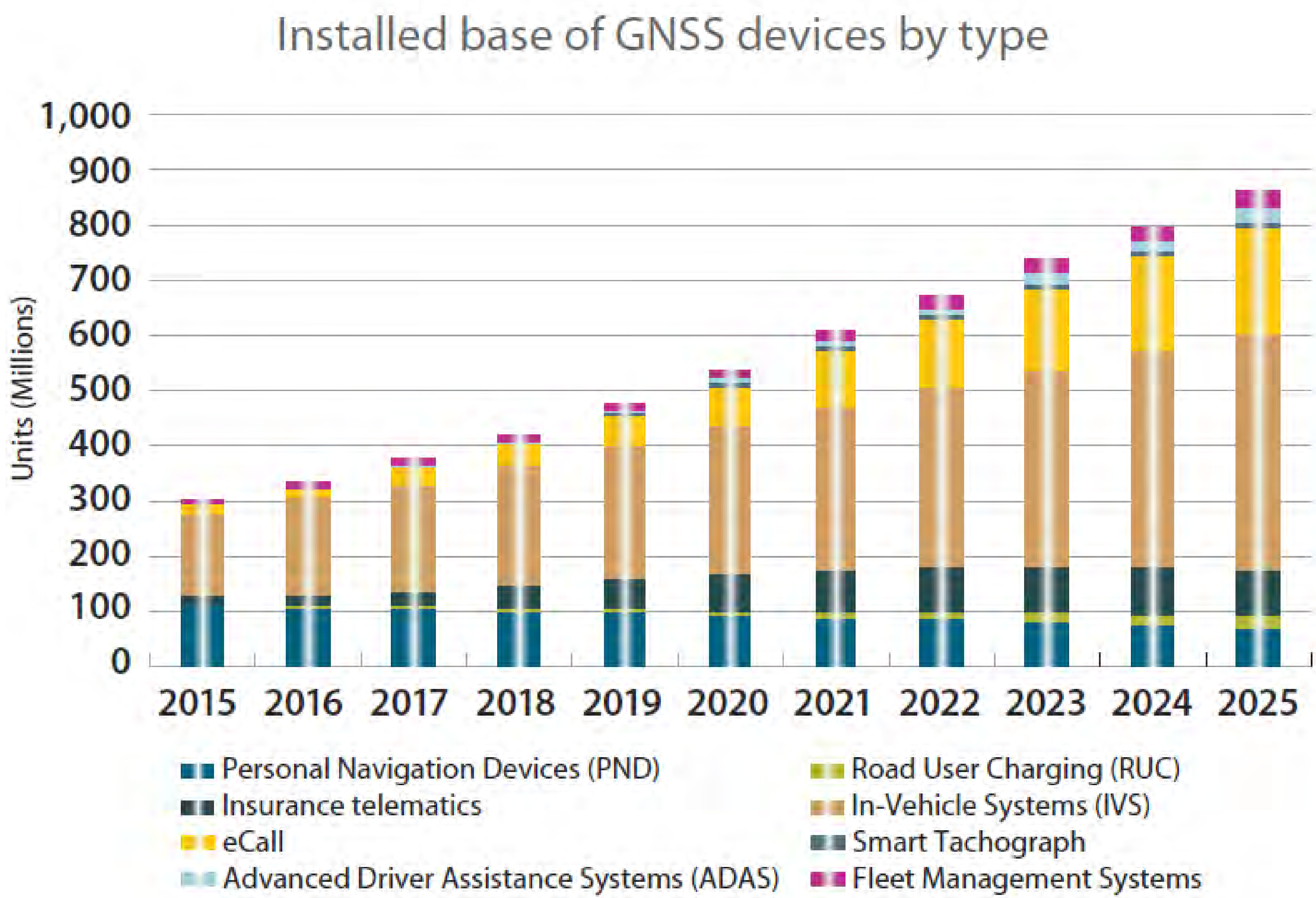


NO individual technology can currently meet these requirements anywhere, anytime and under any condition, requirements.

sensor fusion is considered as the go-to-solution for the development of fully autonomous driving technology.

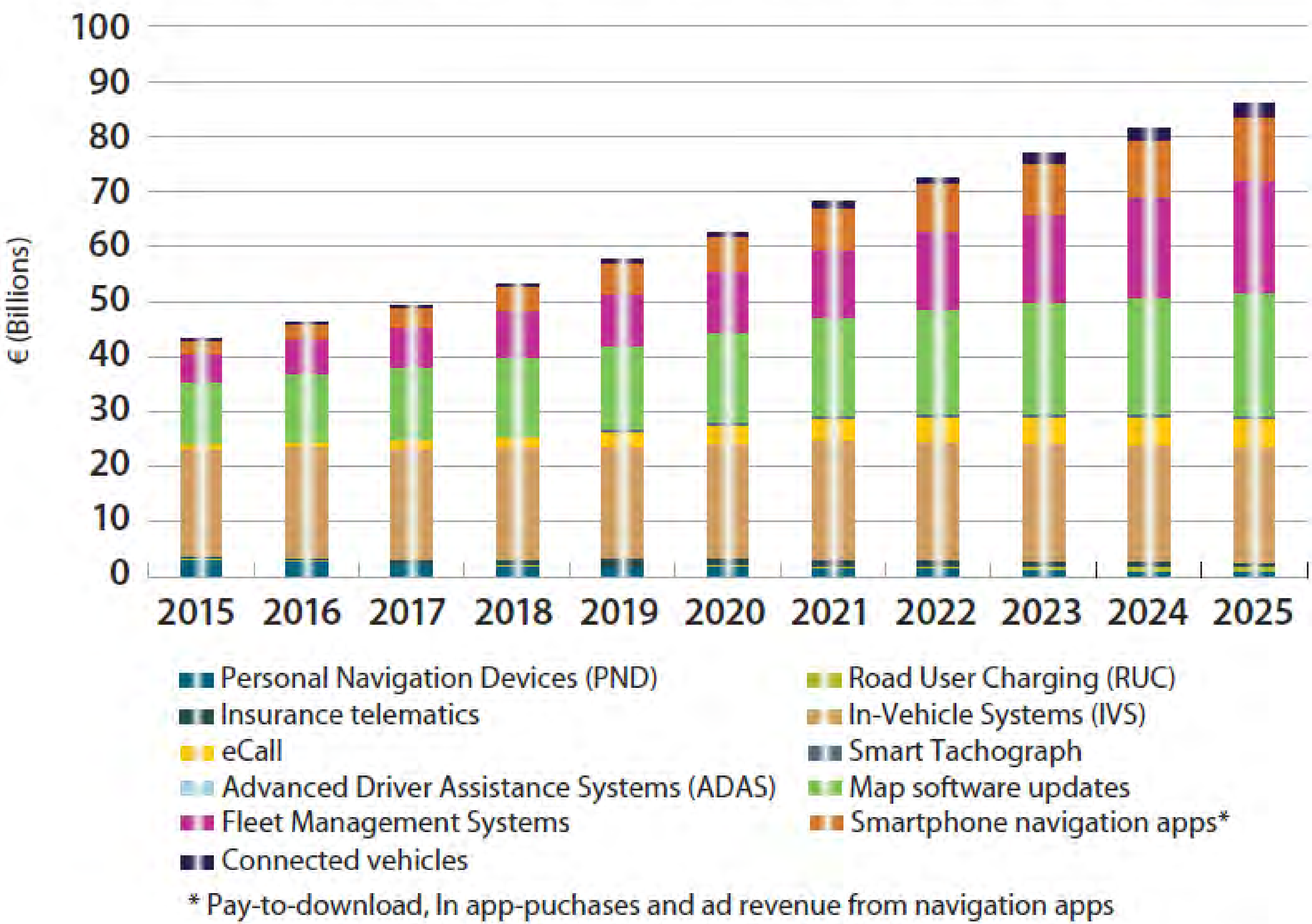
GNSS is an element of a sensor fusion based navigation system that includes LiDARs/Radars, Inertial sensors and cameras.

The Market



Installed base of GNSS devices by type
Units (Millions)
1,000
900
800
700
600
500
400
300
200
100
0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Personal Navigation Devices (PND)
Insurance telematics
eCall
Advanced Driver Assistance Systems (ADAS)
Road User Charging (RUC)
In-Vehicle Systems (IVS)
Smart Tachograph
Fleet Management Systems

The Market



100
90
80
70
60
50
40
30
20
10
0
€ (Billions)
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Personal Navigation Devices (PND)
Insurance telematics
eCall
Advanced Driver Assistance Systems (ADAS)
Fleet Management Systems
Connected vehicles
Road User Charging (RUC)
In-Vehicle Systems (IVS)
Smart Tachograph
Map software updates
Smartphone navigation apps*
* Pay-to-download, In app-puchases and ad revenue from navigation apps

New Business Models

- **Pay as you drive**

  Driving services costs according to vehicle usage

- **Mobility As A Service**

  The most appropriate means of transport, with the best conditions, for the actual needs and mobility conditions, in real time

- **Predictive Maintenance**

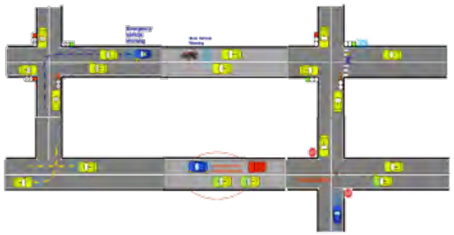
  Long term service enable through data captured from sensors and predictive analytics

Autonomous vehicles deployement

Deployment of autonomous vehicles foresees different scenarios

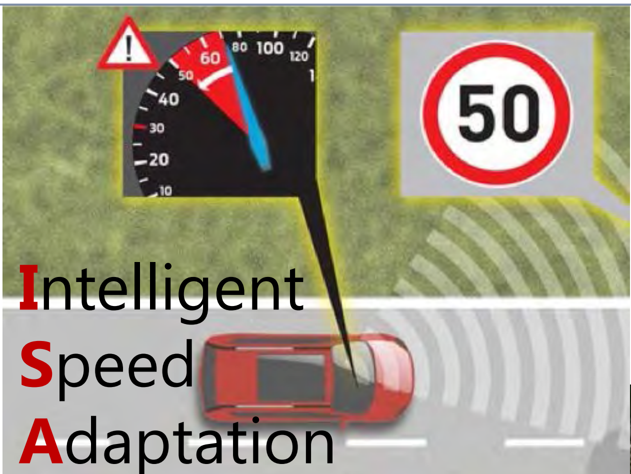
Scenarios	Conservative	Disruptive
2040s	Conditionally autonomous vehicles will account for 30-35% of new sales.	90% of new sales will be represented by fully autonomous vehicles.
2030s	18 mln sales of semi autonomous vehicles, first use cases of fully autonomous vehicles.	Fully autonomous vehicles sum up to 15% of new sales.
2020s	Large-scale testing of autonomous vehicles on public roads.	Fully autonomous vehicles launched on the market by tech giants and premium OEMs.
2016	Semi-autonomous vehicles tested on private and public roads supported by UNECE updating the 1968 Vienna Convention on Road Traffic.	

Use cases



Cooperative Collision Avoidance

Dynamic vehicle warning



Co-operative Awareness

Traffic Hazards Warning

eCall

Vulnerable Road User Discovery

Automated Overtake

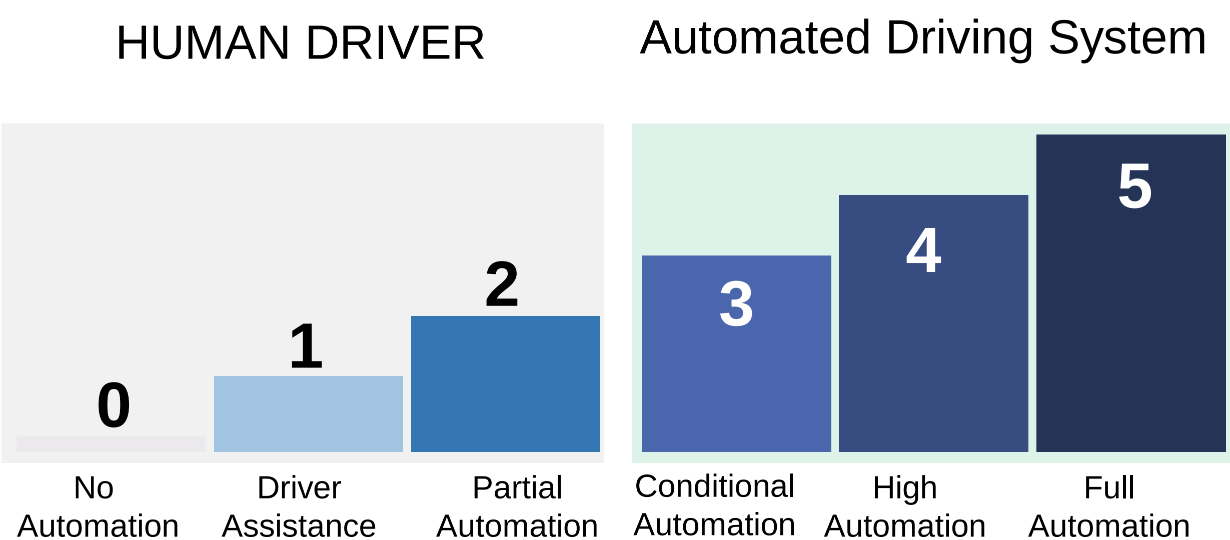
Automotive requirements

Use Case	Note
Cooperative Collision Avoidance	risk situations: • vs. another vehicle, • vs. other dynamic obstacles, • vs. static obstacles
Automated Overtake	It requires cooperation among vehicles on multiple lanes to create the gap in time to avoid collision with an oncoming vehicle
Road Hazard Warning	• Emergency Electronic Break Light • Safety function out of normal condition warning • Roadwork warning • Decentralized floating car data
Co-operative Awareness	• Emergency vehicle warning • Slow vehicle warning • Motorcycle warning
Traffic hazards warning	• Wrong way driving warning • Stationary vehicle warning • Traffic condition warning • Signal violation warning

Automotive requirements

Use Case	Note
Dynamic vehicle warning	Overtaking vehicle warning Lane change assistance Co-operative merging assistance
High Density Platooning	Vehicles will be driving very close to each other
Vulnerable Road User Discovery	VRUs equipped with a GNSS receiver announce their presence by broadcasting their status
ISA - Intelligent **S**peed **A**daptation	The driving speed is monitored and compared with the prevailing speed limit on the road (or the lane) the vehicle is on
eCall	Pan-European eCall generates an automatic 112 emergency call and transmits an MSD containing the absolute position of the damaged vehicle

SAFETY CRITICAL Requirements



KPI	Value
Position accuracy	**< 30 cm**
Trajectory handshake latency	<100 msec
Status message latency	<10 msec
Status message loss rate	$< 10^{-6}$
Status message rate	> 10 Hz

ELECTRONIC HORIZON

Vehicles and Road users

- Position, speed
- acceleration
- direction (heading)
- Yaw rate

Static obstacles

- Position

Infrastructure

- **High Accuracy Digital map**

From other sources

- traffic
- weather information

Enabling Technologies

	Application Domain	Accuracy	Integrity
SBAS	Aviation	< 2 m	10^{-7}/150s
GBAS/DGNSS	Aviation/Maritime	<16 m	10^{-7}-10^{-9}/150s
RTK/NRTK	Surveying	< 5 cm (AF)	n.a
PPP	Surveying, Maritime, Autonomous Driving	10 cm (Float) < 10 cm (AR)	n.a.

- **No single system can currently meet Automotive requirements**

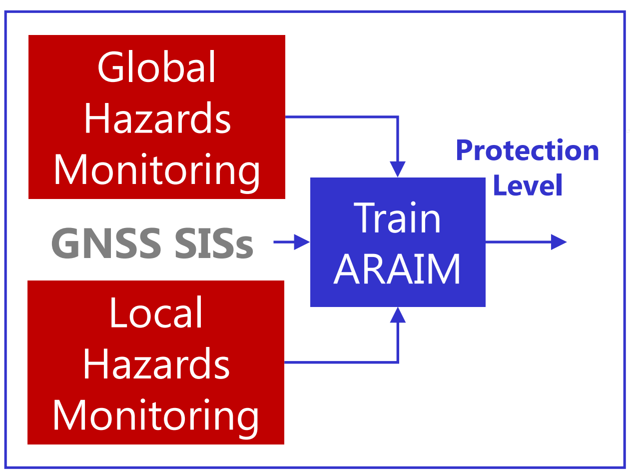
APPROACH

- **MULTICONSTELLATION GPS+GALILEO+ ГЛОНАСС+BEIDOU**
- **SBAS EGNOS, WAAS, SDCM**
- **Integrity Monitoring and Augmentation Services**
  - **High Accuracy RTK, PPP**
  - **Multifrequency Rx E1 E5a E5b, L1 L2C L1C**
- **ARAIM**

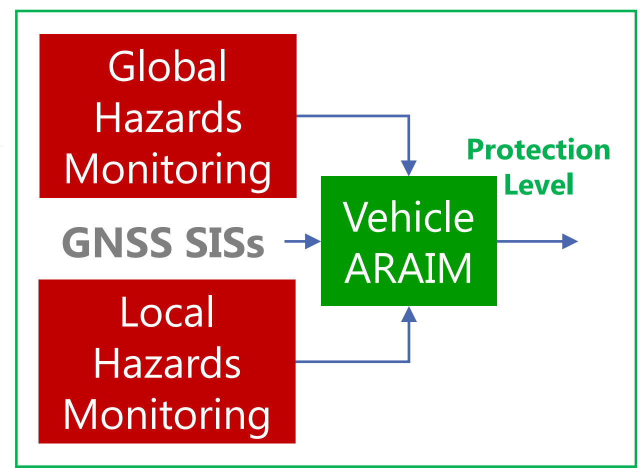
AUTOMOTIVE Reference Architecture

1. Based on Road Environment **MODELLING**
2. **Candidate solution(s) Architecture derived from Rail (RHINOS)**
   - Integrity Monitoring and Augmentation System Reference **Architecture**
   - On Board System Reference **Architecture**
   - **Local** hazards detection and effects mitigation,

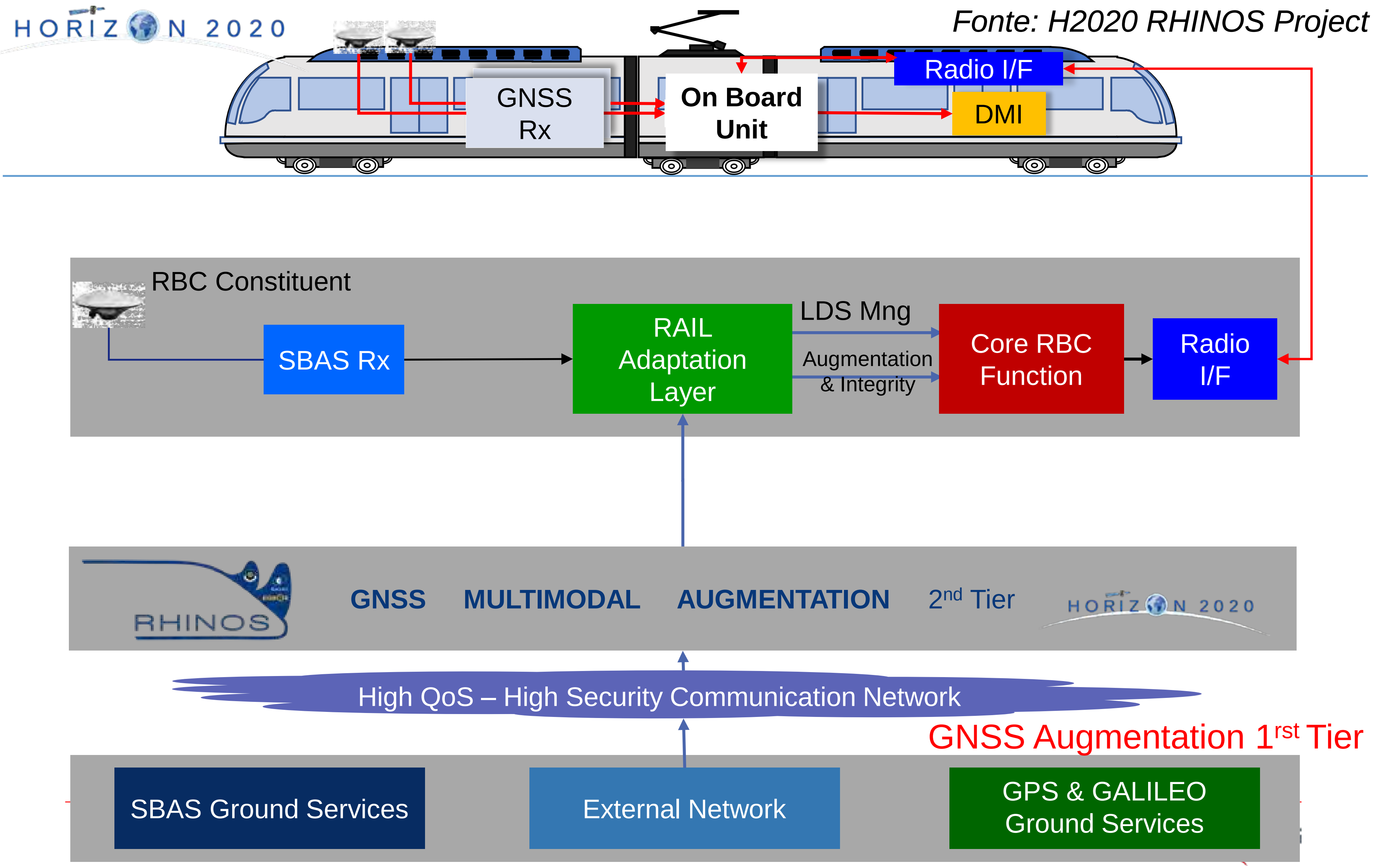
RAIL



AUTOMOTIVE

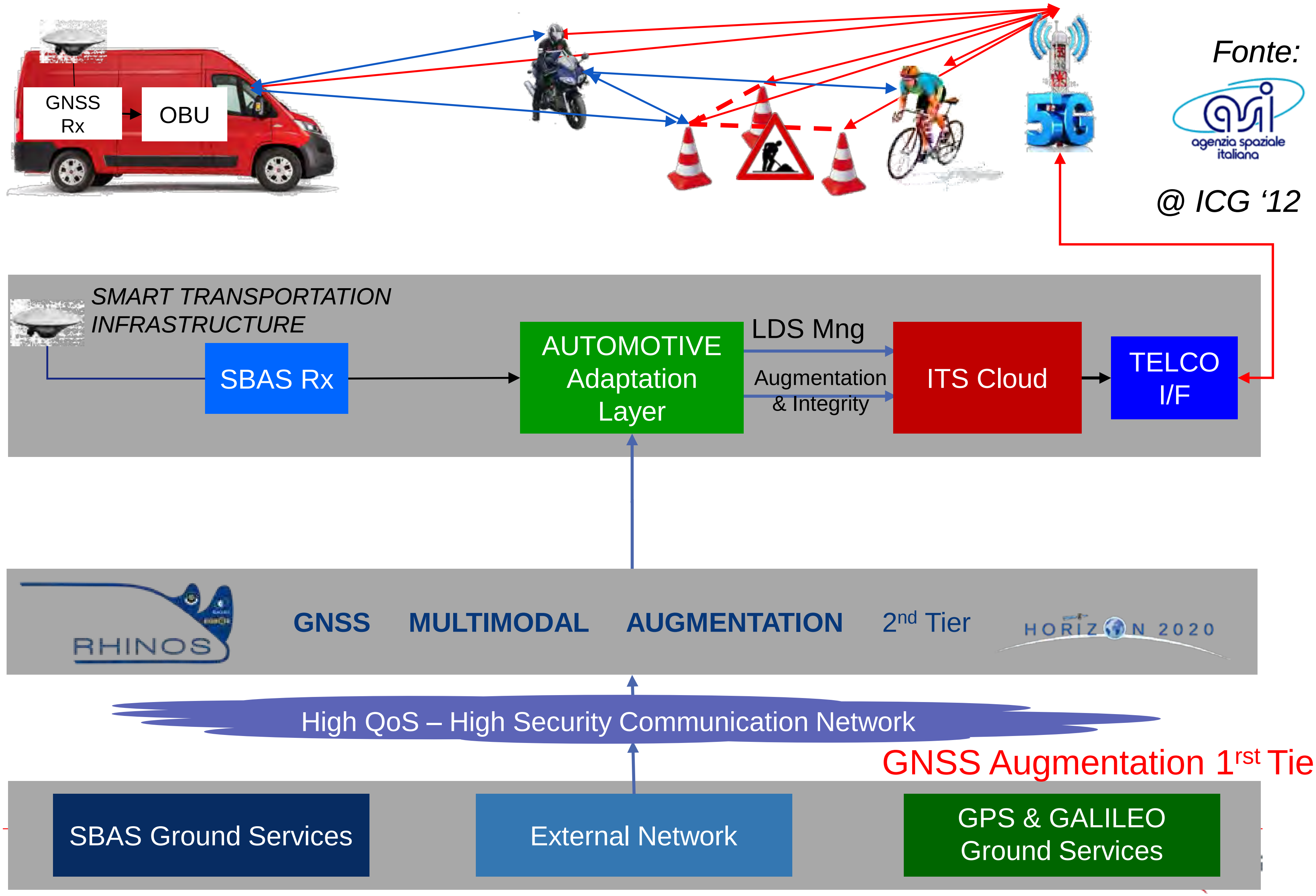


RAIL Reference Architecture

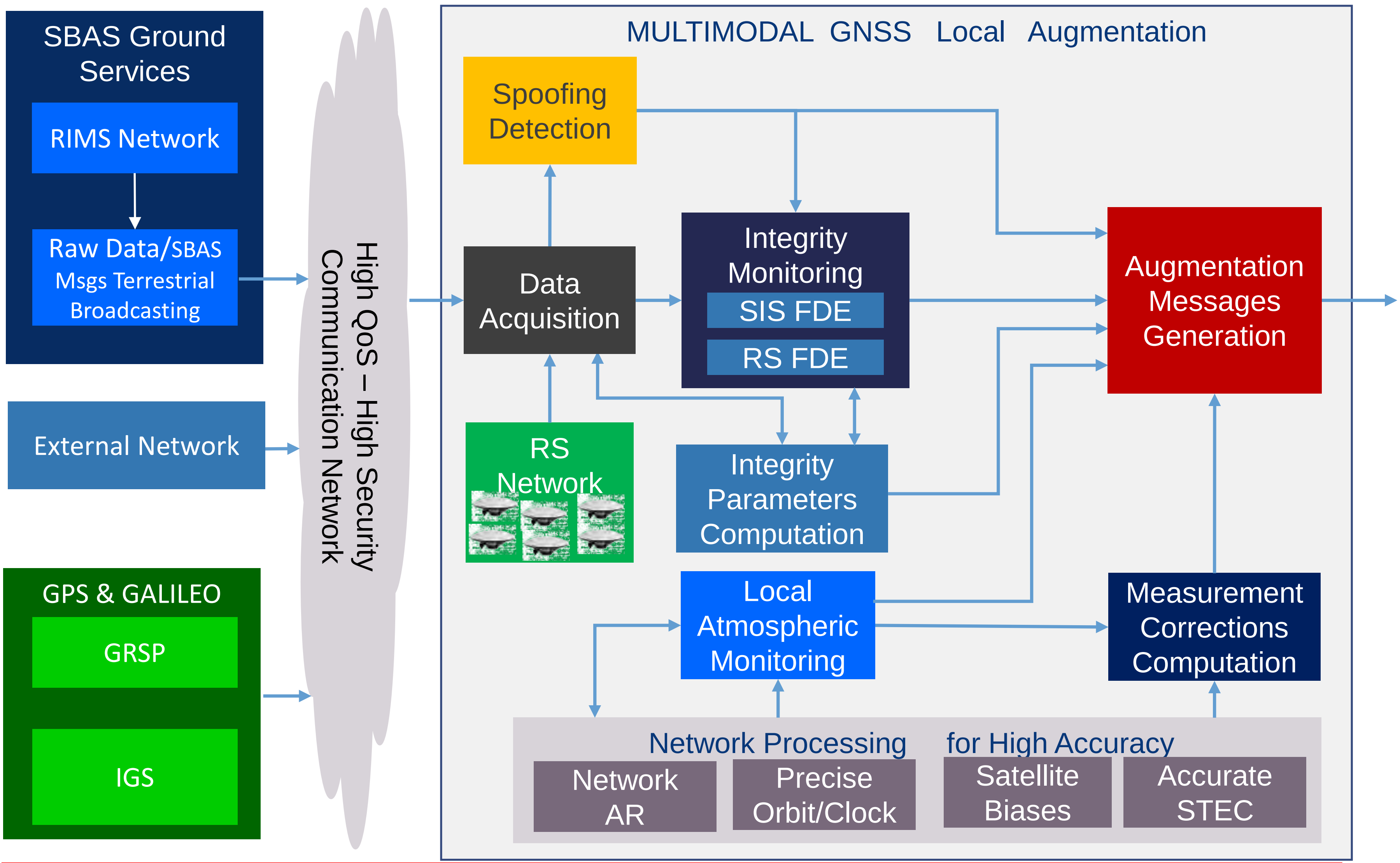


Fonte: H2020 RHINOS Project

AUTOMOTIVE Reference Architecture

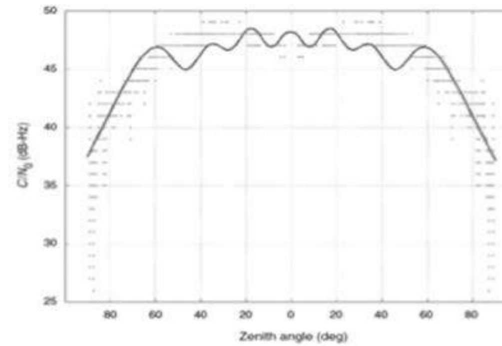


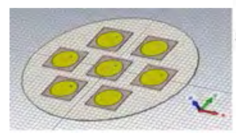
Reference GNSS Local Augmentation Architecture

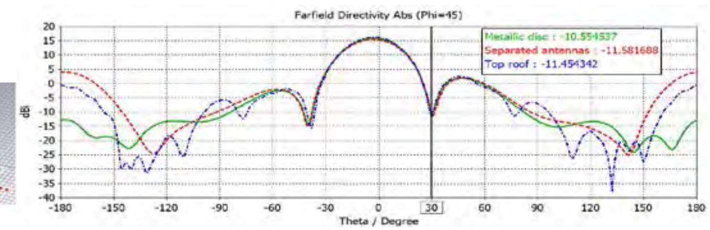


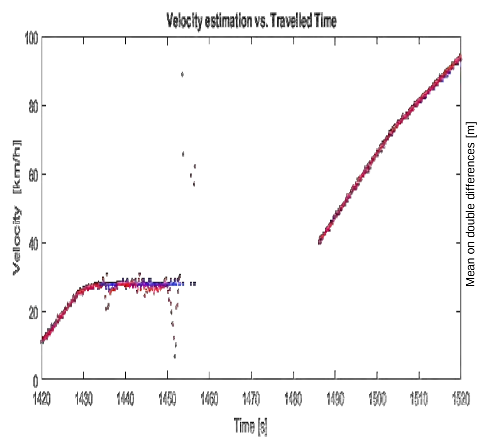
OBU: PVT Solution + ARAIM

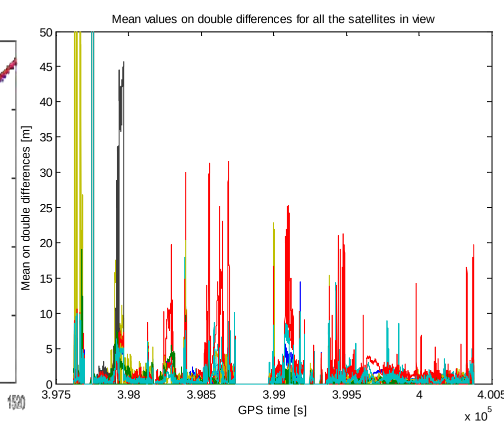
- Camera Visible Horizon
- Signal Domain
- Correlation Domain
- Measurement Domain
- Position Domain (ARAIM)











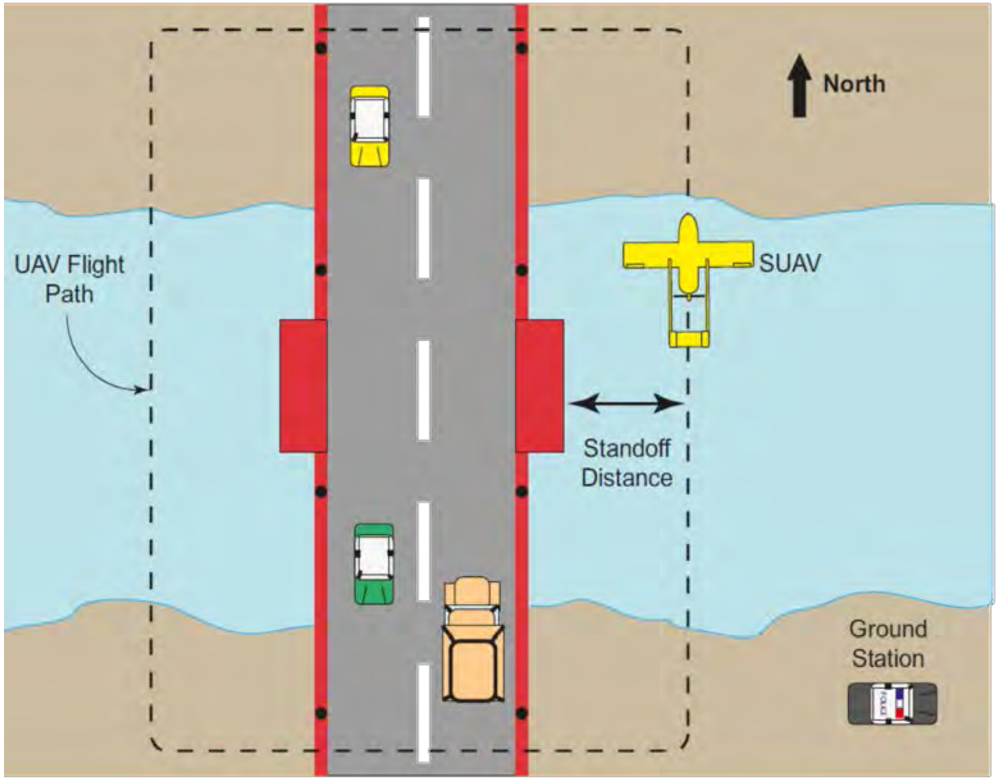
UAV Survey

Accurate **Infrastructure DB** is a **KEY ELEMENT** of RAIL and ROAD TM

Survey & Continuos Infrastructure Monitoring Can Benefit from **UAV** Tecnologies

HIGH ACCURACY required in post processing

HIGH INTEGRITY required for safe survey during operations



Source: Demoz Gebre-Egziabher Zhiqiang Xing, *Analysis of Unmanned Aerial Vehicles Concept of Operations in ITS Applications*

Collision Avoidance

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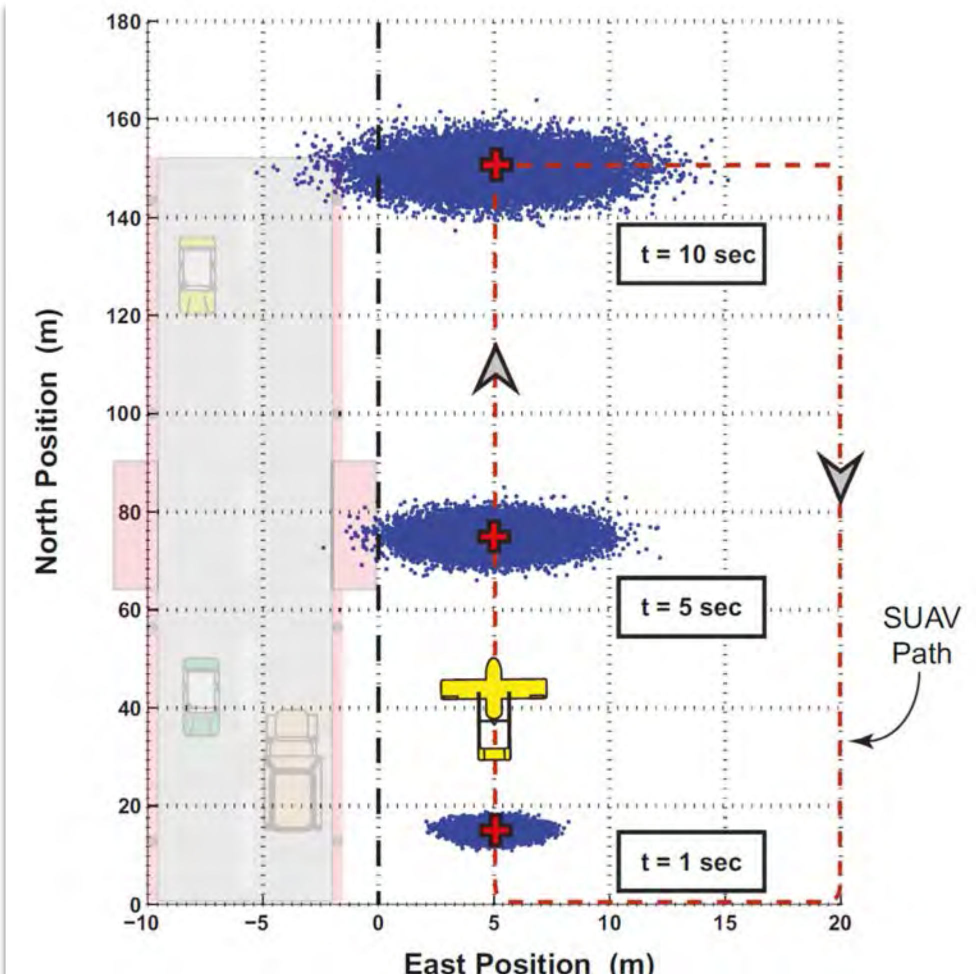

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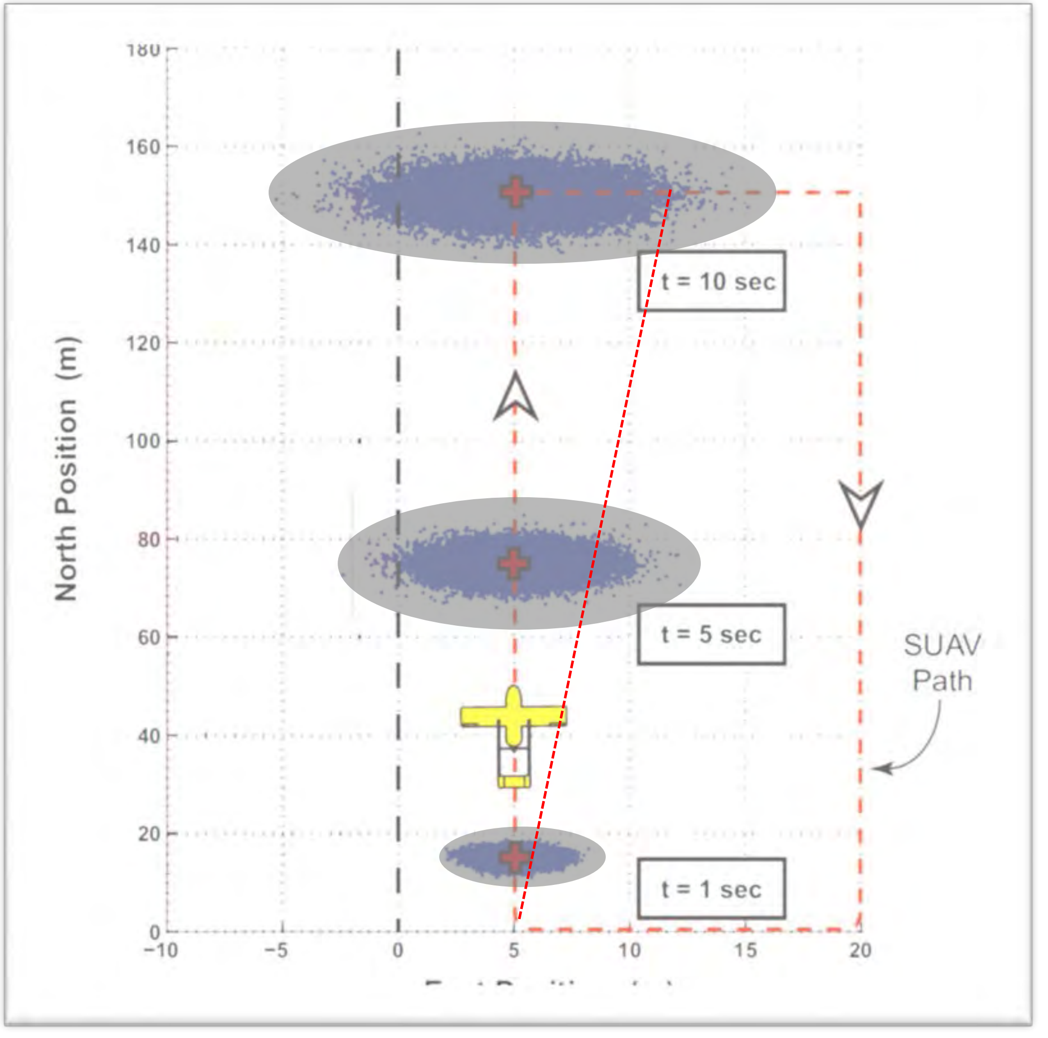


MAAST Simulations

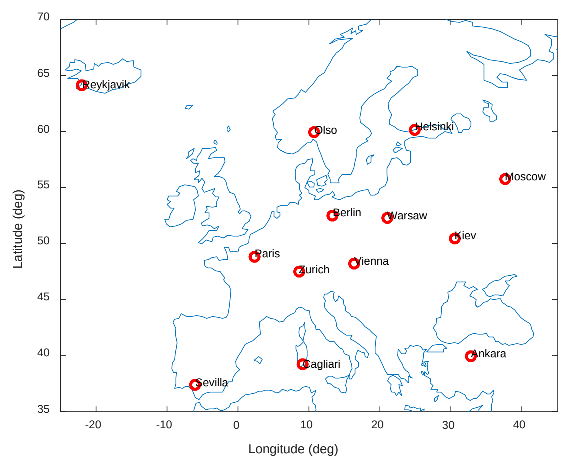
Stanford simulator adapted to RAIL

RHINOS

24 GPS + **24 Galileo** satellites

Source: 1st GALILEO USER ASSEMBLY 28-29 NOVEMBER 2017 MADRID

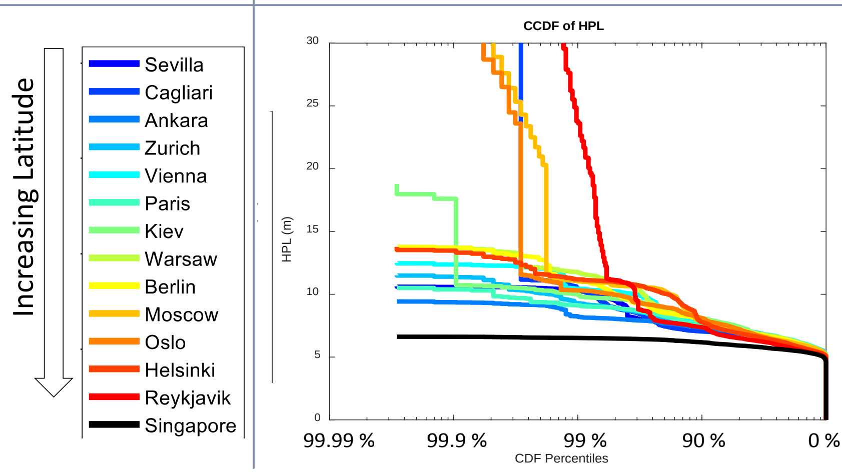
13 European user locations
Singapore (on equator) added for comparison

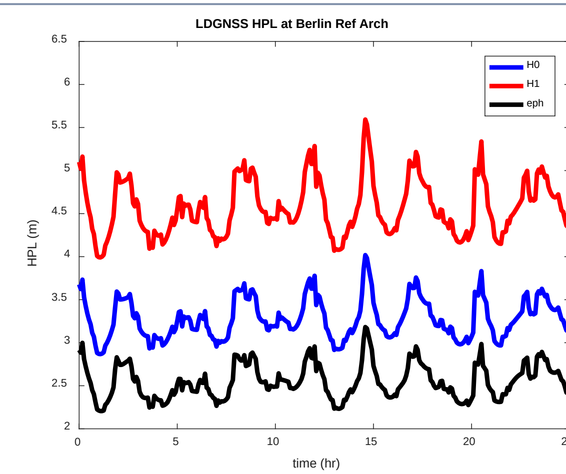


- SBAS monitoring reduces ephemeris HPL to insignificance,
- but other LDGNSS HPLs dominate

L1 C/A and E1 OS signals only

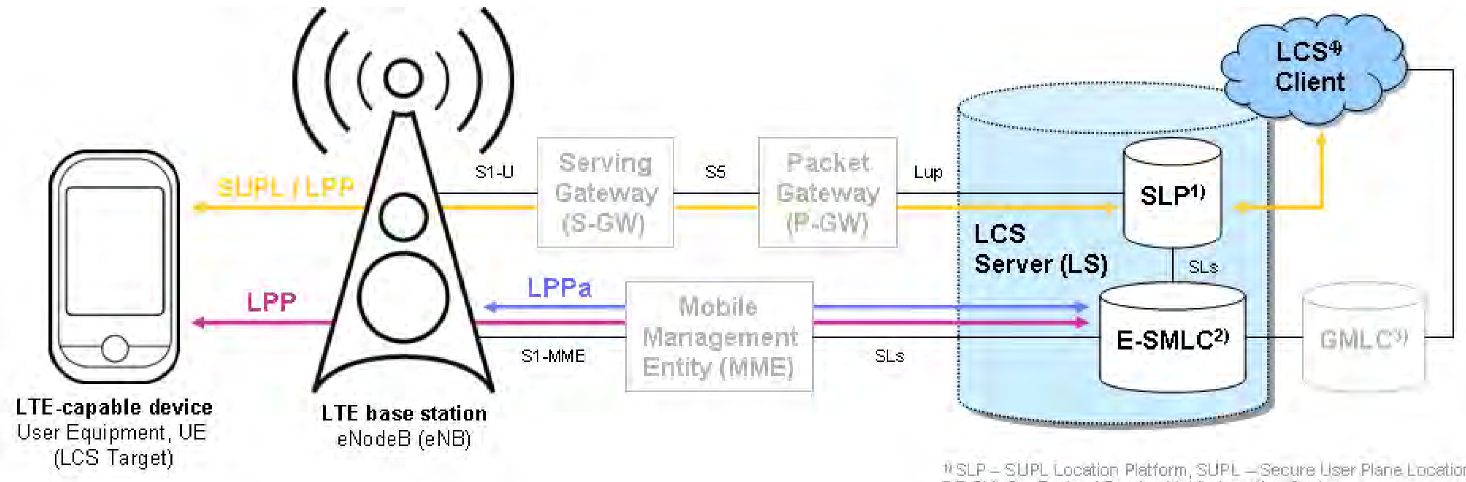
5-min updates over 1 or 10 days





Indoor Positioning

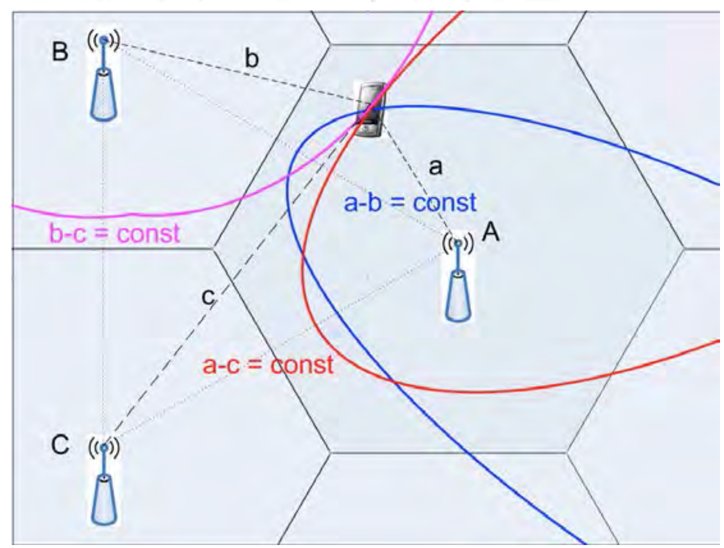
LTE – Location services



[1)] SLP – SUPL Location Platform, SUPL – Secure User Plane Location
[2)] E-SMLC – Evolved Serving Mobile Location Center
[3)] GMLC – Gateway Mobile Location Center
[4)] LCS – Location Service
[5)] 3GPP TS 36.455 LTE Positioning Protocol Annex (LPPa)
[6)] 3GPP TS 36.355 LTE Positioning Protocol (LPP)

- In principle the eNodeB synch signals could be used for localization
- Due to the intercell interference, only in a few cases at least 4 different signals useful for localization are available

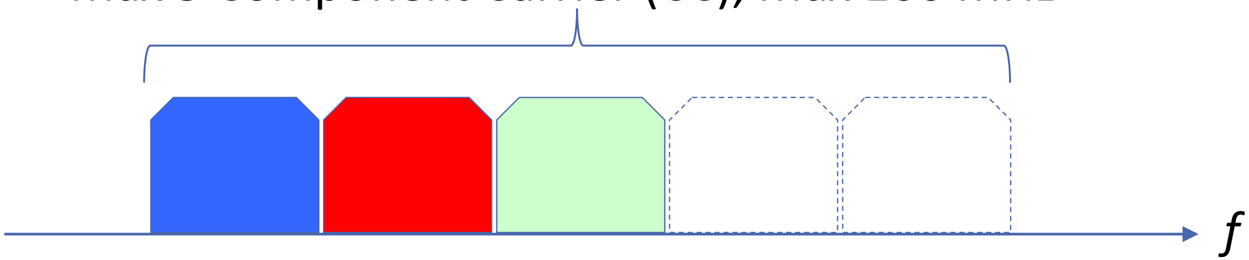
- Thus, 3GPP introduced the Positioning Reference Signal (PRS) for measuring the Difference of Time of Arrival (DTOA)



UMTS – LTE Advanced

- Very high bit rate
    - Down Link 3 Gb/s, Up Link: 1.5 Gb/s
- High spectral efficiency
    - 30 bit/(s x Hz)
- Large number of simultaneous users
- Main Functionalities
    - Carrier aggregation
    - Mutiple antennas (MIMO)
    - Relay Nodes (RN).

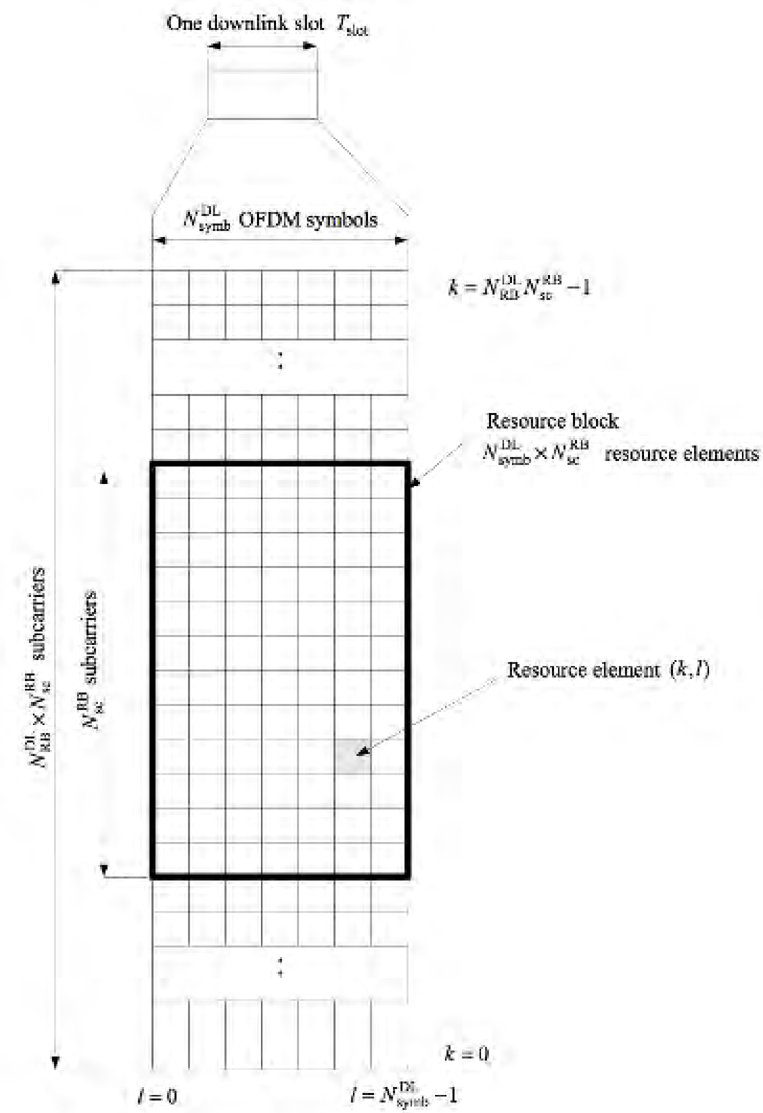
Max 5 Component Carrier (CC), Max 100 MHz



Bandwidth CC: 1.4,3,5,10,15,20 MHz

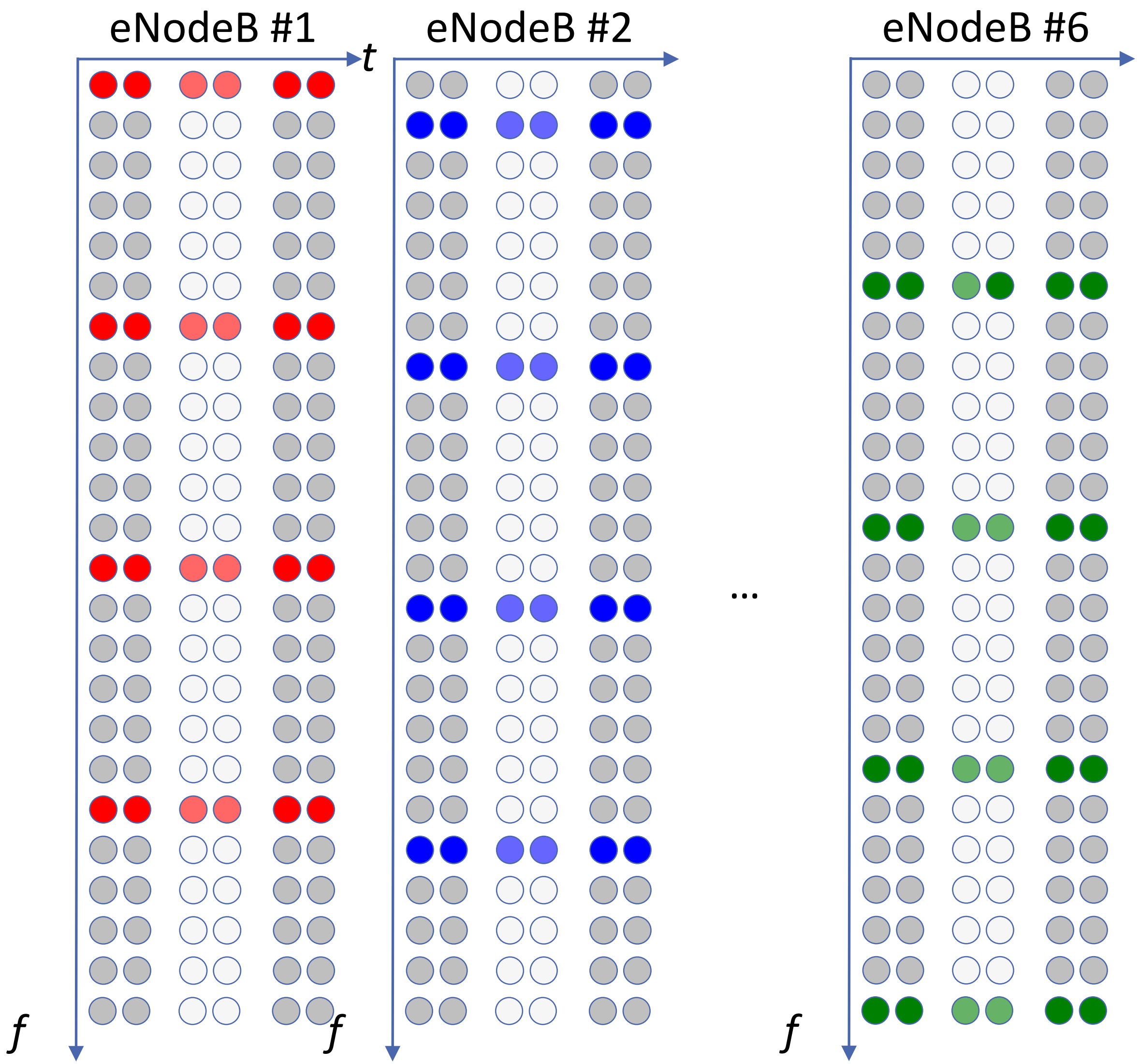
LTE Downlink Resource grid

- Down link Channels
  - Physical Downlink Shared Channel, PDSCH
  - Physical Broadcast Channel, PBCH
  - Physical Multicast Channel, PMCH
  - Physical Control Format Indicator Channel, PCFICH
  - Physical Downlink Control Channel, PDCCH
  - Physical Hybrid ARQ Indicator Channel, PHICH
  - Enhanced Physical Downlink Control Channel, EPDCCH



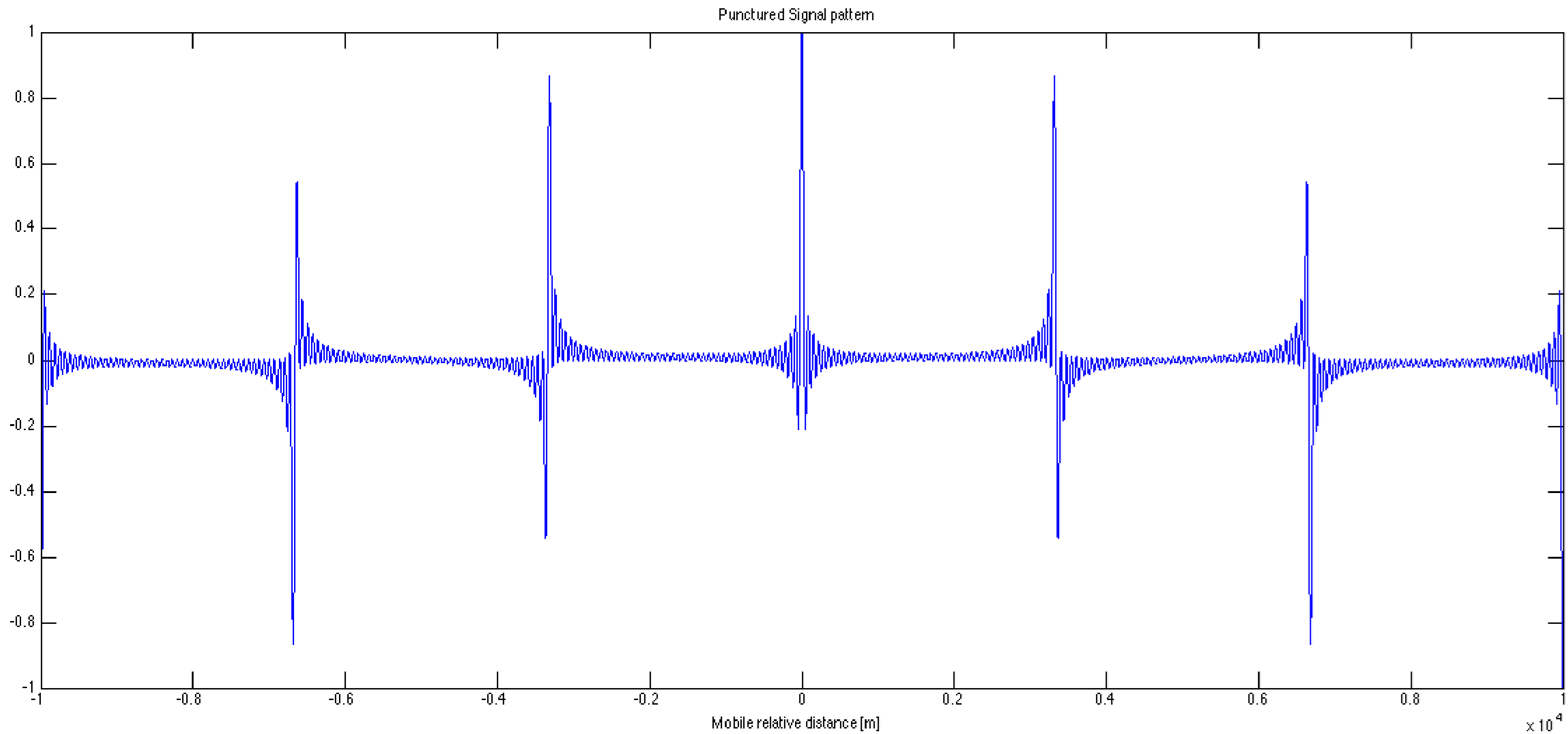
LTE-Advanced - PRS

- To allow joint transmission from several eNodeB (up to 6), each node employes only an interlaced subset of the OFDM subcarriers,
- The other eNBs apply radio silence.



Outdoor: weakness

- Short ambiguity distance due to puncturing
- LOS required
- Multipath mitigation required

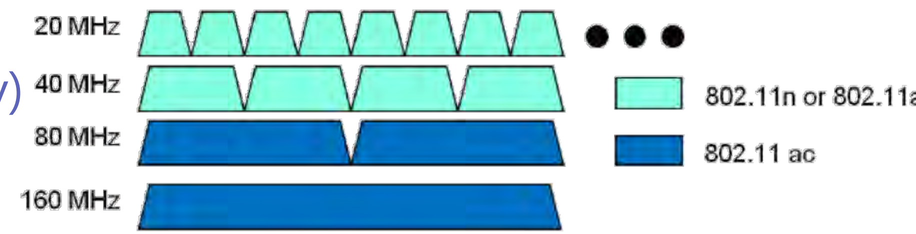


IEEE 802.11

- IEEE 802.11ac and IEEE 802.11ad adopt a Physical Layer based on WideBand OFDM

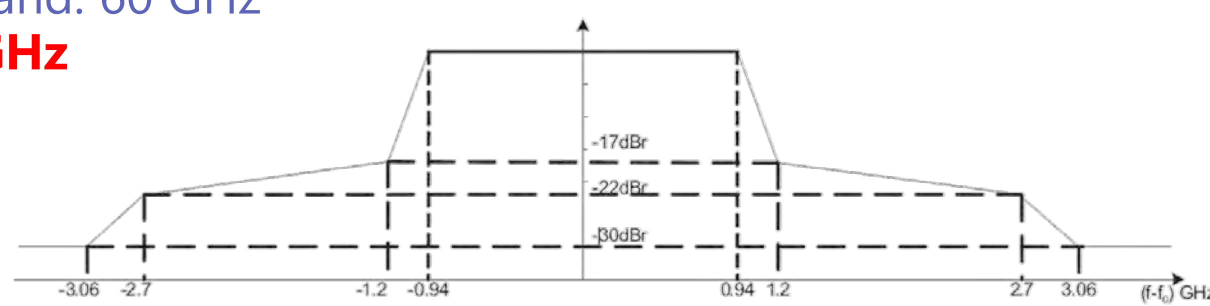
- **IEEE 802.11ac**

  - Carrier frequency band: 5 GHz
  - Bandwidth: 80 MHz (mandatory)
    160 MHz (optional)



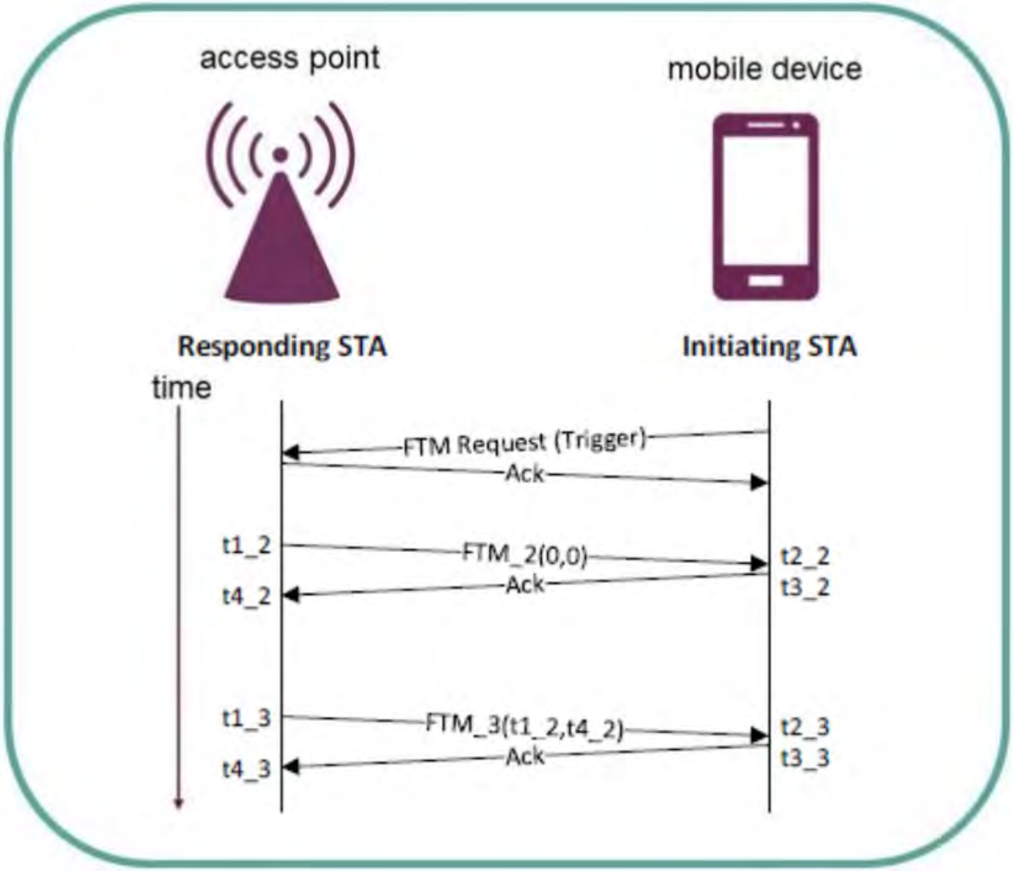
- **IEEE 802.11ad**

  - Carrier frequency band: 60 GHz
  - Bandwidth: **2.16 GHz**



Wi-Fi

The Fine Timing Measurement has been introduced in the 802.11ad standard with the purpose to measure the **time of arrival between any two Wi-Fi stations**

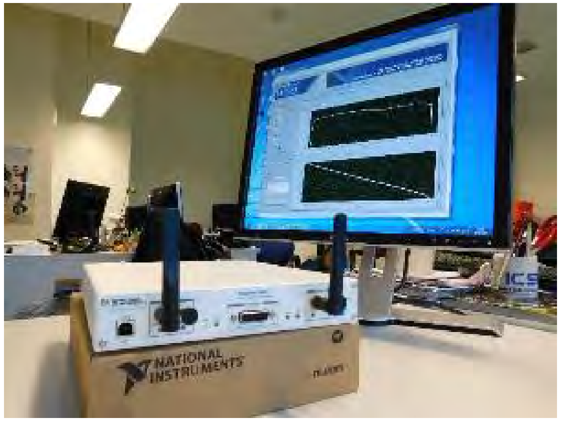


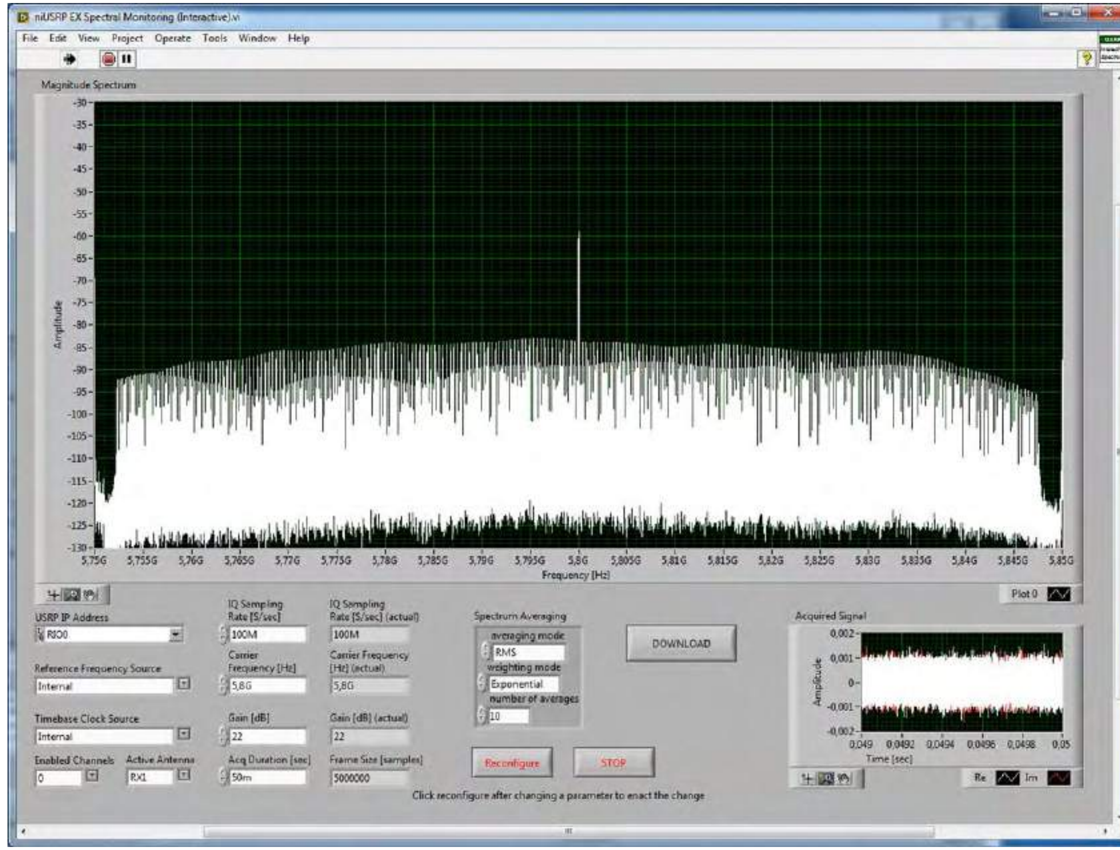
Taking into accounts all the factors that can influence the measure, the **Wi-Fi alliance declares an overall location accuracy of about 1m**

Measuring the distance of a beacon at a time has a drawback…

$$t_{TOA} = \frac{\left(t_{2\_2} - t_{1\_2}\right) + \left(t_{4\_2} - t_{3\_2}\right)}{2}$$

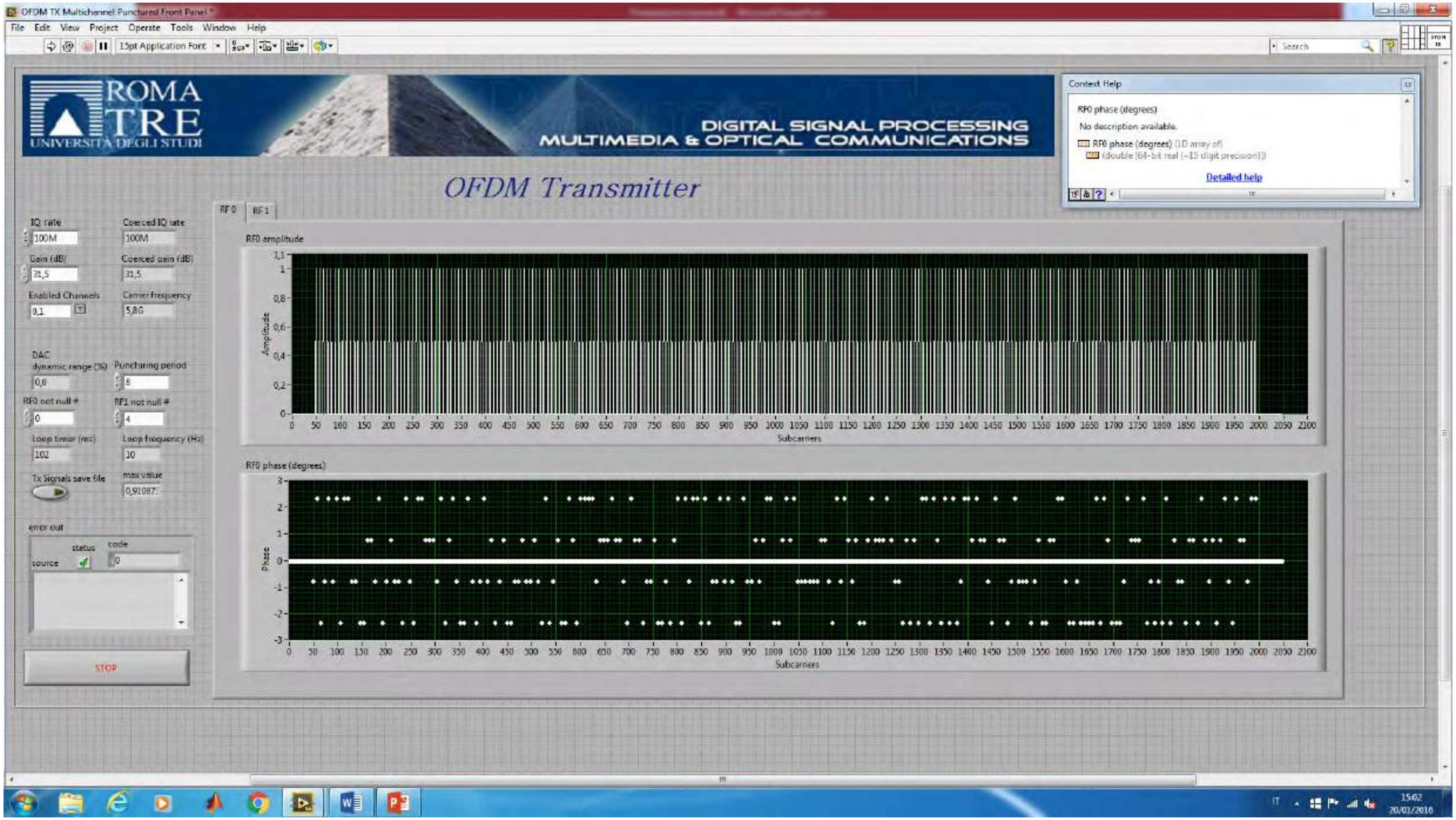
Test Bed


NATIONAL INSTRUMENTS


niUSRP EX Spectral Monitoring (Interactive).vi
File Edit View Project Operate Tools Window Help
Magnitude Spectrum
Amplitude
Frequency [Hz]
USRP IP Address
RIO0
Reference Frequency Source
Internal
Timebase Clock Source
Internal
Enabled Channels
Active Antenna
RX1
IQ Sampling Rate [S/sec]
100M
Carrier Frequency [Hz]
5,8G
Gain [dB]
22
Acq Duration [sec]
50m
IQ Sampling Rate [S/sec] (actual)
100M
Carrier Frequency [Hz] (actual)
5,8G
Gain [dB] (actual)
22
Frame Size [samples]
5000000
Spectrum Averaging
averaging mode
RMS
weighting mode
Exponential
number of averages
10
DOWNLOAD
Reconfigure
STOP
Click reconfigure after changing a parameter to enact the change
Acquired Signal
Time [sec]
Plot 0

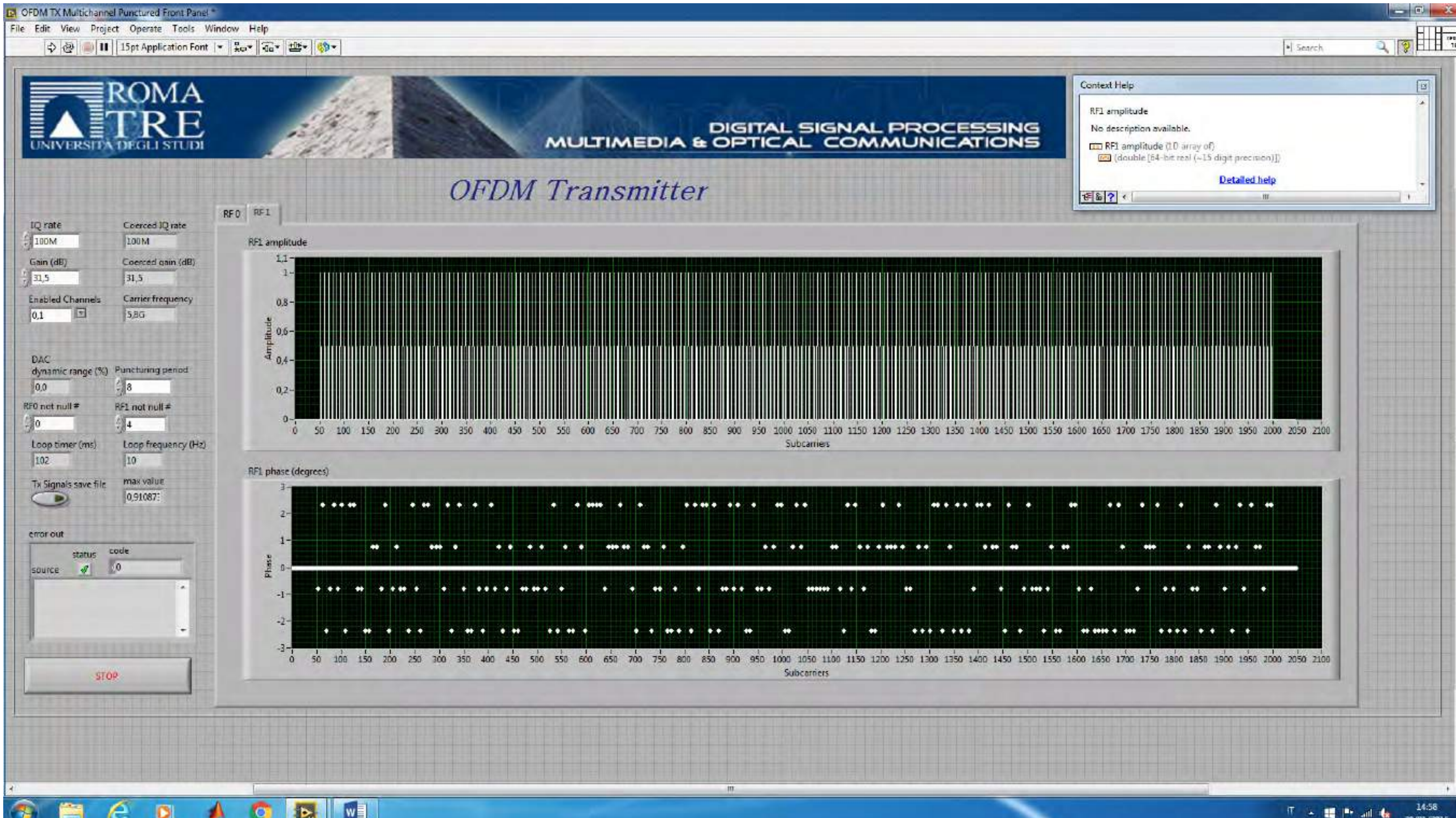
Trasmitter 1

- Signal Bandwidth: 100 MHz
- # of carriers= 2048



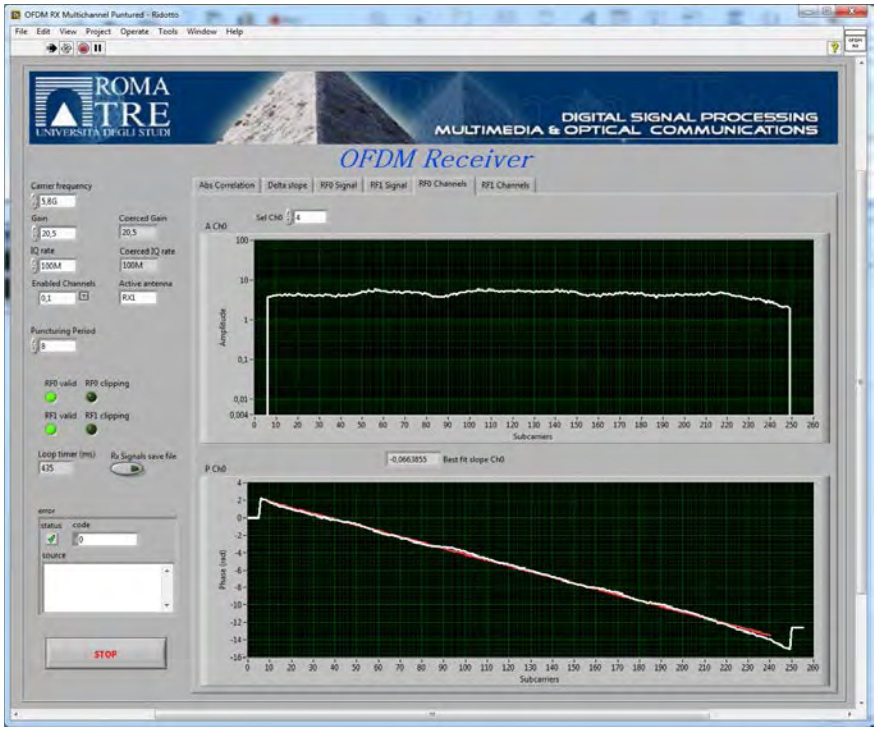
Transmitter 2

- Signal Bandwidth: 100 MHz
- # of carriers= 2048

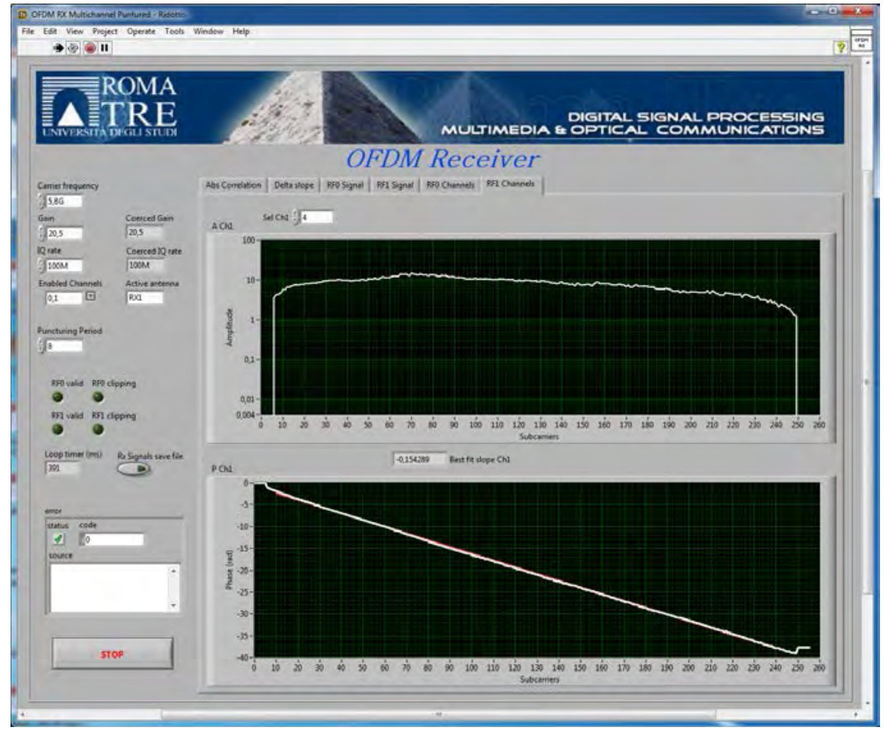


Received Signals

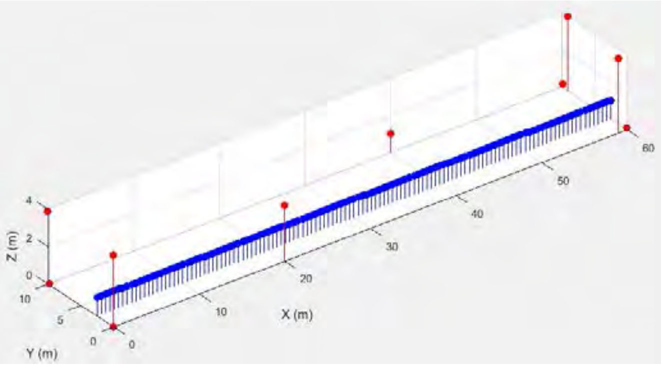
Rx #0



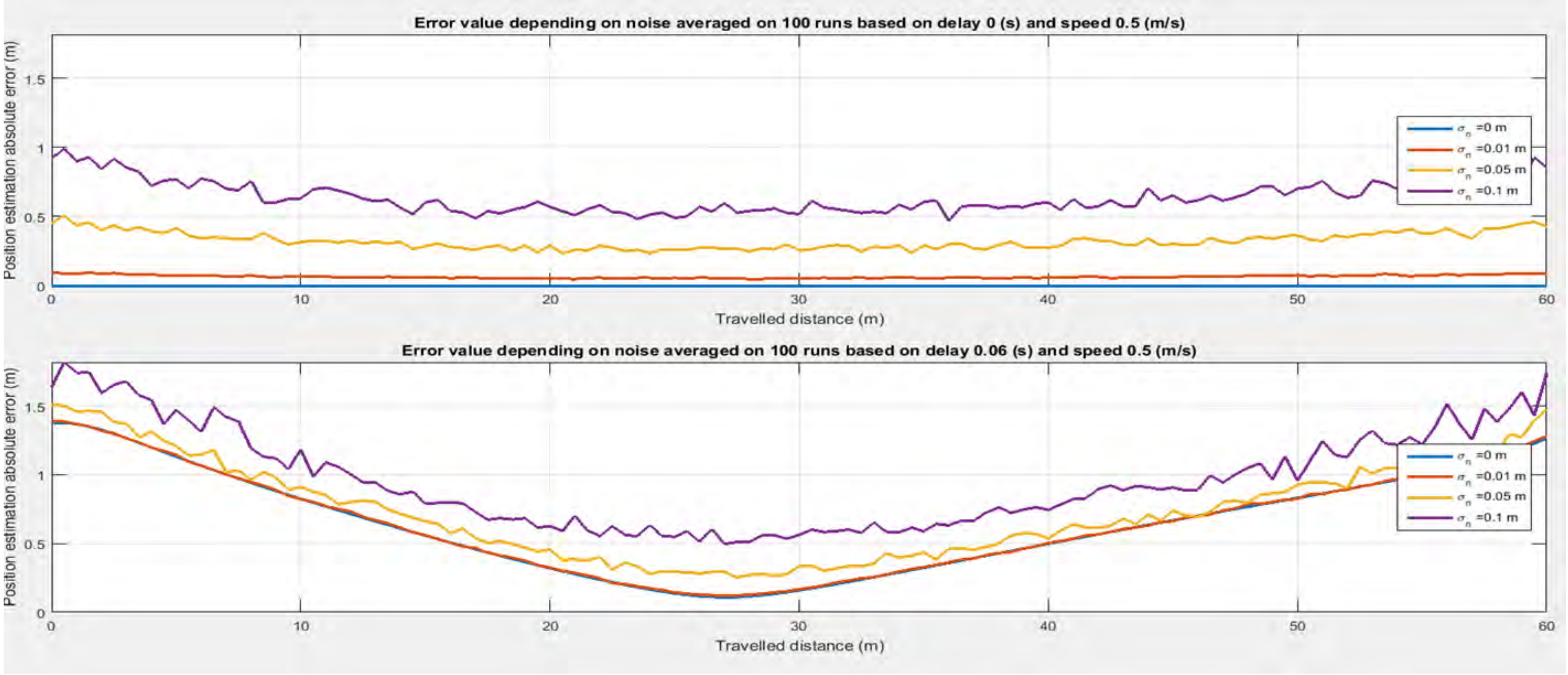
Rx #1



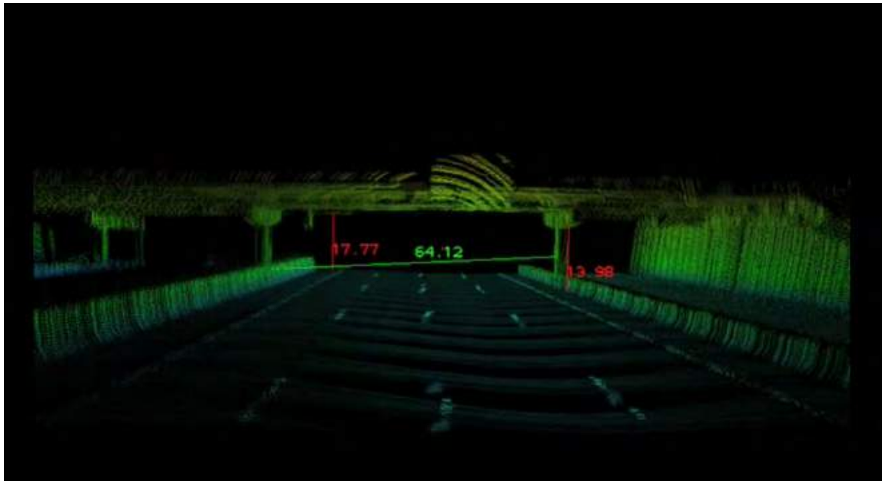
Simulator Scenario: Tunnel

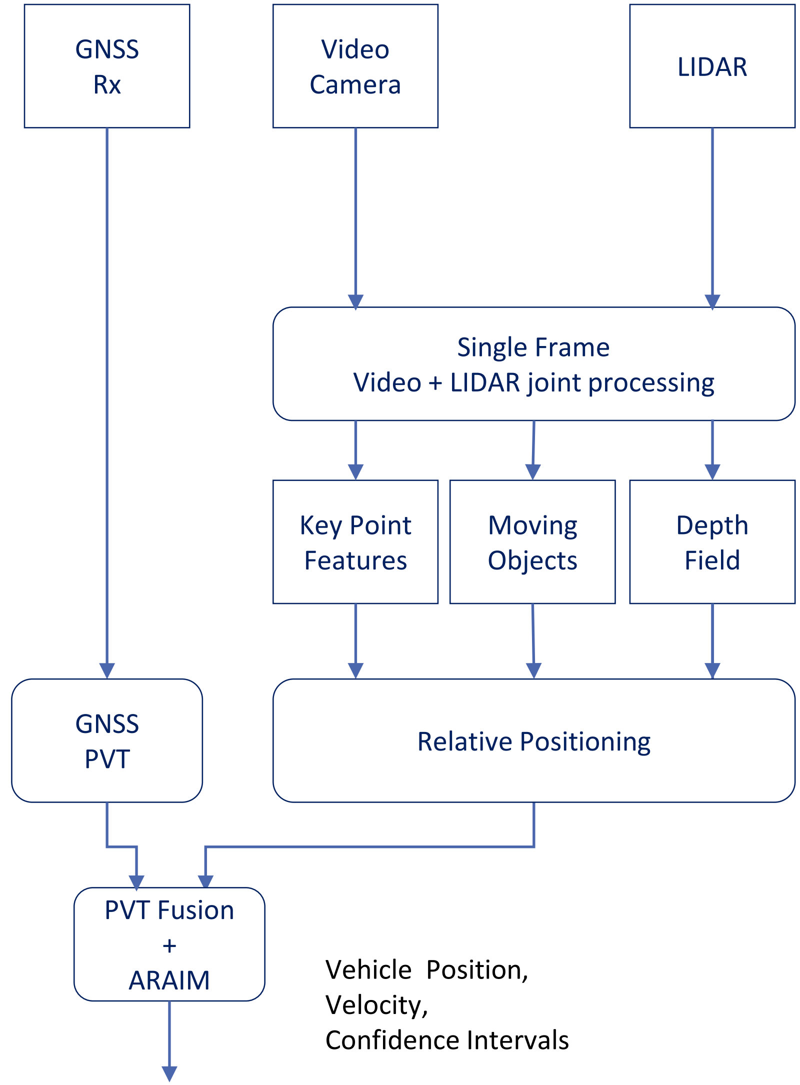


Length: 60m
Width: 10m
Height: 4m



LIDAR





- A Lidar is a remote sensing system that allows to measure the distance to a target by illuminating that target with a pulsed laser light and measuring the reflected pulse with a sensor.
- A Lidar is generally based on some key components: a laser, a scanner, and a receiver.

Conclusion

1. **SBAS** and **LDGNSS** mitigate satellite and atmospheric anomalies
2. **HPLs** are mostly **driven** by **ARAIM**
3. **Multipath** and Presence of trees as the most impacting **Fault Source**
4. **RTK** provides good results for Start of Mission operations
5. **OBU multipath mitigation** is **key** to making ARAIM monitoring practical
6. **Multi-Frequency SIS** integrity **monitoring** (including phase and doppler) supporting **RTK** & **PPP** is **required**
7. Exploitation of **GALILEO SIS** charcteristics can **boost** High **Accuracy** Location Services
8. **SHARING** of a unified **multimodal** Overlay Network for Location Services for Rail, Automotive, UAV is **FEASIBLE**

Thank you for your attention