Geo-localisation in CERN's underground facilities

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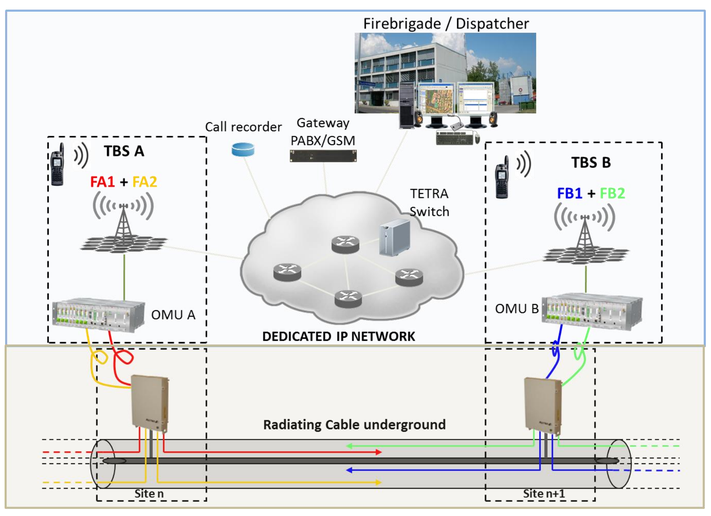
CERN has recently deployed a digital radio network, based on **TETRA** technology, to be used by the Fire Brigade and other services, both on the surface and in CERN's underground facilities. As a key TETRA feature for the Fire Brigade is the integrated **GPS localisation** system, we faced the challenge of providing an Indoor Localisation System to cover the underground facilities.
The solution chosen is based on autonomous **beacons** placed in strategic locations, each broadcasting a specific identification number. TETRA handsets compare signal strengths from beacons within range and transmit the ID of the closest beacon to the Fire Brigade Control Center where, by making use of CERN's Geographic Information System (GIS), the localisation system highlights the position of TETRA handsets on a detailed map.

CERN TETRA network architecture

TETRA (**TE**rrestrial **T**runked **RA**dio)

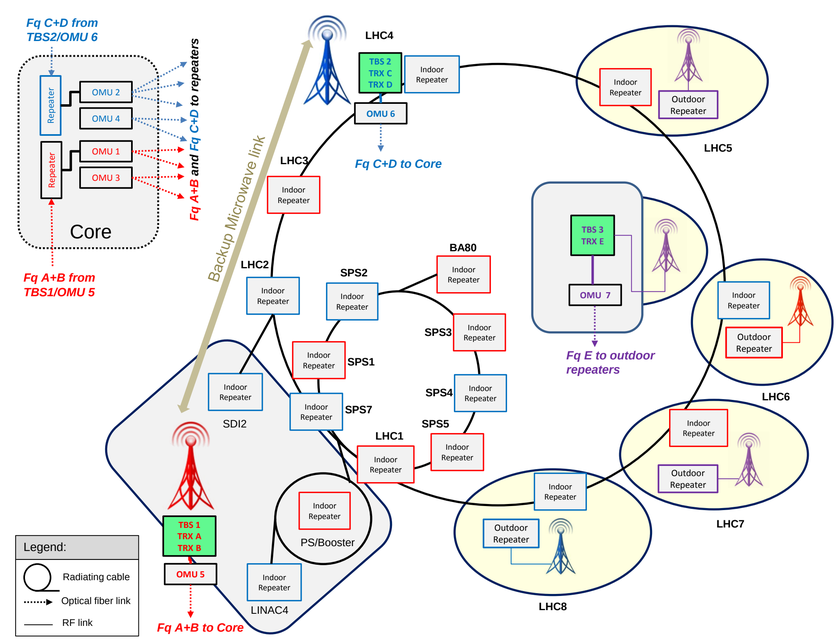
- **E.T.S.I.** standard
- digital radio technology working in the 410-430MHz frequency band
- based on **TDMA** (**T**ime **D**ivision **M**ultiple **A**ccess) multiplexing and phase modulation
- uses up to 2 Control Channels for signalling and SDS (Short Data Messages)

This technology provides voice services (individual and group calls), message services (SDS), pre-emptive prioritisation, busy queuing and many other services.
Its main purpose is to enhance radio communication services for professional users in their safety and security daily operations.



Conceptual view of CERN's TETRA network

CERN's TETRA architecture

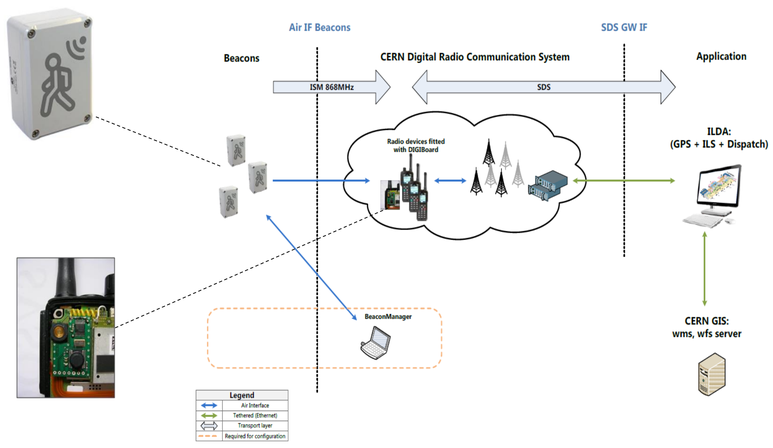


- 3 **TBS** (TETRA Base Stations) ensure outdoor radio coverage
- 5 TMO (Trunked Mode Operation) frequencies enable up to 17 simultaneous calls
- 2 redundant TETRA **Switches** handle handover between TBS
- 2 **PABX gateways** link TETRA to GSM and fixed telephones
- **OMUs** (Optical Master Units), Optical/RF **repeaters** and 50km of radiating cable allow deliver radio coverage to underground sites
- a dedicated, fibre-based, IP network
- a backup microwave link between the two main TBS

Localisation System concept

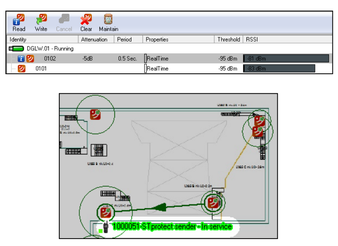
Indoor **L**ocalisation **S**ystem (ILS) components

- Beacons integrating a transmitter in ISM 868MHz band and an antenna. They are identified by an ID stored in internal memories
- A receiver module in the TETRA handsets
- An **I**ndoor **L**ocalisation and **D**ispatcher **A**dd-on (ILDA) application integrated in the TETRA dispatcher workstation
- A GIS server recording beacon locations



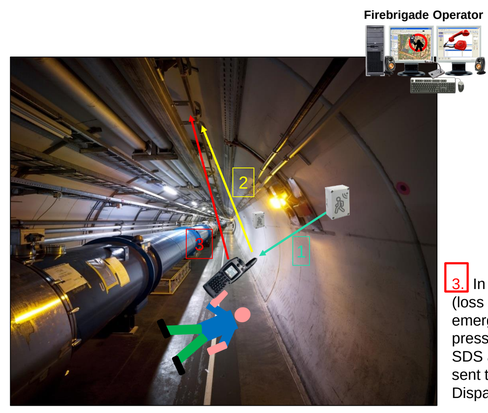
System configuration

By configuring specific settings on the beacons (output power, sensibility threshold, ID *corresponding to beacon's location*, ID sending period) a precise **mapping** of the area can be established.
Beacon icons can then be placed on a dedicated layer into a **GIS** server. A simple request from ILDA to this server enables the display of the expected map.



Application

With beacons deployed, TETRA handsets transmit, **encapsulated into an SDS**, the beacon IDs they detect to the ILDA. Then the position (ID) of the beacon is displayed, indicating the information on the **last known location** of the handset. The application also allows to display the **direction of radio** moving in CERN indoor infrastructure.
Combined with **ManDown** (lose of verticality) and **Emergency** alarming features, the ILS brings crucial additional information in case of rescue intervention.



1. Beacons located in the tunnel each broadcast their ID through an integrated antenna

2. Handsets forward the ID of the nearest beacon to the Indoor Geolocalisation Display at the Fire Brigade (via a "leaky feeder " which provides GSM and radio coverage in the tunnel)

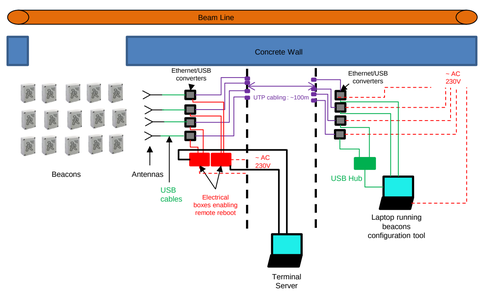
3. In case of incident (loss of verticality or emergency button pressed) an emergency SDS and an alarm are sent to the Fire Brigade Dispatcher

Challenges Faced—and Overcome!

A High Radiation Environment (up to 600Gy/yr!)

Problem: spontaneous beacon ID changes due to radiation.

Solution: ID is stored in triplicate; beacon firmware ensures recovery from single corruption, only halting ID transmission if all stored IDs are inconsistent.



SDS overload

Problem: Transmission of beacon IDs presents heavy load due to number of SDS messages---from handsets to TBS and from TBS to ILDA

Solution: Enable direct IP connection from TBS to ILDA reducing SDS messages by factor of two

Providing Power

Problem: Beacon placement must ensure full coverage of the underground areas; external electrical power is not available in all selected locations.

Solution: Beacons are powered by a high-capacity battery; the normal 10-year duration is reduced to 5-years in the LHC environment, but this is sufficient to cover the time between major maintenance periods.

Frequency planning: very complicated!

- **Multiple frequencies needed!**
- **How to deal with both Swiss and French regulatory authorities?**
- **How to ensure failover for redundancy?**