Software & Standards
for Smart Networks & Services

Network digital twin: modelling and data related challenges

Presented by:

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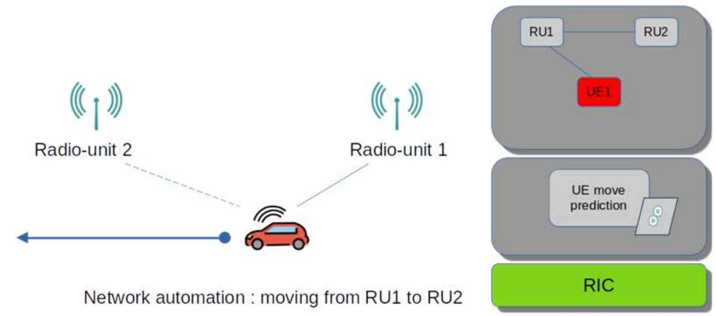
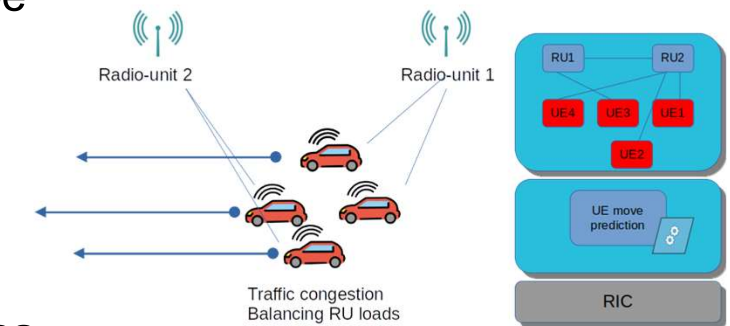
Introduction

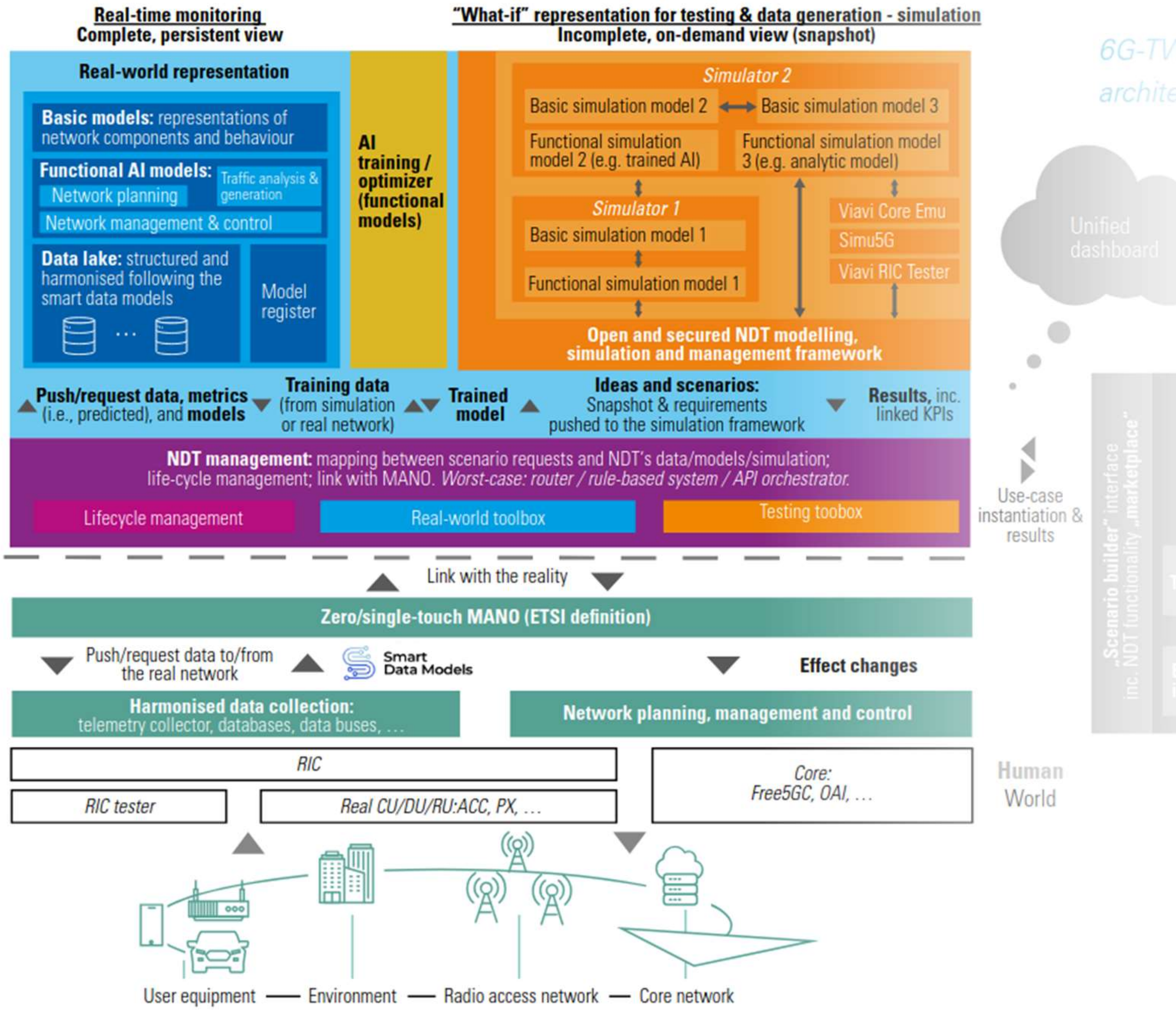
- Network Digital Twins (**NDT)** have emerged to deal with the increasing complexity of mobile network management and optimization
- Data is the fuel of NDT...
- … But **data alone is not sufficient**; it must be structured, complemented by human expertise, and its semantics must be explicitly represented.
- Similarly, simulations, optimization processes, and other network functions must be explicitly modeled.

  This requires modeling

Such models enable managing NDT **with situational awareness** and is a complement to intelligent network, e.g., O-RAN RIC





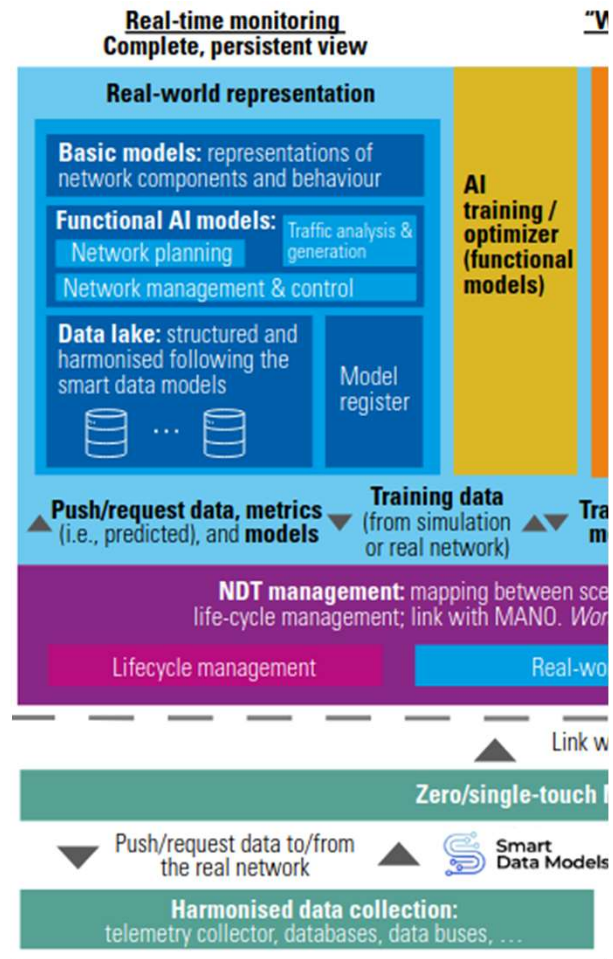


6G-Twin Architecture

https://6g-twin.eu/

Focus on models & data collection

- ITU-IT 309x inspired
- Basic models: assets and network data representation (structural model)
- Functional model: network dynamic aspect, management, predictions
- Data harmonization: at data collection (telemetry); reinforced by data models.

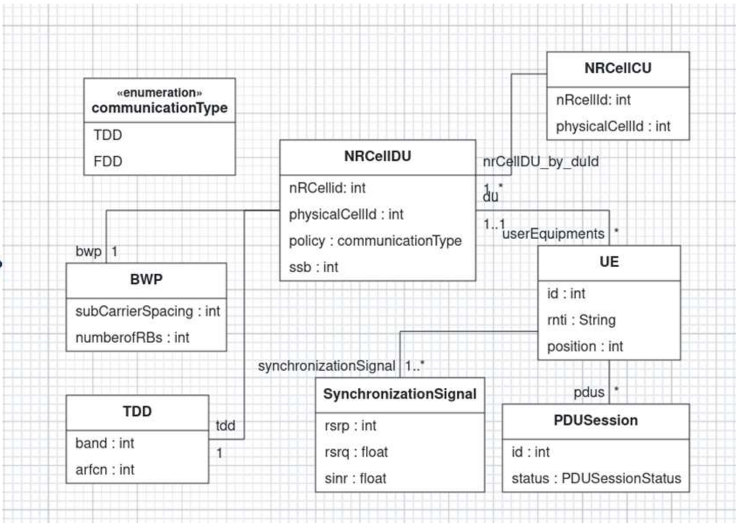


Building a basic model

From standard(s)

Category	Data name (3GPP TS 38.215)	Data description
Synchronization signal (SS)	SS reference signal received power (SS-RSRP) SS reference signal received quality (SS-RSRQ) SS signal-to-noise and interference ratio (SS-SINR) SS reference signal received power per branch (SS-RSRPB) SS reference signal antenna relative phase (SS-RSARP)	Synchronization signal (SS) is used to synchronize UE with a gNB. These signals consist of the Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS).
Channel State Information (CSI)	CSI reference signal received power (CSI-RSRP) CSI reference signal received quality (CSI-RSRQ) CSI signal-to-noise and interference ratio (CSI-SINR)	Channel State Information (CSI) reference signals are transmitted according to TS 38.211 and used by the UE to estimate the channel and report channel quality information (CQI Channel Quality Indicator) to the gNB.
Global navigation satellite system (GNSS)	UE GNSS Timing of Cell Frames for UE positioning for E-UTRA UE GNSS code measurements UE GNSS carrier phase measurements	UE location-related measurements via GNSS.
Wireless Local-Area Network (WLAN)	IEEE 802.11 WLAN RSSI	Received Signal Strength Indicator (RSSI) from IEEE 802.11 WLAN.
Evolved Universal Terrestrial Radio Access (E-UTRA)	Reference signal time difference (RSTD) for E-UTRA System Frame Number (SFN) and frame timing difference (SFTD) E-UTRA RSRP E-UTRA RSRQ E-UTRA RS-SINR	Measearements related to E-UTRA, used by the UE for synchronisation and channel quality estimation.
Sounding Reference Signal (SRS)	SRS reference signal received power (SRS-RSRP)	The SRS transmission occurs periodically on a non-primary set of carriers and at appropriate power levels, such that a gNB can measure the quality of its synchronization to the UE that it is serving.

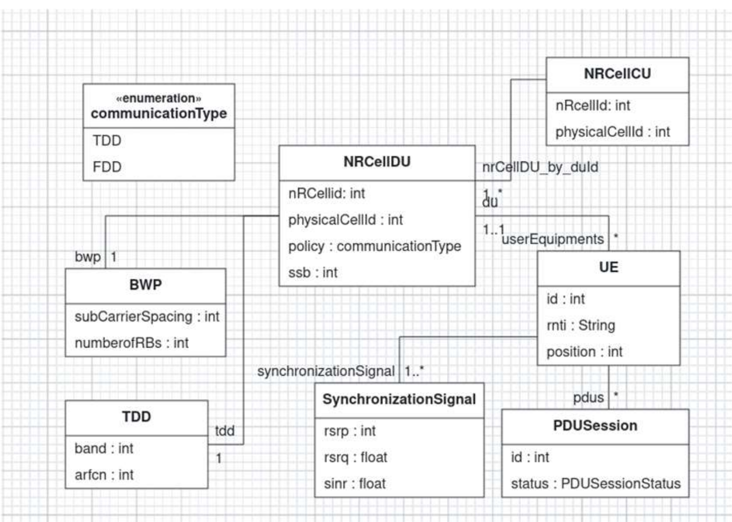
3GPP Standard +
requirements for NDT

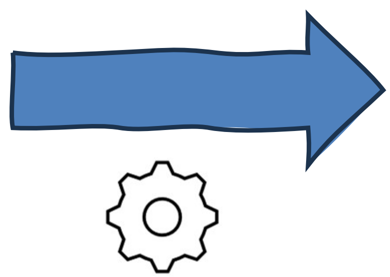


Basic model
UML representation
(excerpt)

Generating common schema

Basic model





BESSER
better software faster

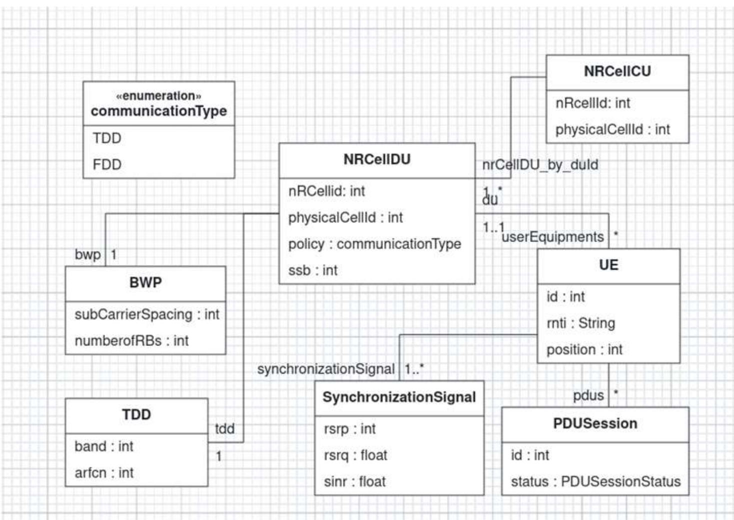
https://besser.readthedocs.io

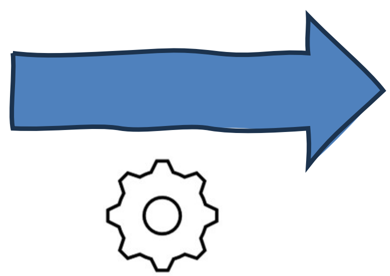

```
},
"id": {
  "type": "string",
  "description": "Property. Model:'https://schema.org/Text'. id valu
},
"position": {
  "type": "string",
  "description": "Property. Model:'https://schema.org/Text'. positio
},
"rnti": {
  "type": "string",
  "description": "Property. Model:'https://schema.org/Text'. rnti va
},
"du": {
  "description": "Relationship. Model:'https://schema.org/URL'. Refe
  "type": "string",
  "format": "uri"
},
"pdus": {
  "type": "array",
  "items": {
    "description": "Relationship. Model:'https://schema.org/URL'. Re
    "type": "string",
    "format": "uri"
  }
},
"synchronizationSignal": {
  "type": "array",
  "items": {
    "description": "Relationship. Model:'https://schema.org/URL'. Re
```


NSGI-LD (here in Json-LD)
specification for harmonization

Generating operational representation

Basic model





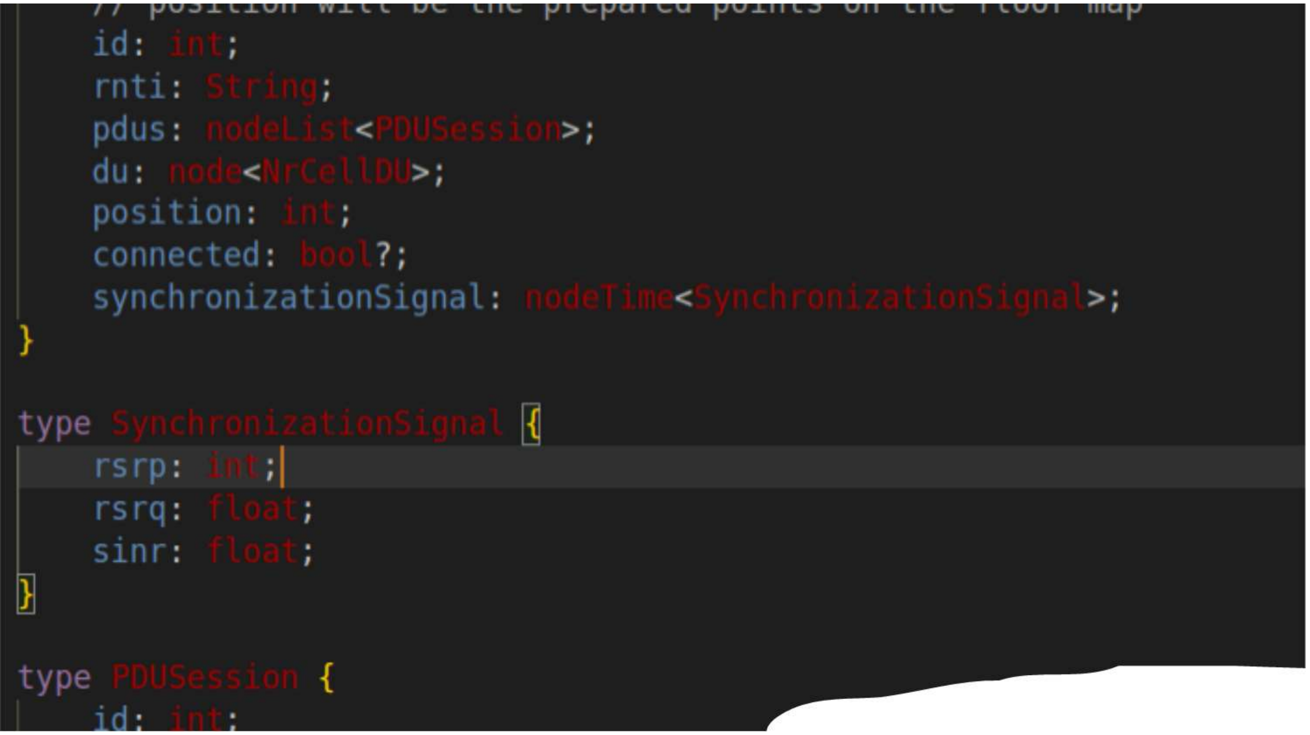
```
type UE {
    // position will be the prepared points on the floor map
    id: int;
    rnti: String;
    pdus: nodeList<PDUSession>;
    du: node<NrCellDU>;
    position: int;
    connected: bool?;
    synchronizationSignal: nodeTime<SynchronizationSignal>;
}

type SynchronizationSignal {
    rsrp: int;
    rsrq: float;
    sinr: float;
}

type PDUSession {
    id: int;
    status: PDUSessionStatus;
}

enum PDUSessionStatus {
    ESTABLISHED("established");
```

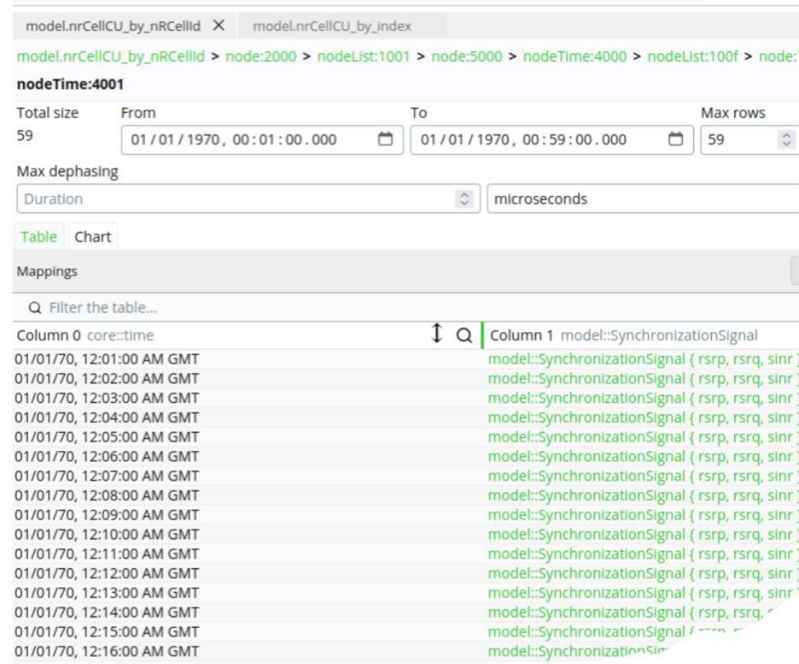
Operational Digital Twin basic model

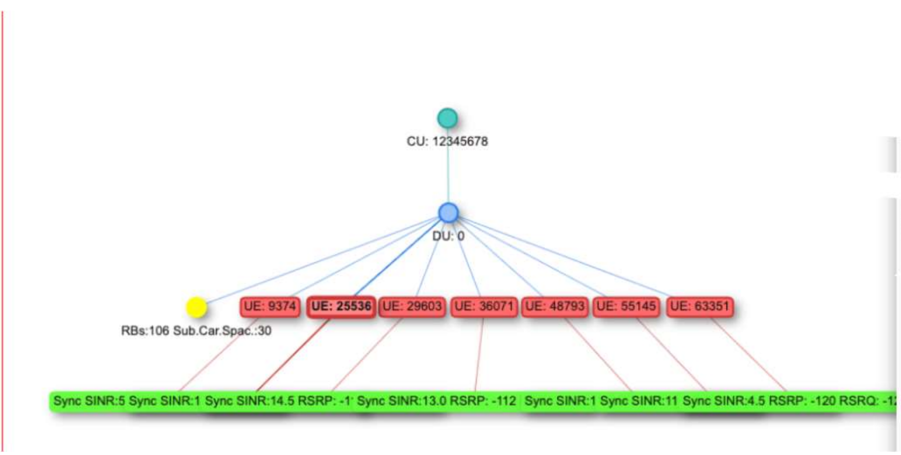
BESSER better software faster

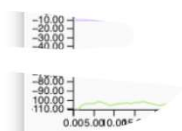
https://besser.readthedocs.io

Powered by GREYCAT





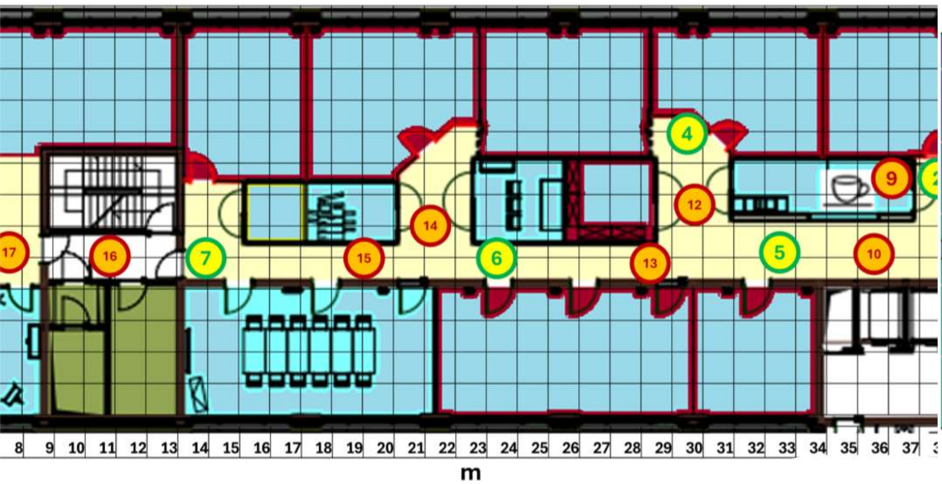


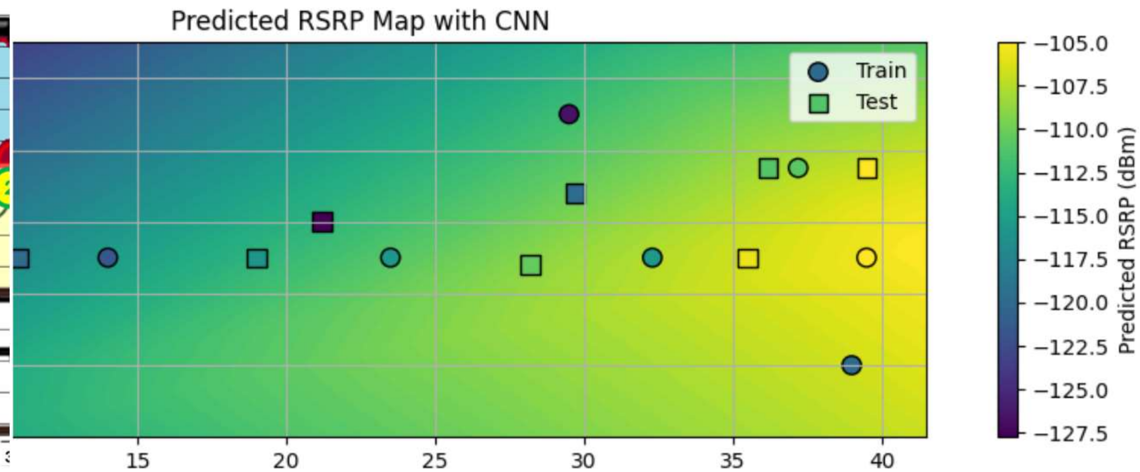


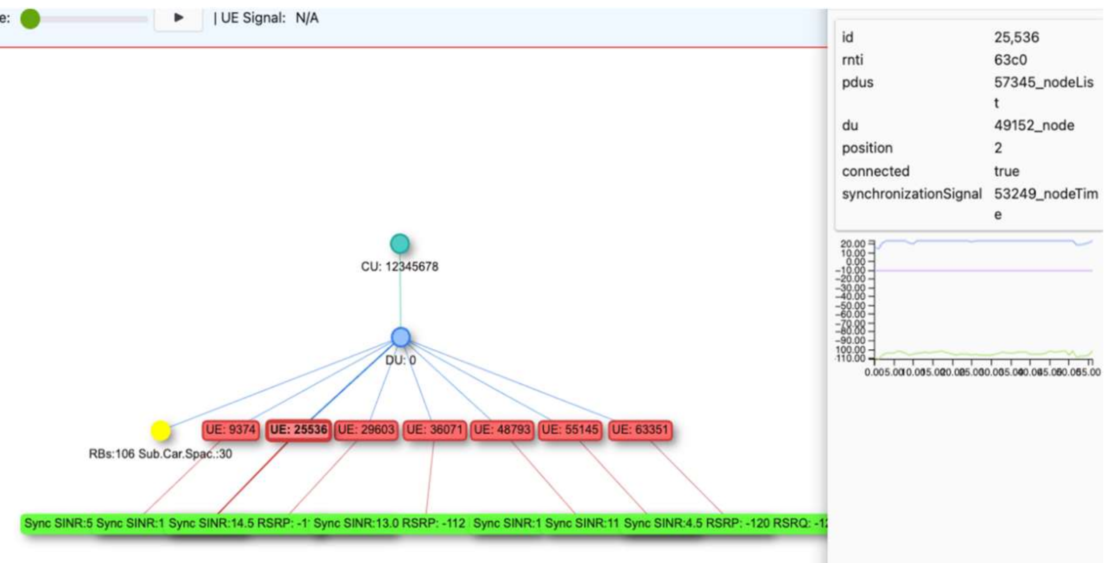
Implementation

Proof of Concept

Powered by GREYCAT





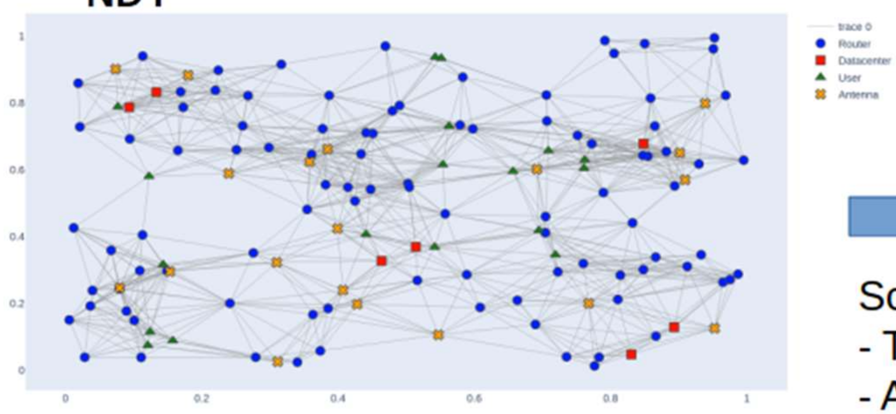


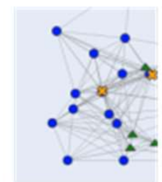
Functional model: prediction

Proof of Concept

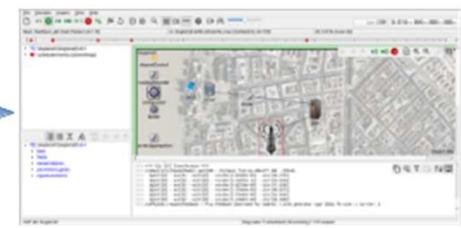
Connecting to simulation

NDT





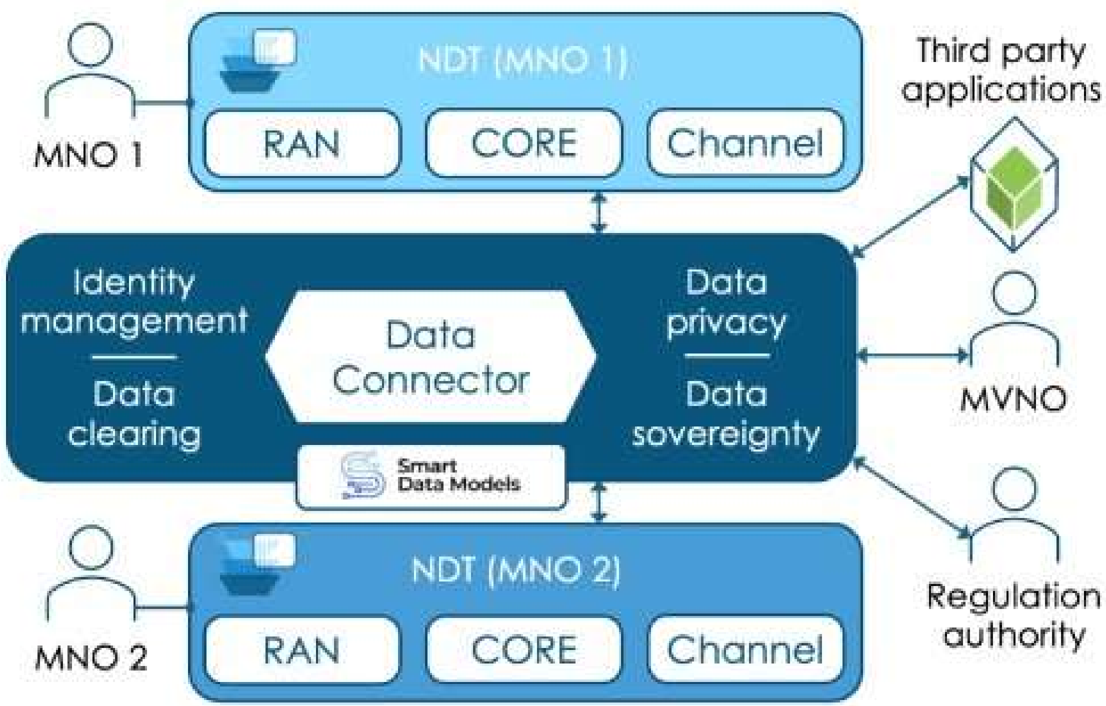
Simulation environment



Scaling :
- Time t,
- Area x,y
- simulation scenario

(Near) Real-time large-scale monitoring

Offline small to medium scale Simulation



Inter-Network data exchange and harmonization (See the poster session)

Security Threats and opportunities

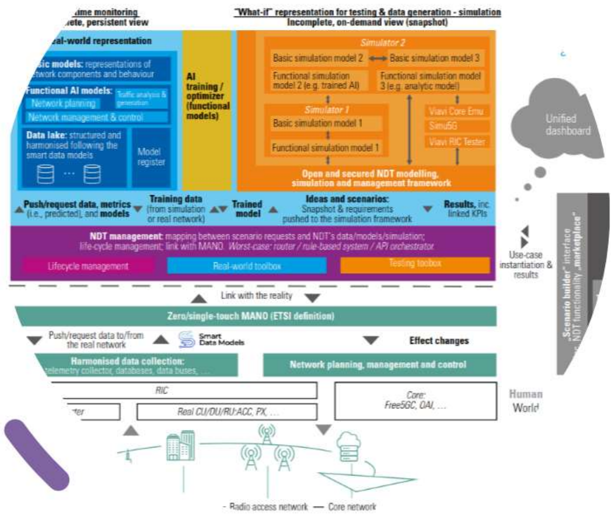
- Centralising information in NDT is a potential huge risk!
  - It could be a single attack point to get access to everything in the network...

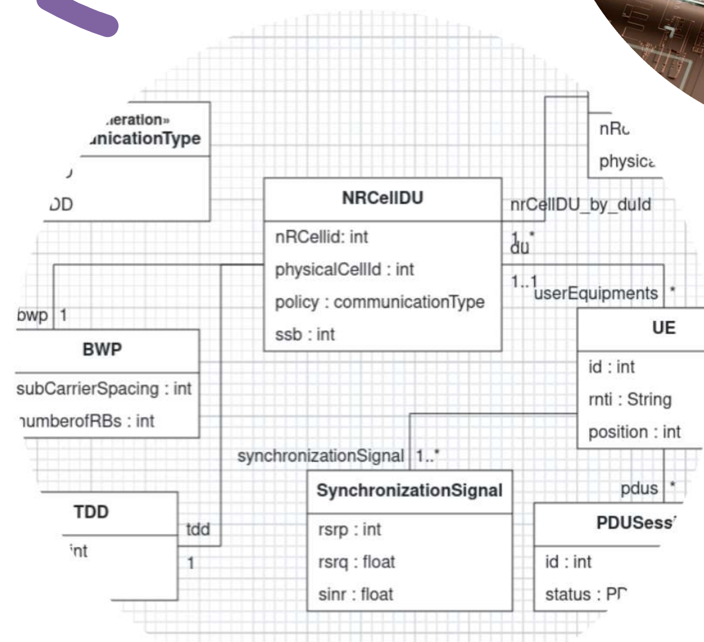
Security Threats and opportunities

- Need to secure data transfer
  - Data trust, validation, provenance, privacy preservation,
  - Separation of real time vs historical
- Need to secure feedback-loop
  - The NDT should not become the network controller (limiting the radius of action)
- Provide human-approved for impacting decision
  - Validating any decision proposed by the NDT

Conclusion

- **NDT architecture** – *Complementing* Smart Network (e.g., ORAN) - inspired by ITU-T 309x specifications
- **Standard format for data** harmonization and exchange expressed in ETSI **NSGI-LD** information model (ETSI GS CIM)
- Operational DT prototype implementation:
  - Systematic modelling : basic model derived from standard
  - Supported by an E.U. solution (Greycat)
  - Pending integration of functional models and simulators
- **Security is a major concern** due to the comprehensive nature of NDT and its potential impact on the real network.





Additional slides for (eventual) questions

Secure the Data Pipeline

- Cryptographic authentication of all telemetry sources (mTLS, signed streaming)
- Strong provenance tracking (who/what/when produced data)
- Data validation & sanity checks (range, rate, topology consistency)
- Separation of real-time vs historical ingestion paths
- Immutable raw data storage (append-only logs)

Secure the functional models

- Sandboxed execution environments (VMs, enclaves)
- Resource caps (CPU, memory, time)
- Explainability hooks for optimization outputs
- Detection of adversarial input patterns
- Explicit failure modes (no silent fallback)

Governance & Process

- Clear ownership of model correctness
- Formal validation before using twin outputs operationally
- Separation of duties: Model builders ≠ operators ≠ approvers
- Documented failure modes and “safe shutdown” paths
- Legal & compliance review (data retention, cross-border data)