5G positioning for applications
- opportunities and challenges

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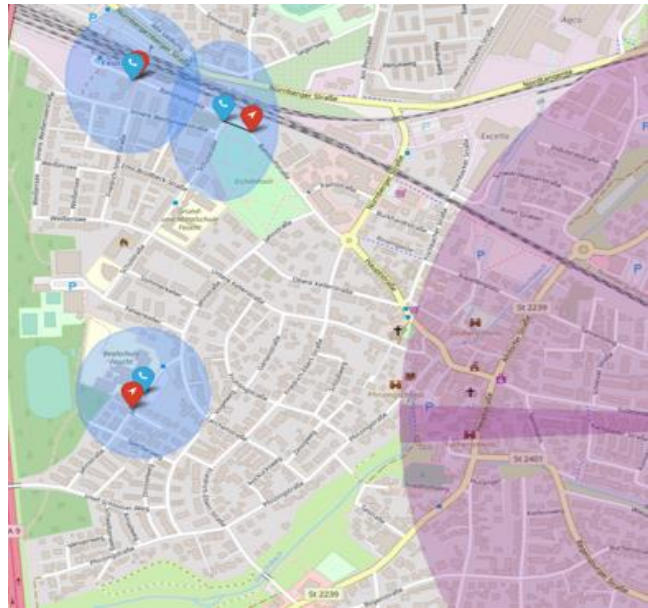
Outline

- Example use cases and fundamentals
- Requirements
- Standardized signals, measurements, procedures, representations
- Capabilities and sensing
- Algorithms and deployments
- Application integration
- An application example

Example use cases and fundamentals

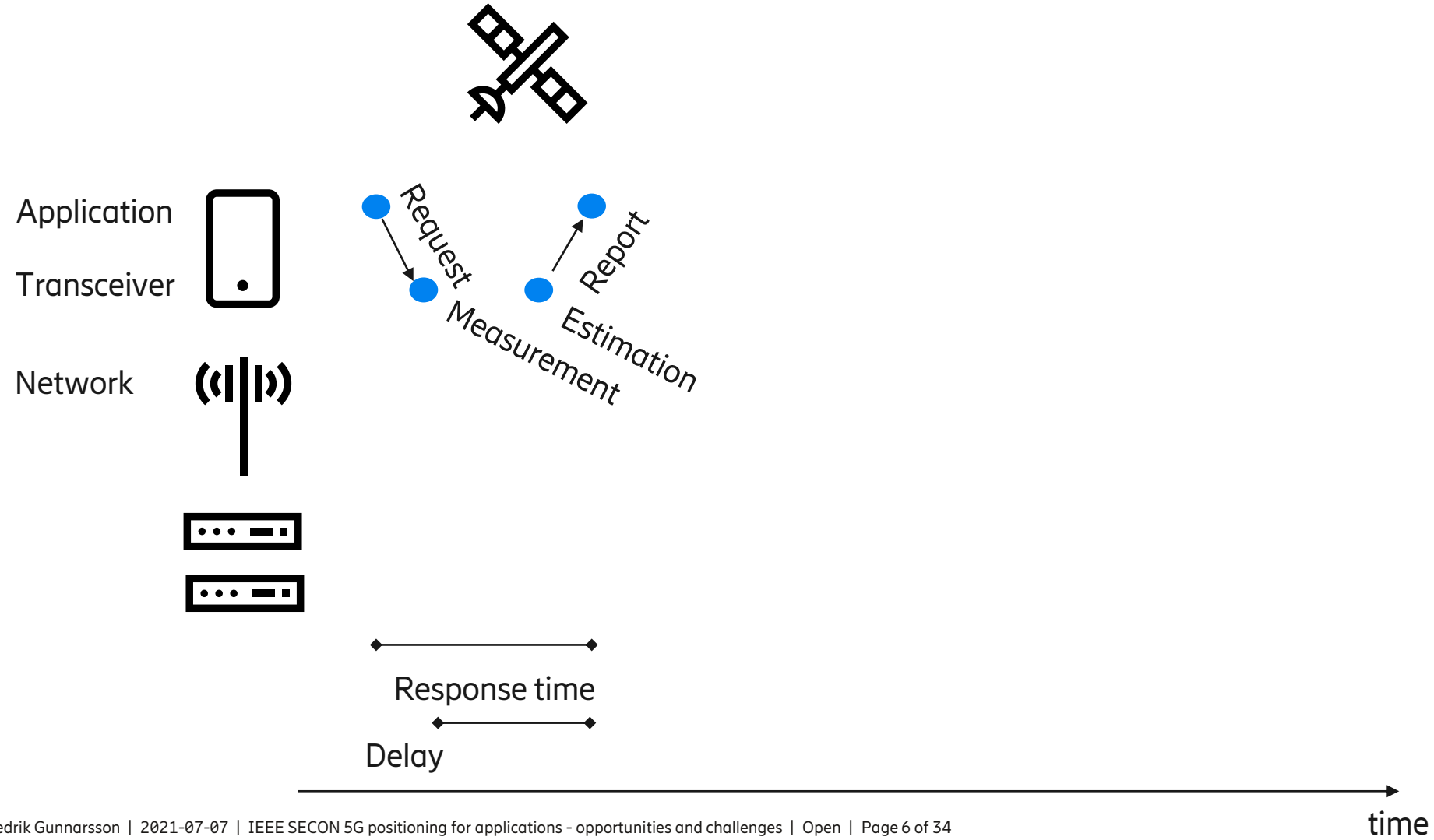
Location is everywhere



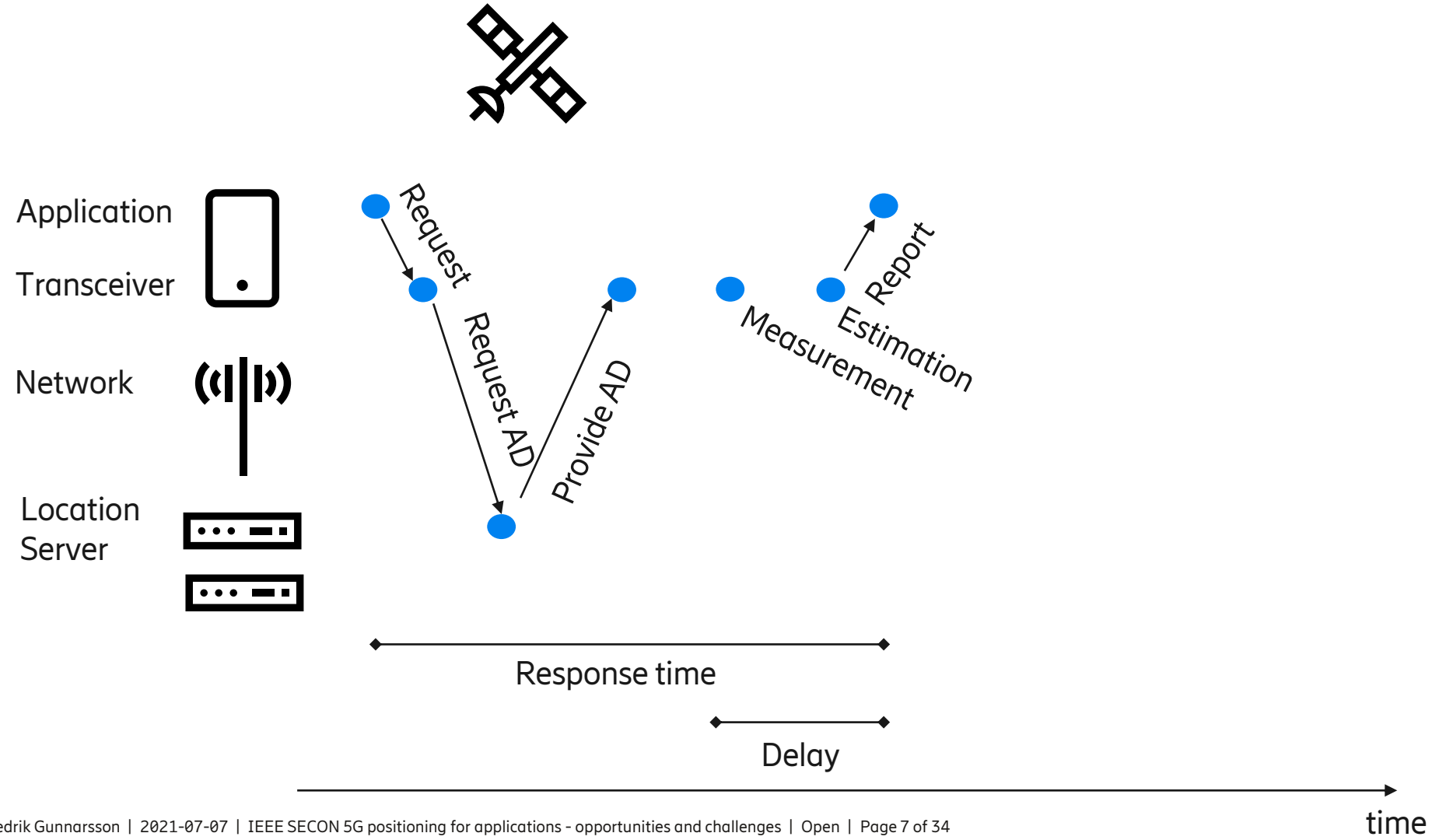
Selected glossary

- RAT-dependent – based on 3GPP radio access technologies
- RAT-independent – based on other enablers such as satellite navigation, sensors etc
- UE-based – device is estimating the position with network assistance
- UE-assisted – network is estimating the position
- Consumer – entity benefitting from the position estimate

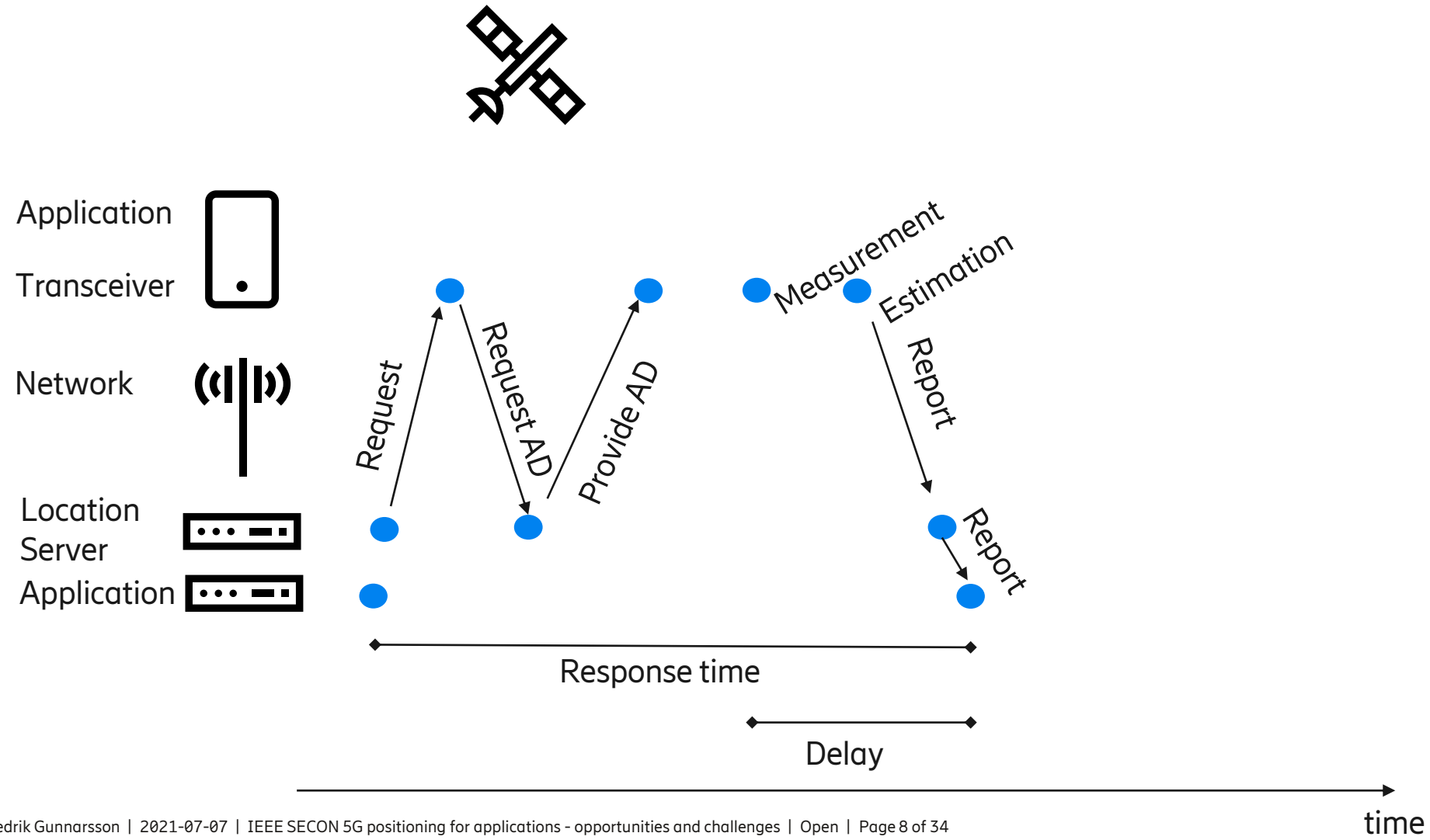
Latency basics
- Within the device



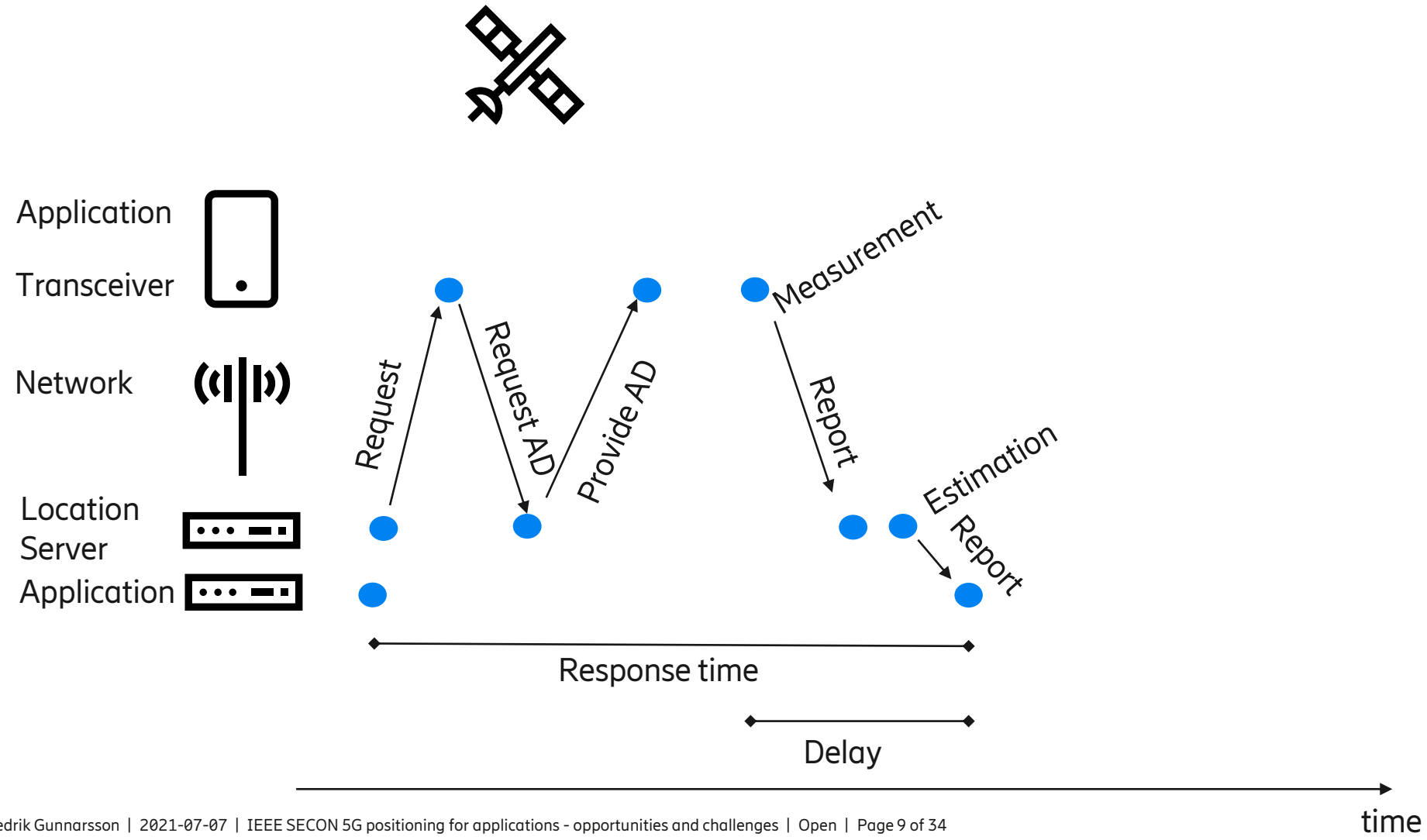
Latency basics
- Within the device with network assistance



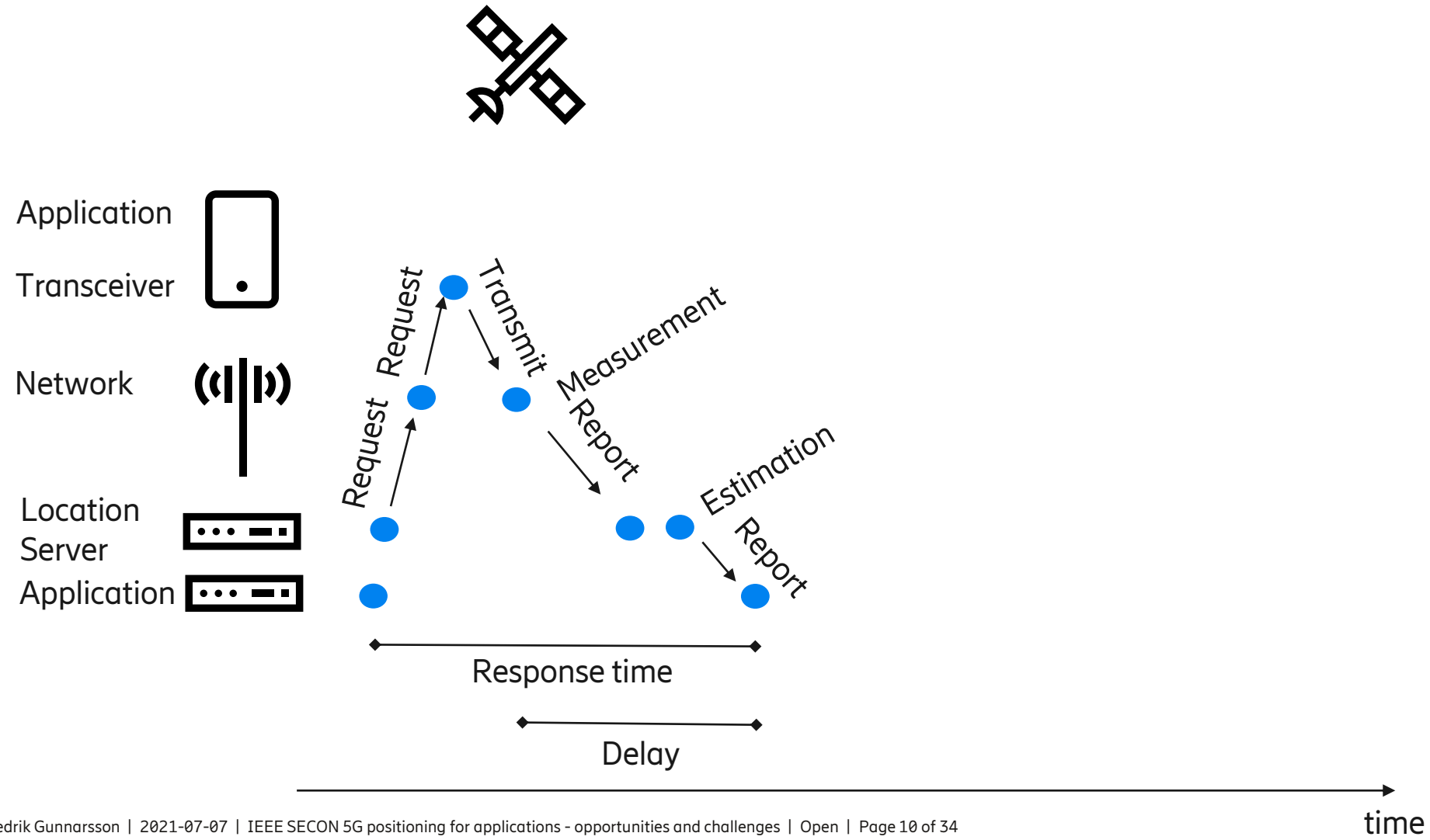
Latency basics
- From the network with assistance, UE-based



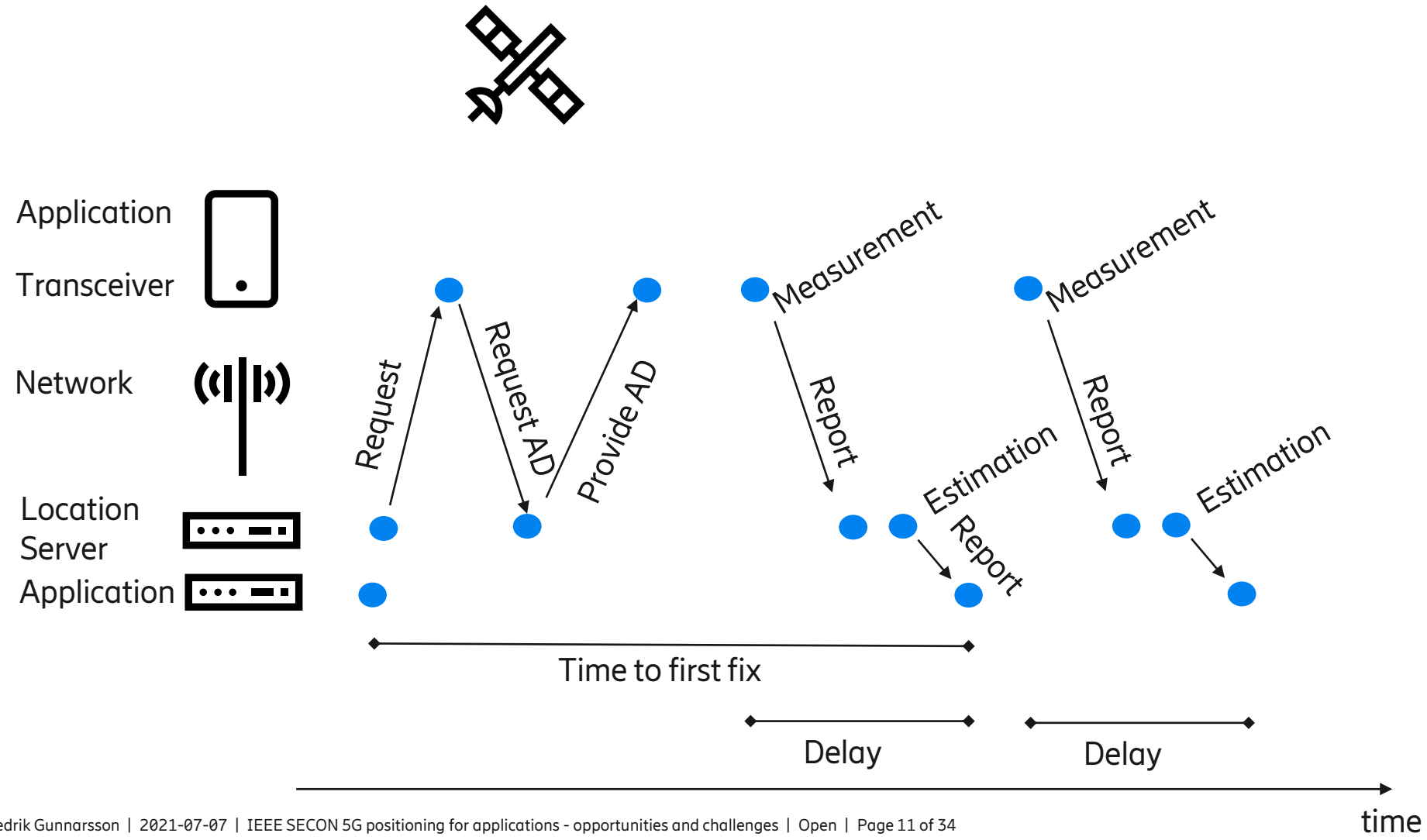
Latency basics
- From the network with assistance, UE-assisted



Latency basics
- From the network with assistance, UE transmission

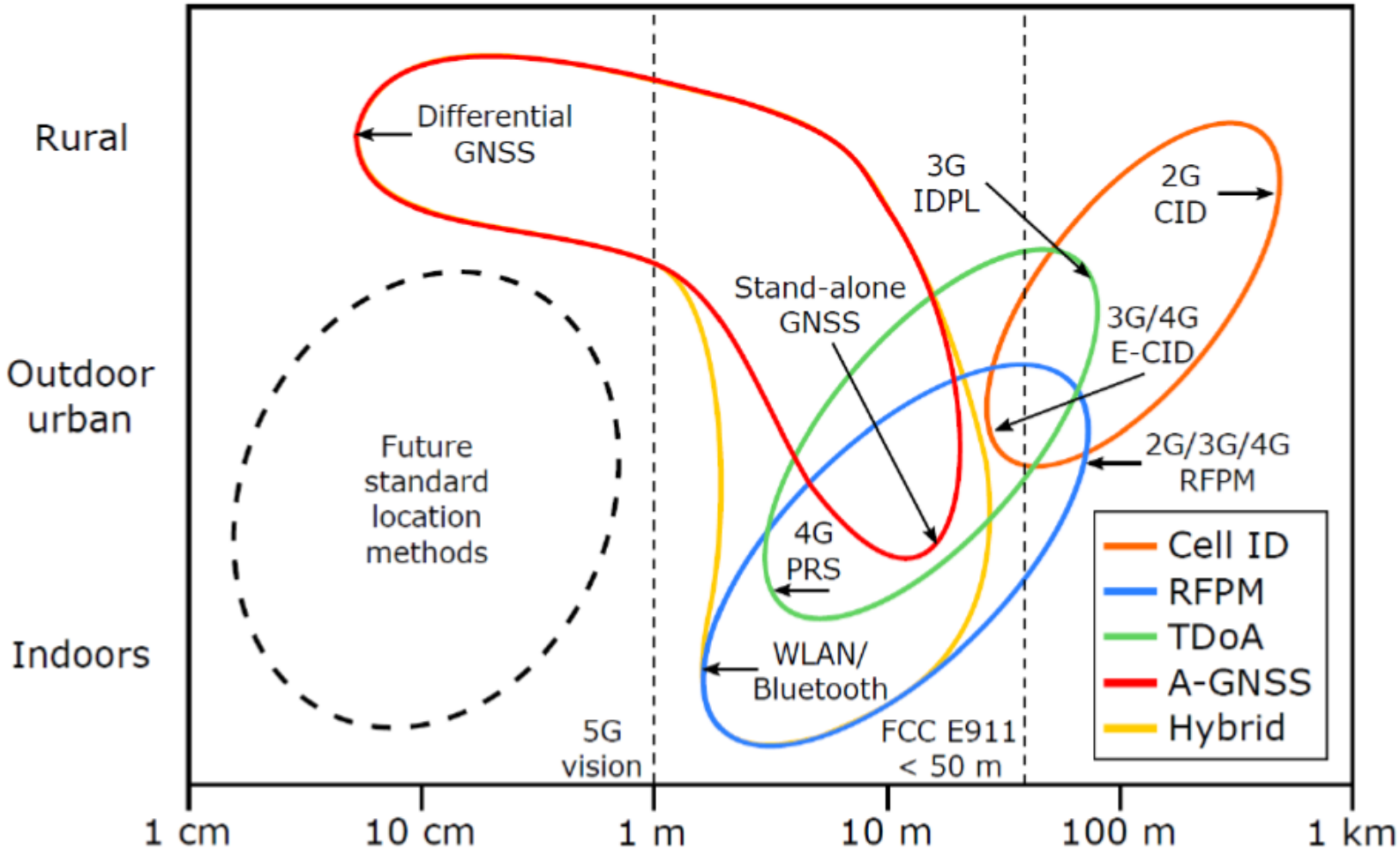


Latency basics
- From the network with assistance, UE-assisted



Requirements

5G Positioning Expectancies



J.A. del Peral-Rosado, R. Raulefs, J.A. López-Salcedo, and G. Seco-Granados, "Survey of cellular mobile radio localization methods: from1G to 5G,"*IEEE Communications Surveys & Tutorials,* vol. 20, no. 2, pp. 1124–1148, 2018.

High Accuracy Positioning

Cyber-physical control applications in vertical domains, 3GPP TS 22.104

Scenario	Horizontal accuracy	Availability	Heading	Latency for position estimation of UE	UE Mobility	Corresponding Positioning Service Level in TS 22.261
Mobile control panels with safety functions (non-danger zones)	< 5 m	90%	N/A	< 5 s	N/A	Service Level 2
Process automation – plant asset management	< 1 m	90%	N/A	< 2 s	< 30 km/h	Service Level 3
Flexible, modular assembly area in smart factories (for tracking of tools at the work-place location)	< 1m (relative positioning)	99%	N/A	1 s	< 30km/h	Service Level 3
Augmented reality in smart factories	< 1 m	99%	< 0,17 rad	< 15 ms	< 10 km/h	Service Level 4
Mobile control panels with safety functions in smart factories (within factory danger zones)	< 1 m	99.9%	< 0,54 rad	< 1 s	N/A	Service Level 4
Flexible, modular assembly area in smart factories (for autonomous vehicles, only for monitoring proposes)	< 50 cm	99%	N/A	1 s	< 30 km/h	Service Level 5
Inbound logistics for manufacturing (for driving trajectories (if supported by further sensors like camera, GNSS, IMU) of autonomous driving systems))	< 30 cm (if supported by further sensors like camera, GNSS, IMU)	99.9%	N/A	10 ms	< 30 km/h	Service Level 6
Inbound logistics for manufacturing (for storage of goods)	< 20 cm	99%	N/A	< 1 s	< 30 km/h	Service Level 7

3GPP 5G NR positioning requirements

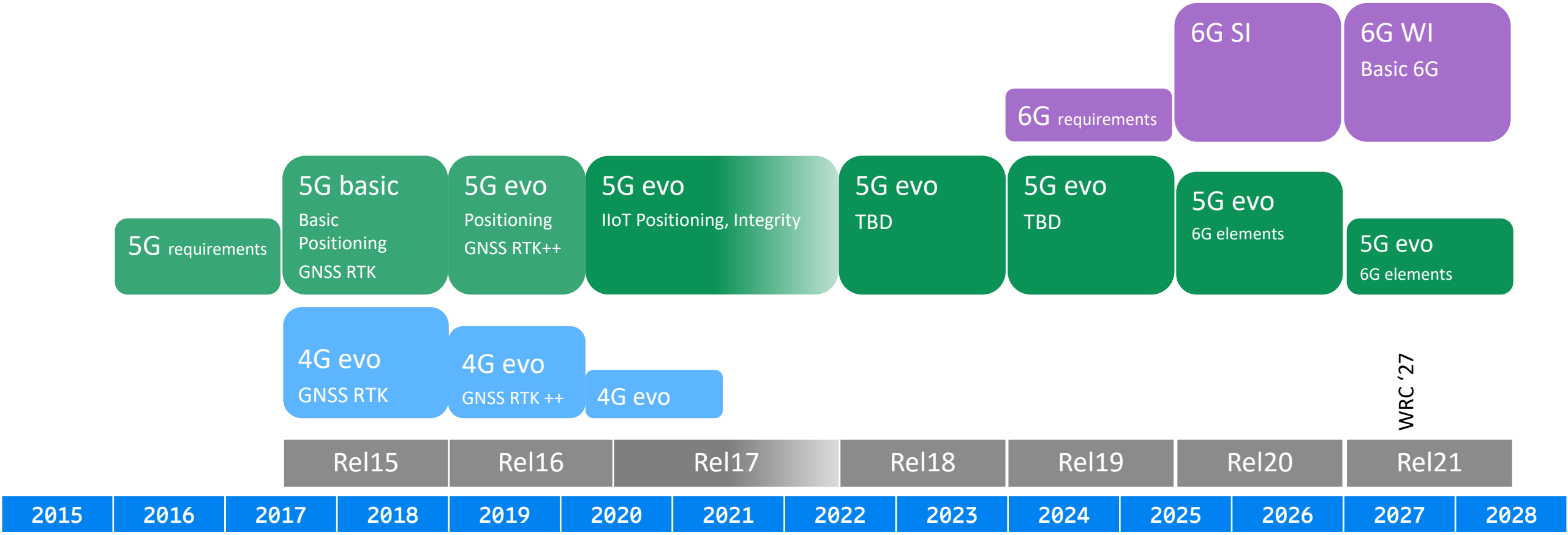
- Rel. 15
  - meet regulatory reguirements (LTE signals)
  - distribute GNSS corrections for precise positioning

- Rel 16
  - meet regulatory requirements (NR signals)
  - Meet commercial requirements, 3m horizontal accuracy
  - Distribute GNSS corrections for precise positioning, phase II

- Rel 17
  - general commercial use cases , sub-meter level position accuracy (< 1 m)
  - IIoT use cases, position accuracy < 0.2 m
  - target latency requirement < 100 ms; for some IIoT use cases, latency ~10 ms is desired.
  - Positioning integrity

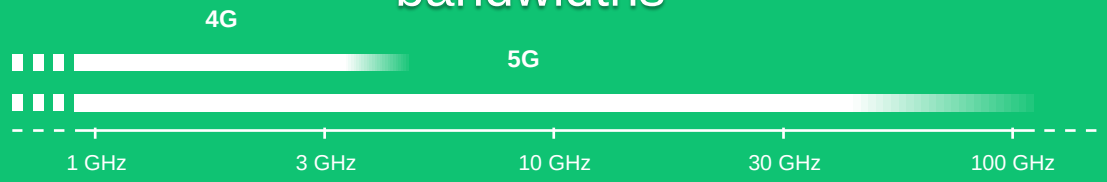
3GPP 5G standardization
- signals, measurements, procedures, representation

3GPP LTE and NR positioning timeline



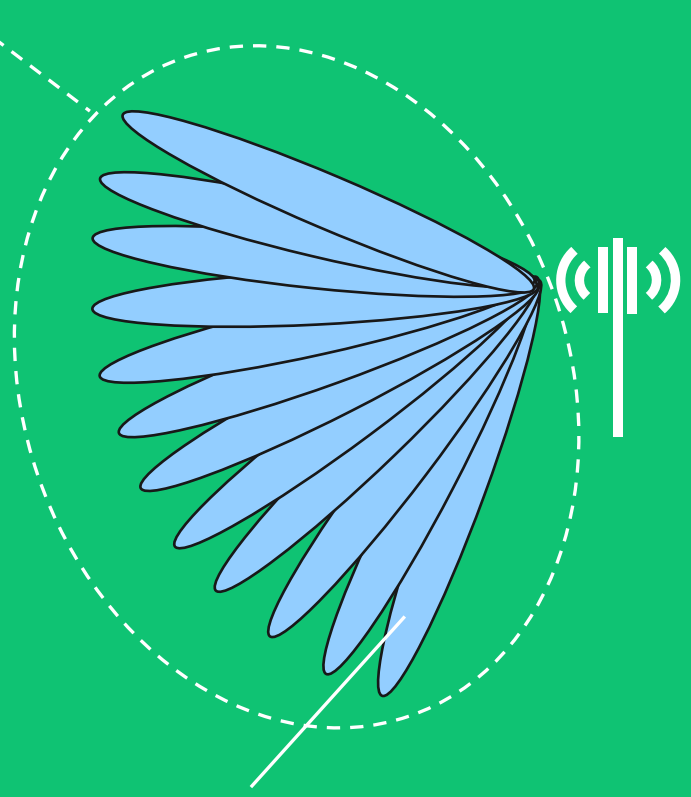
3GPP 5G positioning toolbox

Extension to higher frequencies & wider bandwidths



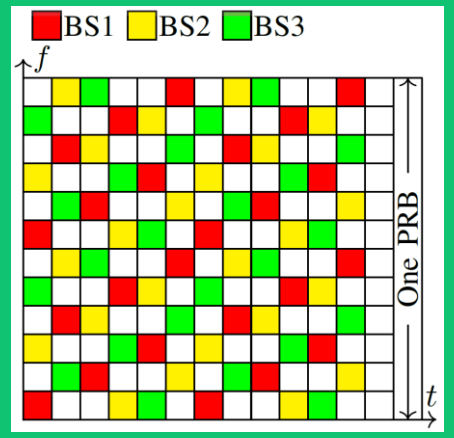
Multiple antennas and advanced beamforming

DL PRS Resource Set

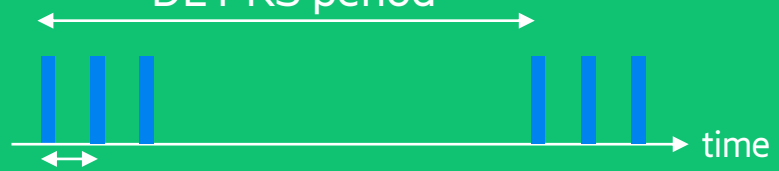


DL PRS Resource

DL/UL signals designed for accurate measurements and low latency



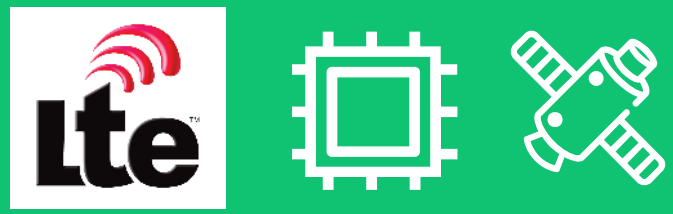
DL PRS period



DL PRS repetition gap

Flexible Network Architecture

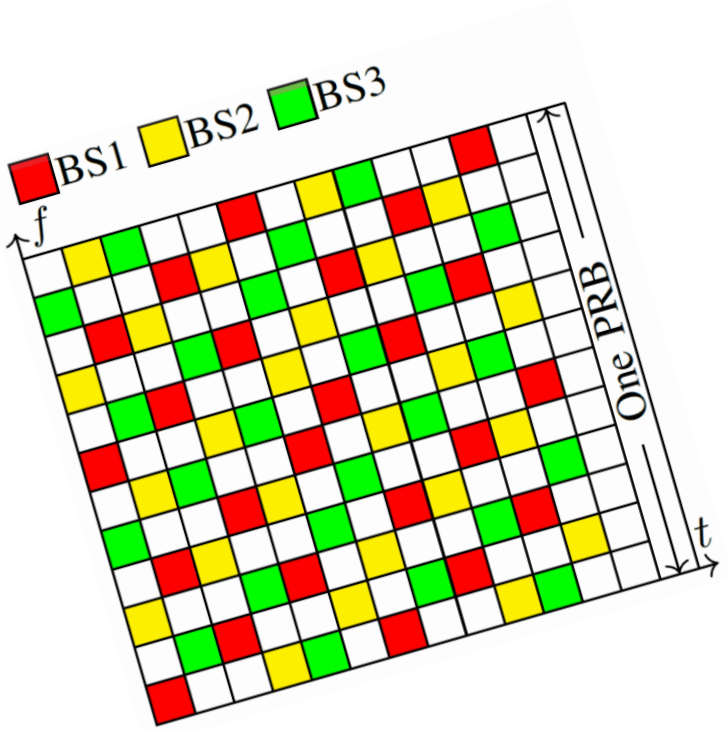
Hybridization and hardware



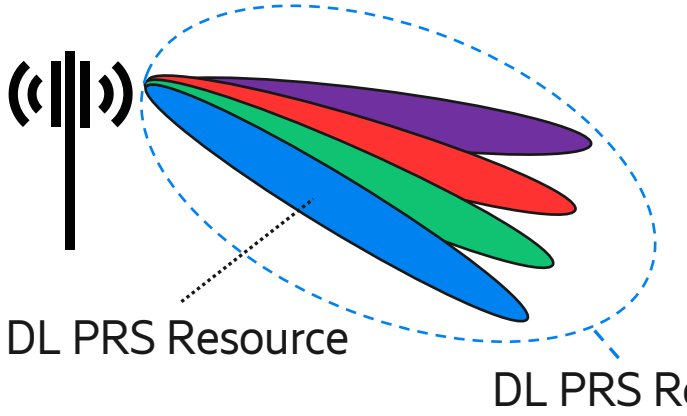
DL PRS

DL Positioning Reference Signal, 3GPP Rel 16

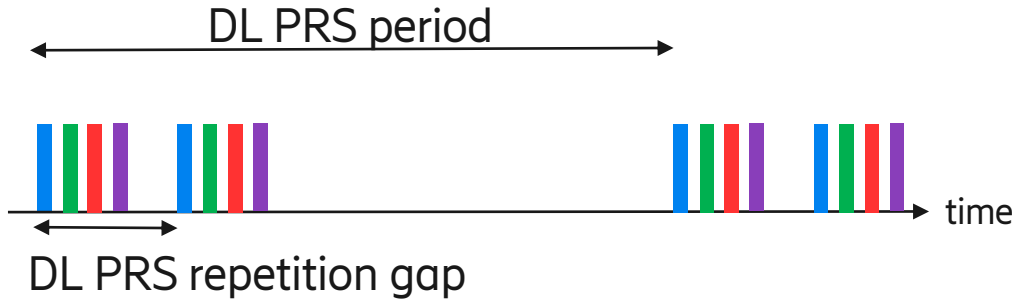
- Comb-N pattern with N = 2, 4, 8 or 12
- Bandwidth of 24 to 276 physical resource blocks
  - Max 100MHz in FR1 and max 400MHz in FR2
- Enables good orthogonalization
- Short transmissions to enable beam sweeping

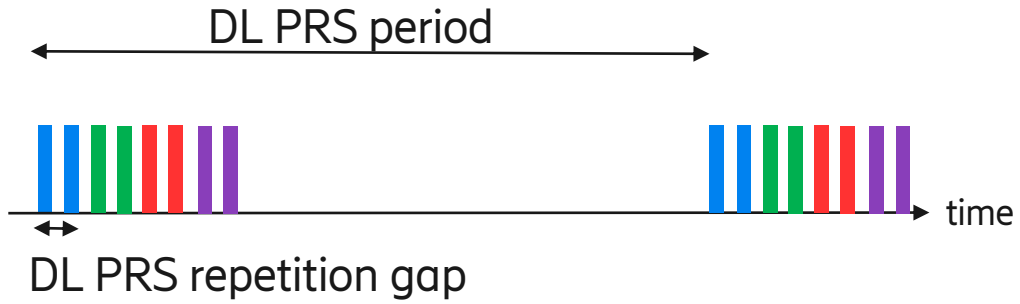


Beamsweeping



- DL PRS resource sets can be configured either to
  - sweep and repeat
- or
  - repeat and sweep





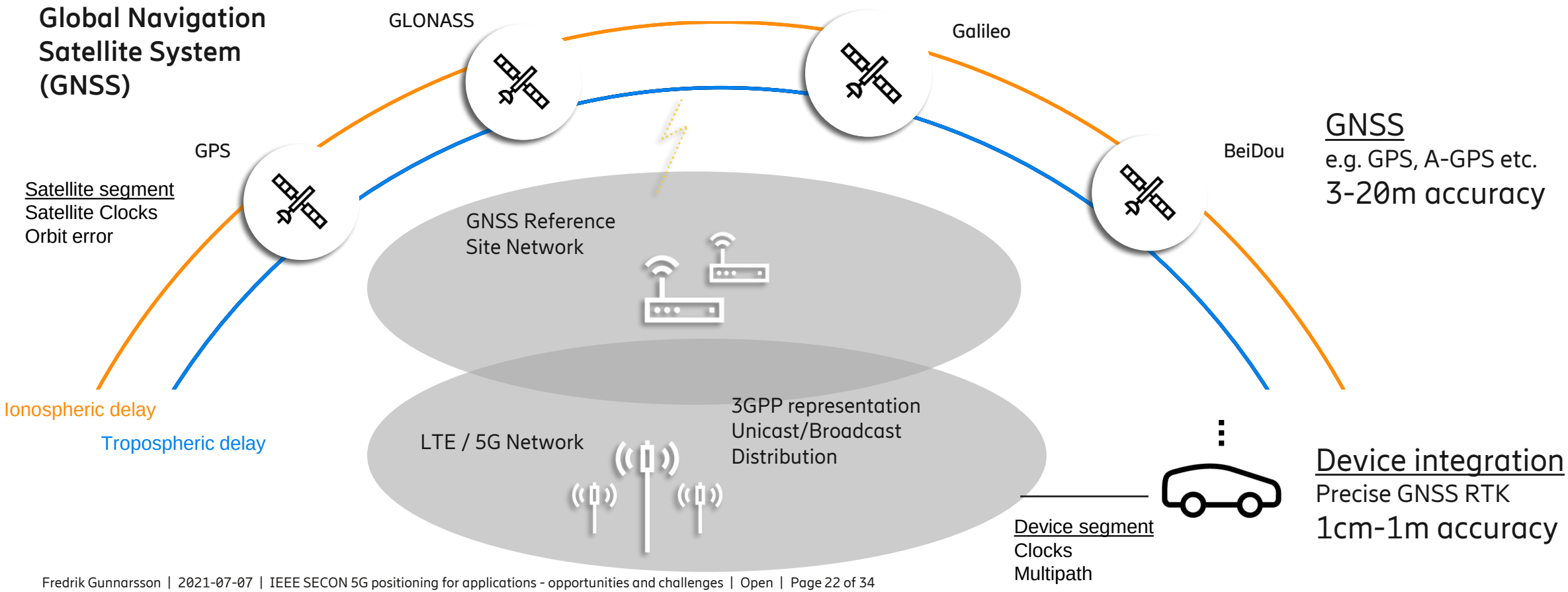
Measurements (RAT dependent)

The following fundamental measurements are enabled for 5G positioning

- UE measurements
  - DL PRS time of arrival
  - DL PRS received signal strength (also for other reference signals)
- Network measurements
  - UL SRS time of arrival
  - UL SRS received signal strength
  - UL Angle of arrival

High precision GNSS with network assistance

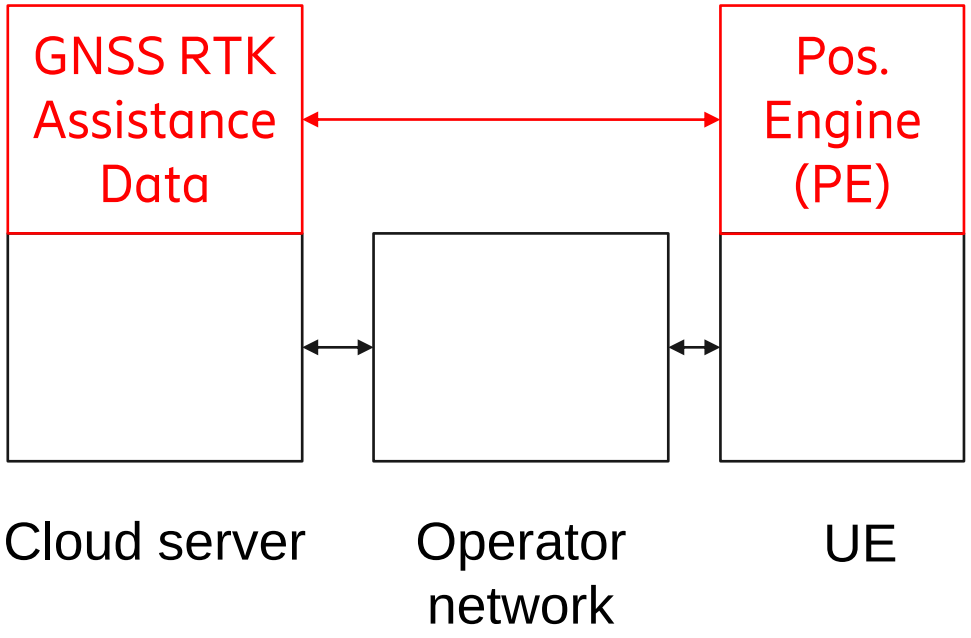
Global navigation satellite systems (GNSS) errors can be compensated for based on data from a reference network, distributed via cellular



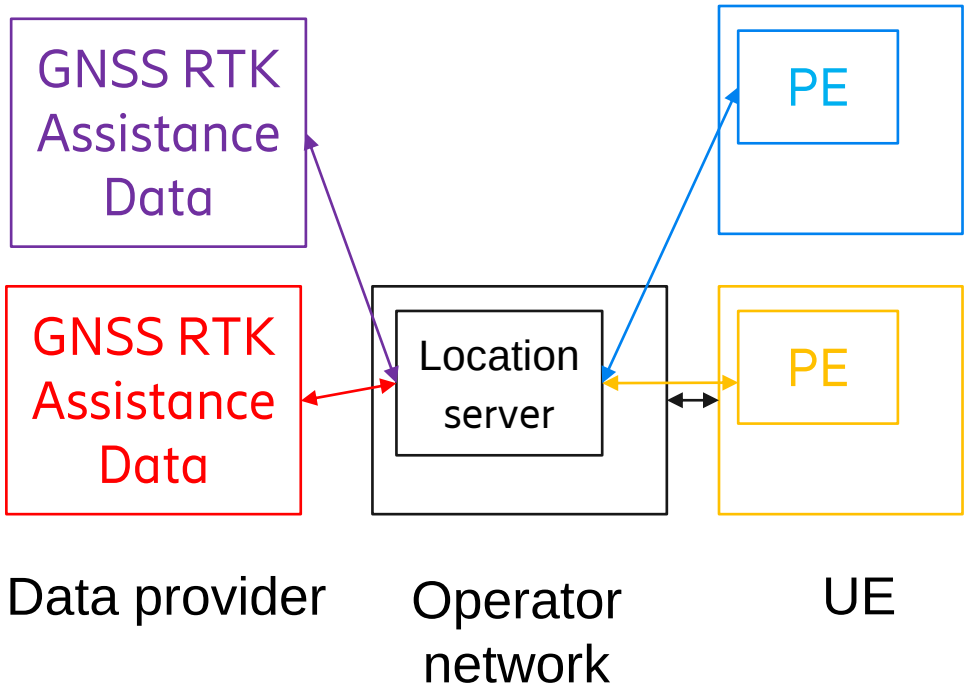
Over the top vs 3GPP

Open interfaces enable competition and replaceability

Proprietary silo solution



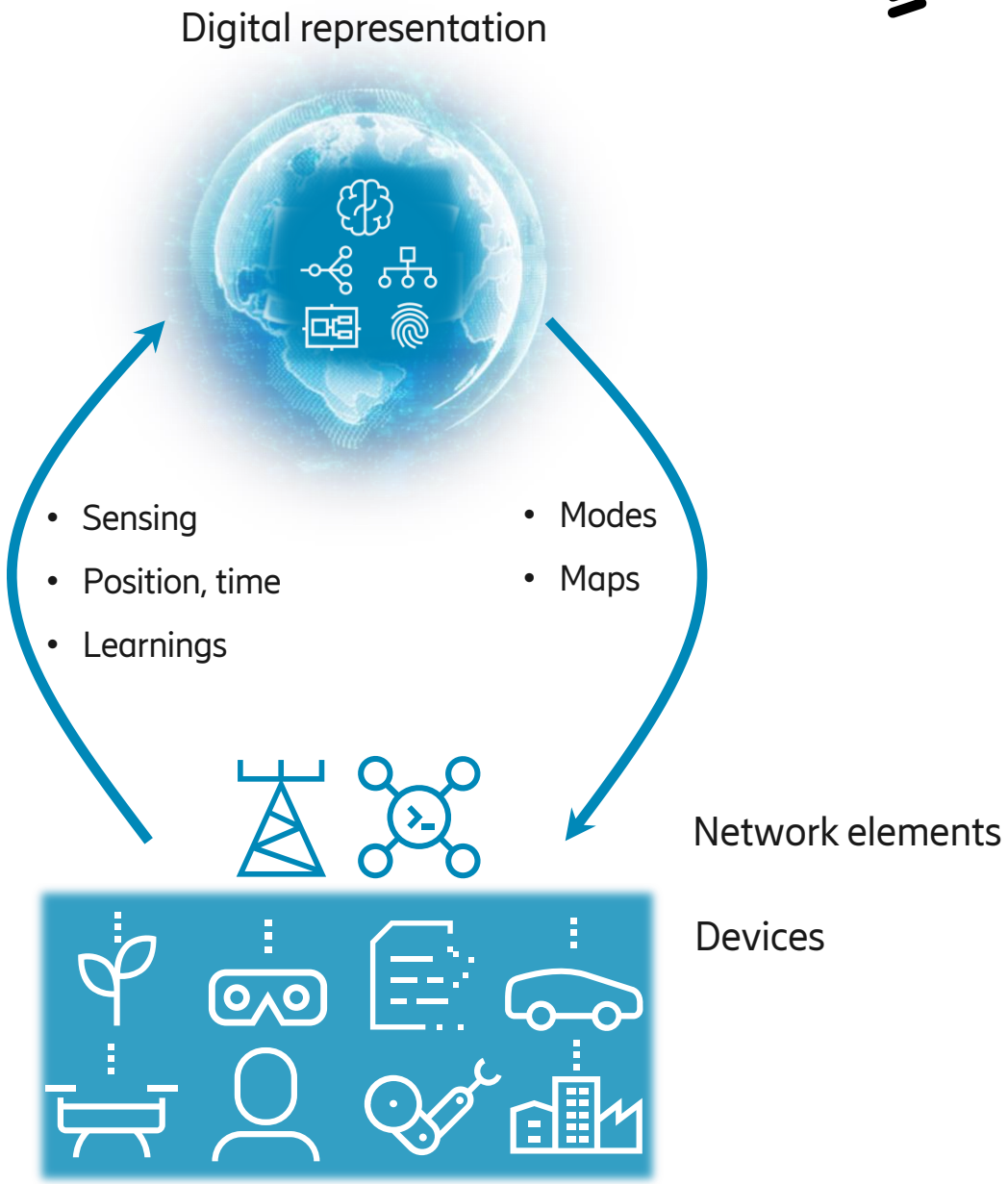
Open and interoperable solution



Capabilities and sensing

Device and network capabilities

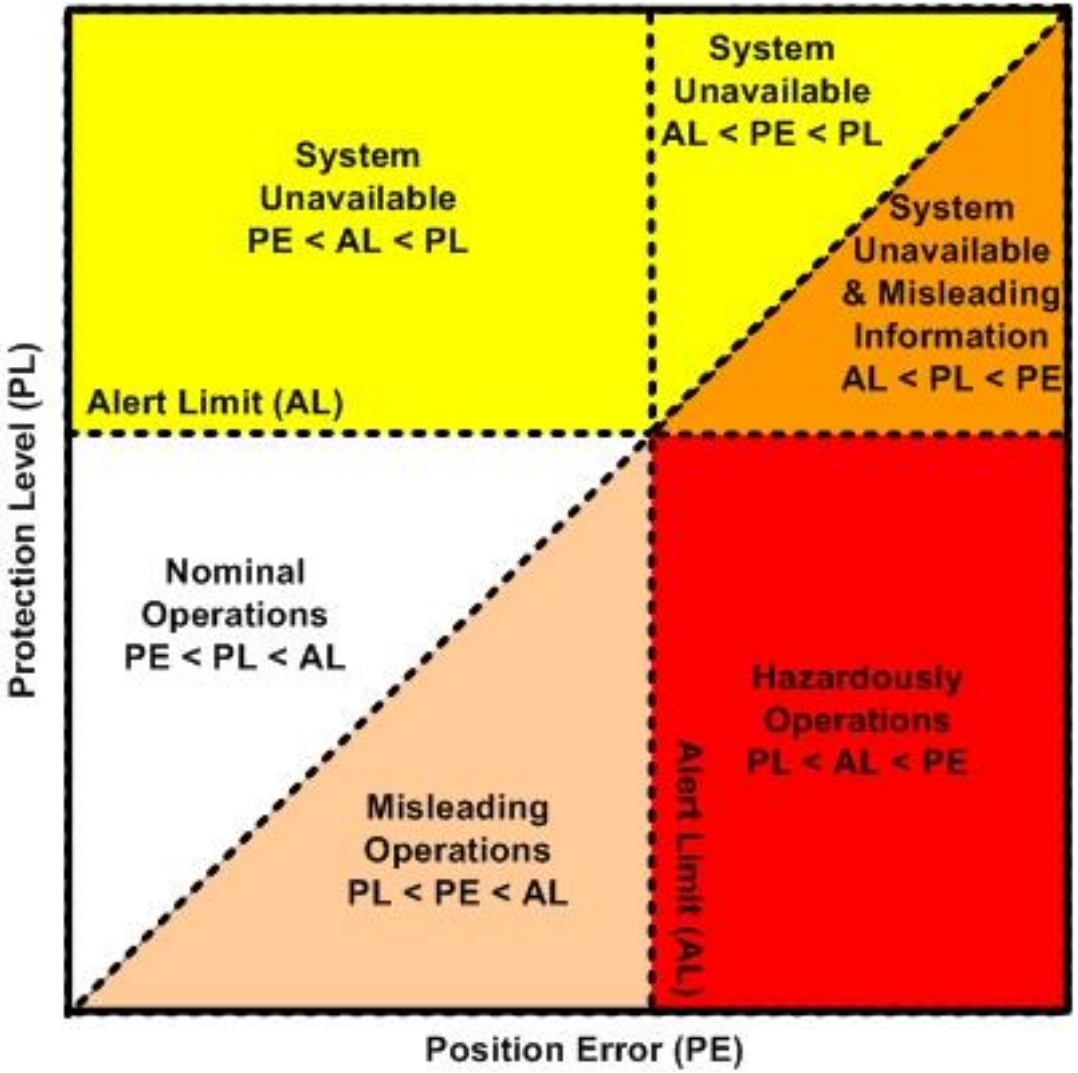
- What is supported from the 5G toolbox?
- What other sensors are integrated?
- What HD maps are available and maintained?
- What performance part is due to 5G radio?



Algorithms and deployments

Algorithms

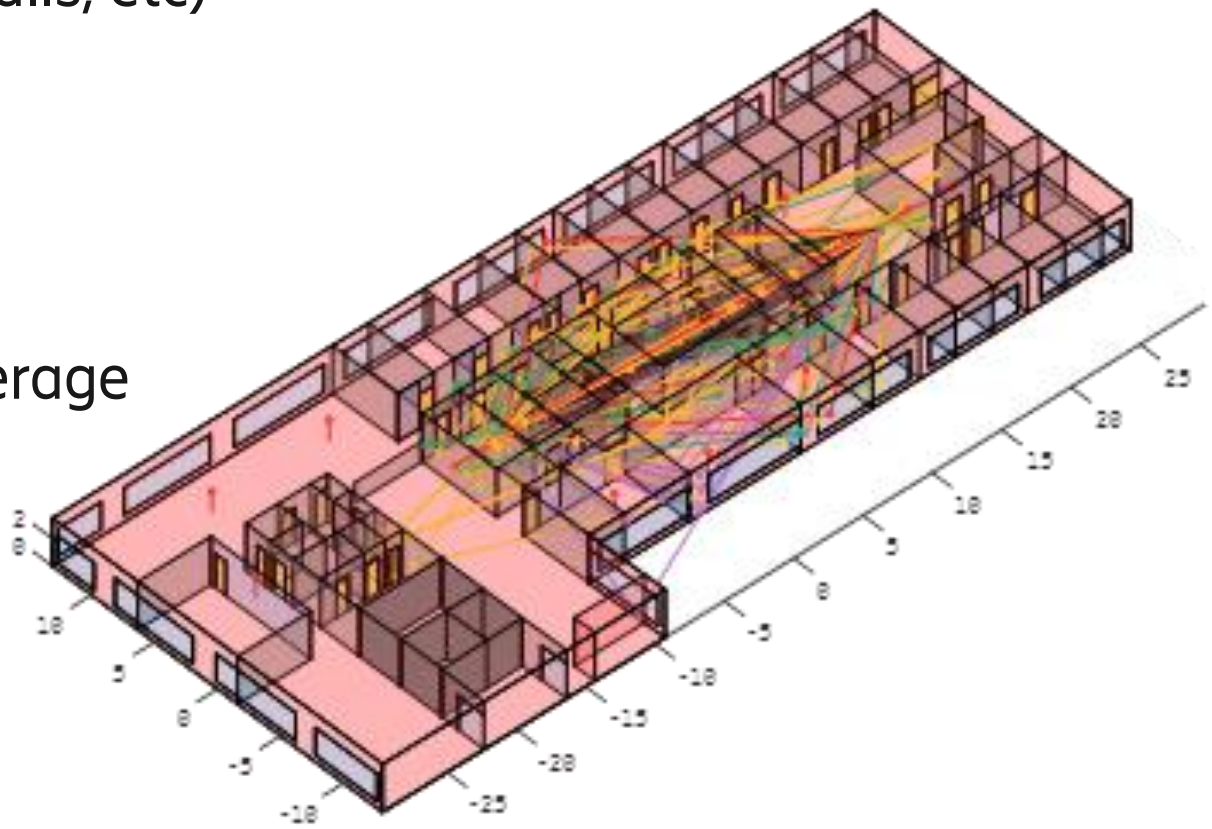
- 5G standardization only provides signals, measurements, procedures and representation – large implementation freedom
- Algorithms need to exploit available information and relate to what is required from the application
- Algorithms based on AI/learning needs annotaded data
- In general – covariance estimation and associated precision important
- Rel 17 also supports GNSS integrity – ability to assess positioning reliability



Deployment Design Challenges

Positioning performance will critically depend on deployment design

- Site density and placements (ceilings, walls, etc)
- Inventory information accuracy
- Carrier bandwidth and frequency range
- Network synchronization
- Hybrid positioning for wider service coverage



Application integration

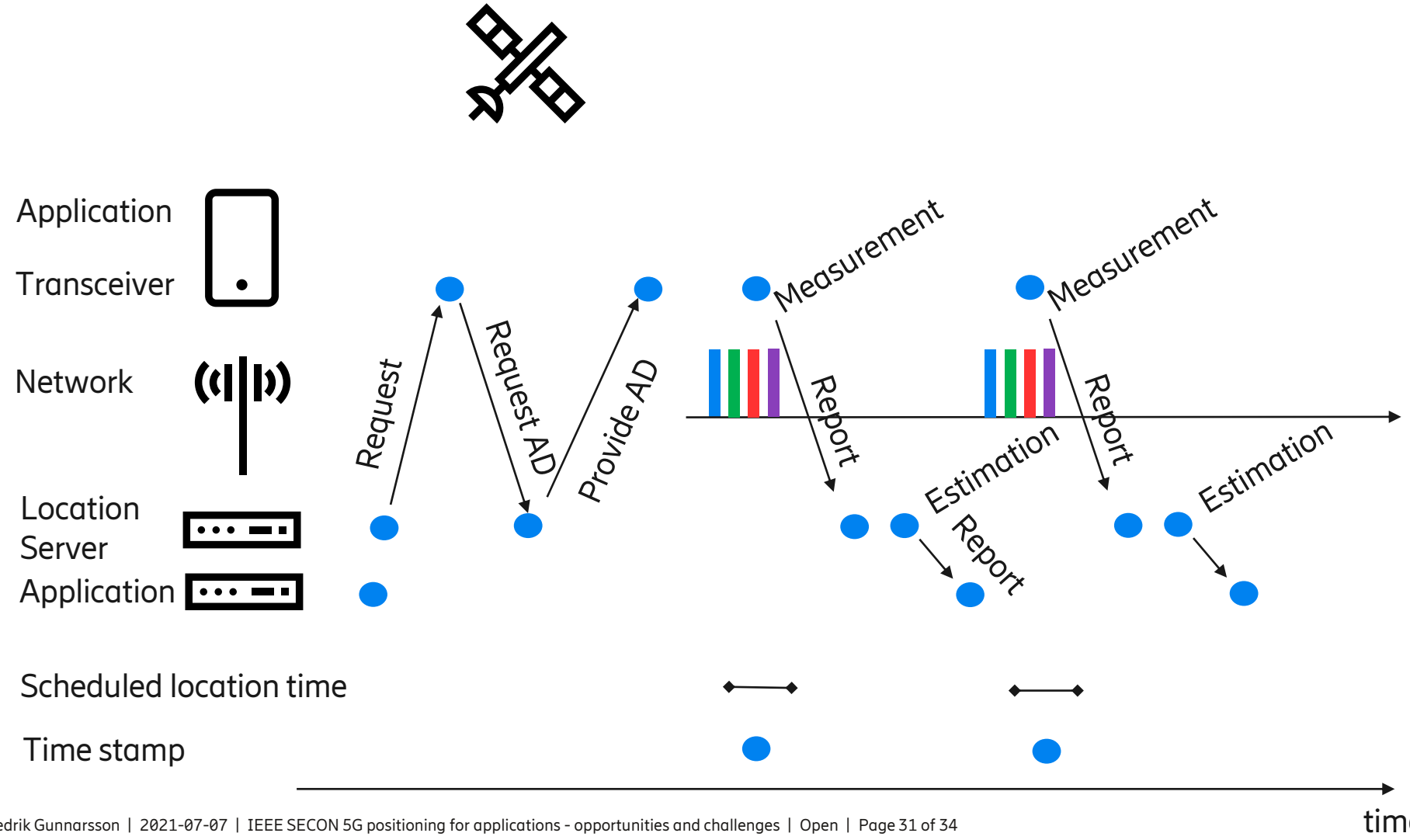
Application configuration

Application functions interacts directly (or via a network exposure function) with the location gateway.

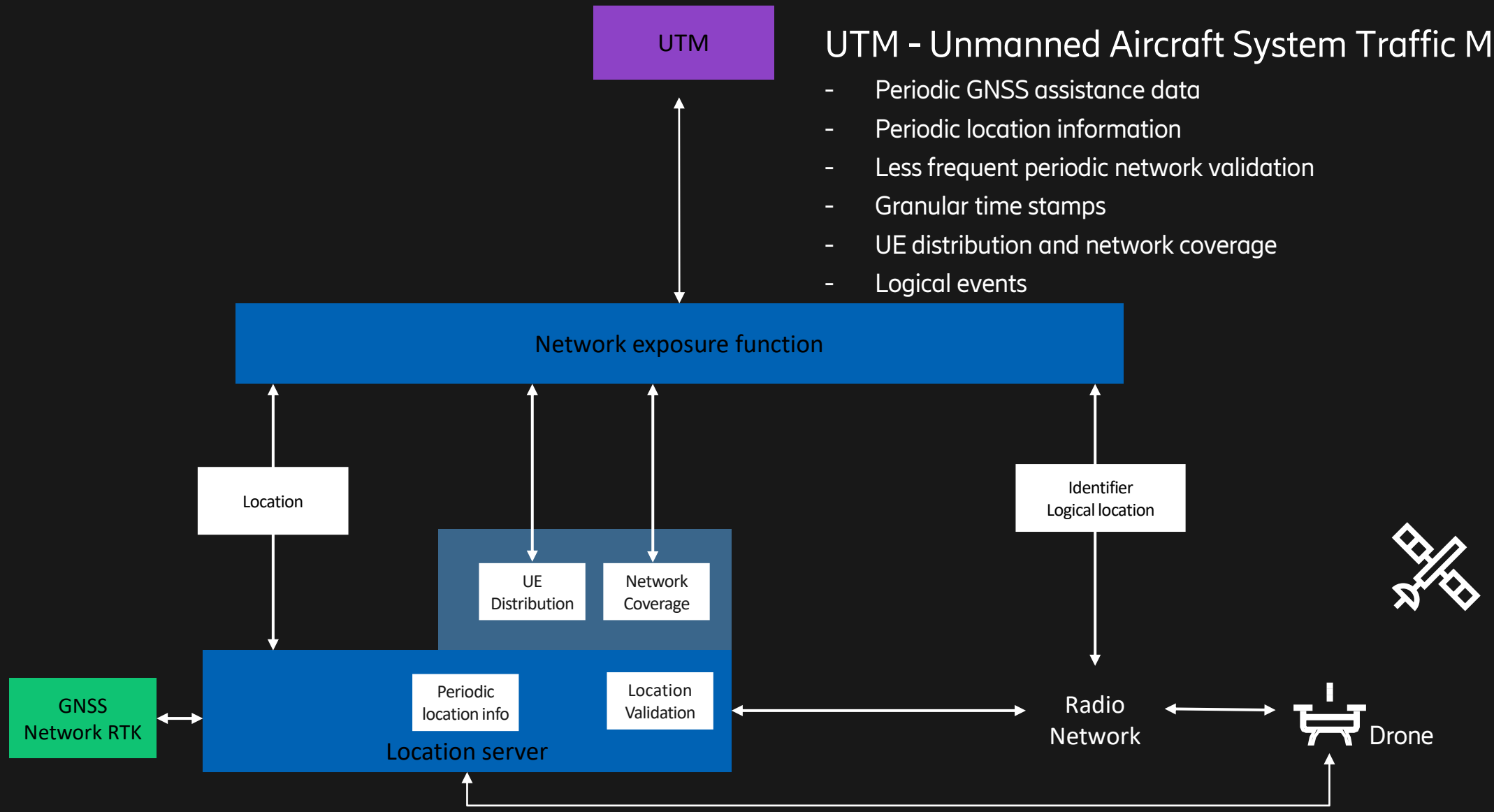
Application functions configure the location gateway to be provided with location information that matches application and use case requirements

- Response time and delay
- Time stamping (time of measurement instant)
- Report triggering
  - Immediate or scheduled location time
  - Event-driven
- Accuracy
- Efficient exposure
- Hybrid or multiple independent positioning solutions for safety

Scheduled location time and time stamps



Example –cellular network support for drone management



UTM - Unmanned Aircraft System Traffic Management

- Periodic GNSS assistance data
- Periodic location information
- Less frequent periodic network validation
- Granular time stamps
- UE distribution and network coverage
- Logical events

Key components

- Application and 5G positioning integration
- The 5G positioning toolbox has much to offer
- 5G positioning is capable to address very different application requirements
- 5G positioning needs adequate
  - device and network capabilities, possibly including sensing and HD map integration
    - network deployment and time stamping
    - algorithms
- Application and 5G positioning integration