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LOCUS 5G

Synchronization and Positioning

5G Critical Functions Supporting Various Applications

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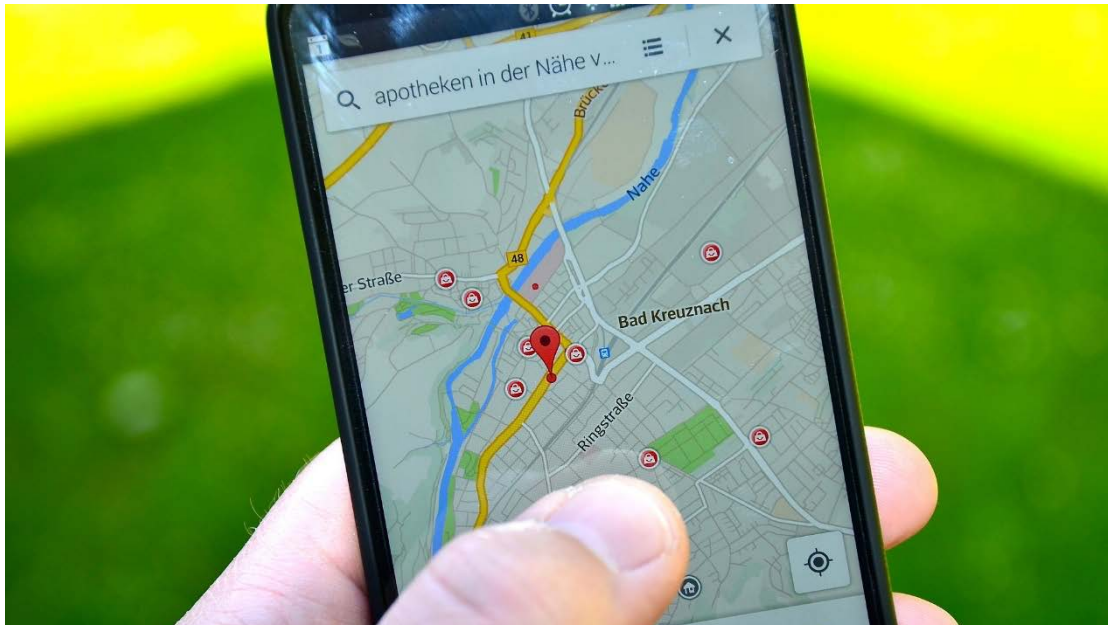
https://www.locus-project.eu/

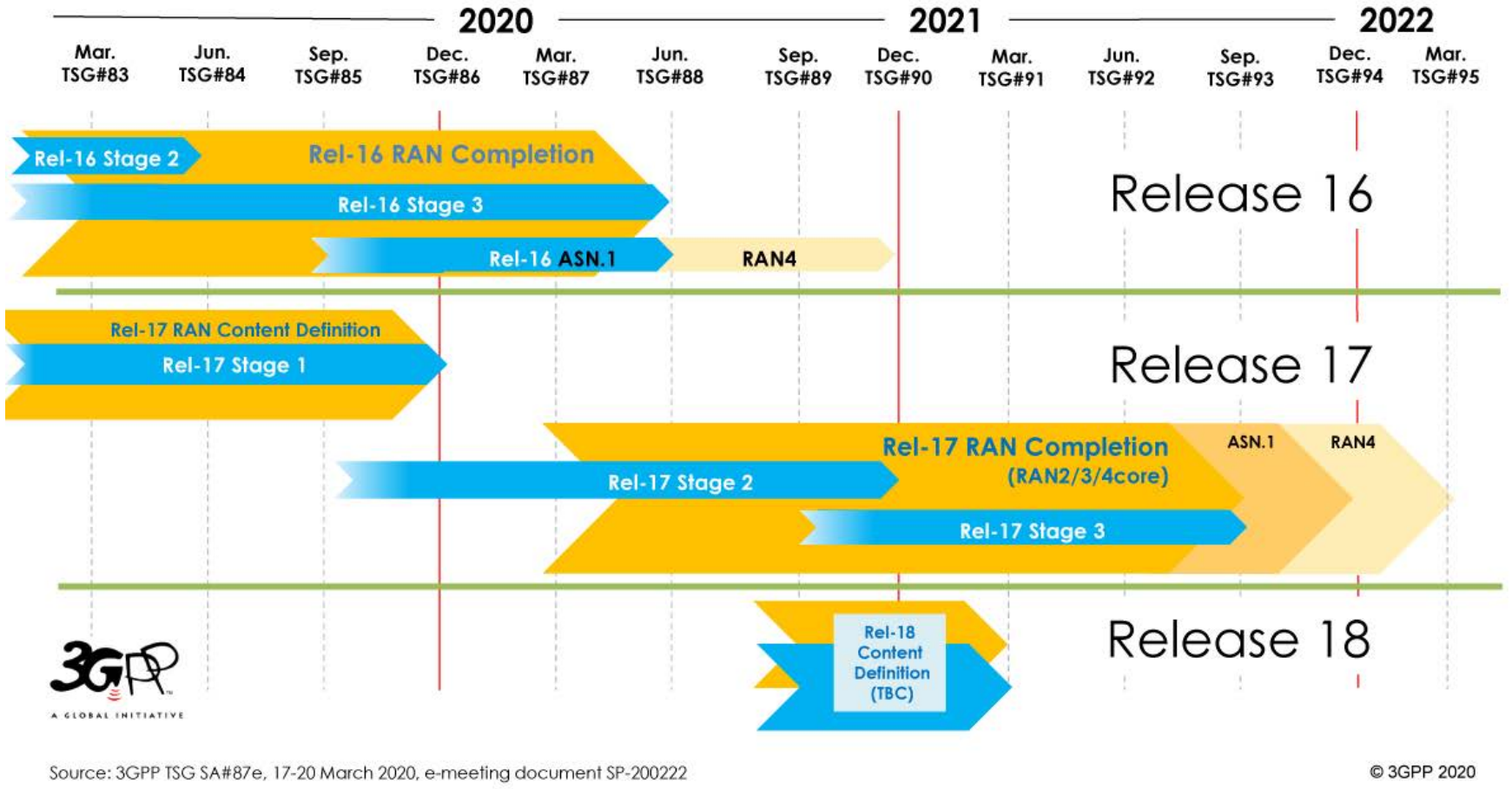
Location Based Services

- LBS market from USD 16 billions in 2019 to USD 40 billions by 2024
- 60% of the global LBS revenues taken by very few leading players



- GNSS technology integrated in the end user device and custom over-the-top (OTT) technologies
- Critical applications demand for *technologies deeply integrated in the mobile network ecosystem*

Positioning in 3GPP

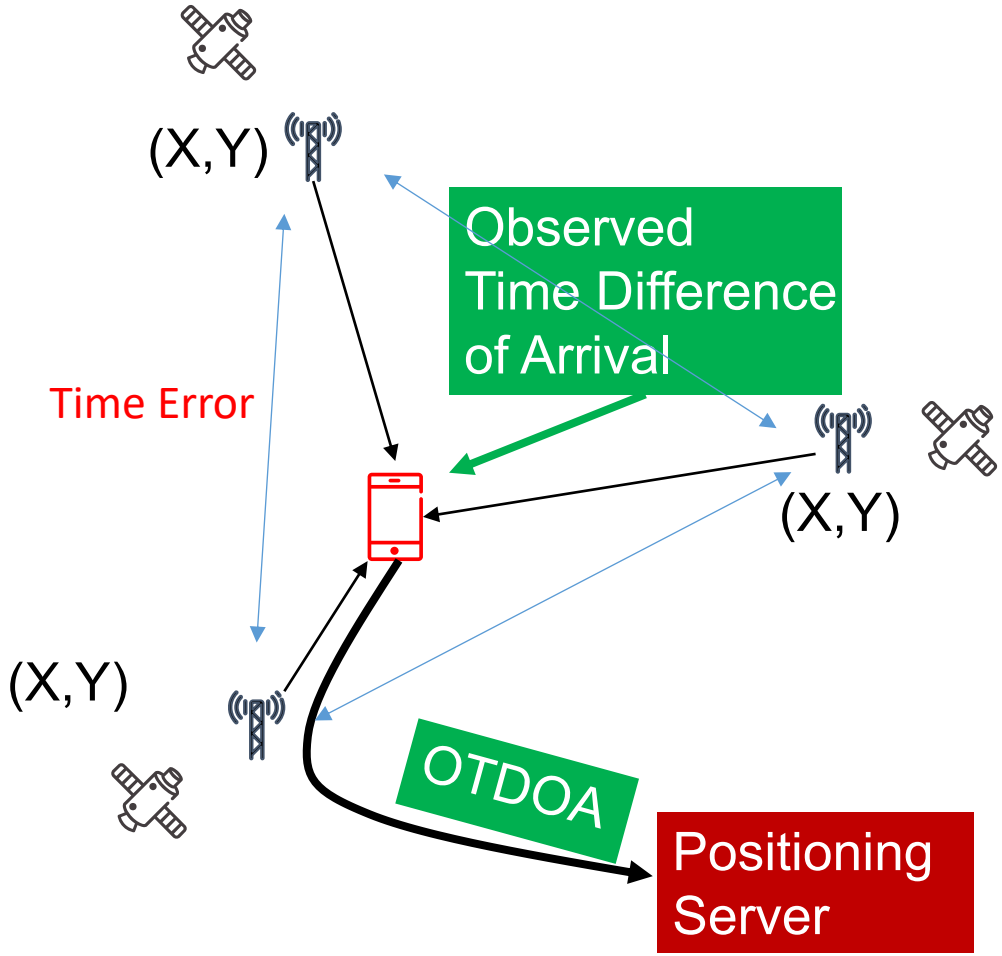


Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

- Targeting sub-meter accuracy through higher carrier frequencies and massive antenna arrays

3GPP Positioning and Synchronization

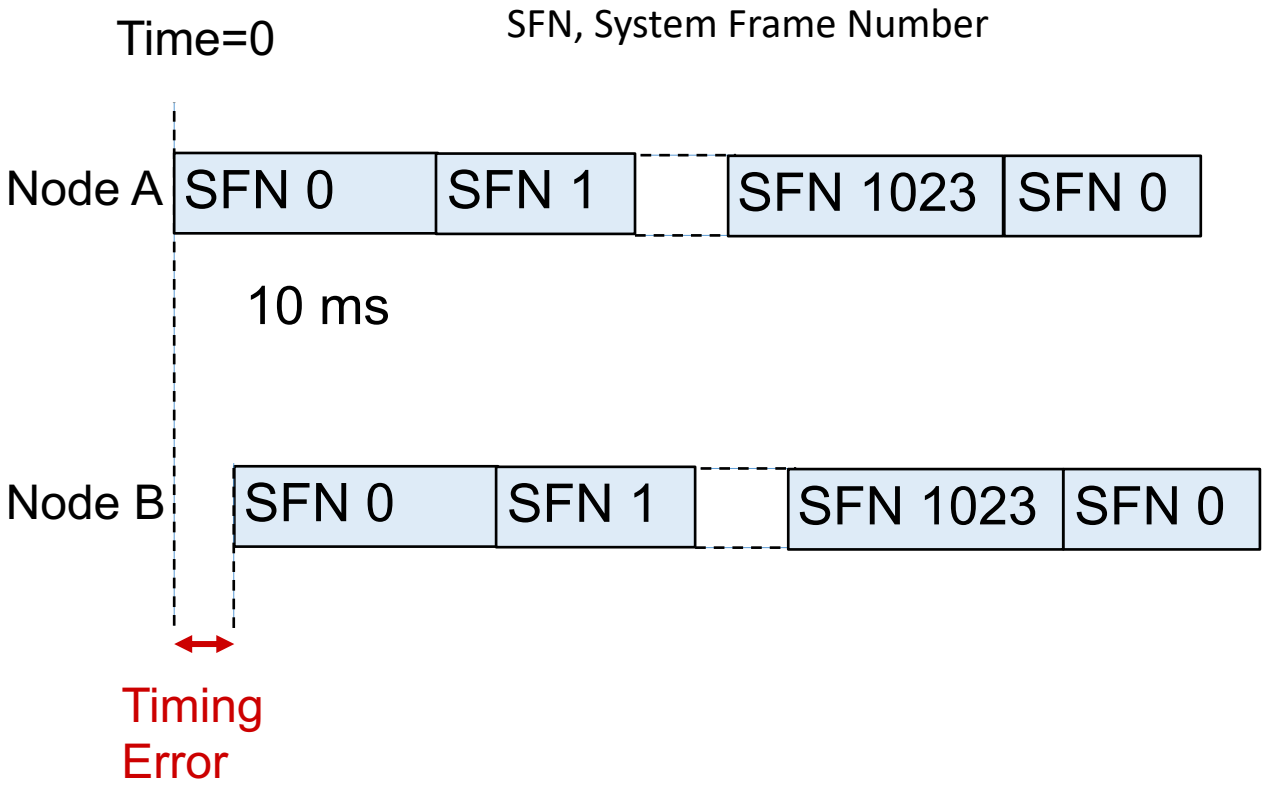
- 5G Localization methods rely on accurate timing (e.g., OTDOA, Observed Time Difference of Arrival)
- The synchronization requirements depend on the location accuracy requirements:
  - As an example, to achieve a location accuracy of 40-60m, a relative time error less than 200 ns is required.
- Other source of timing errors are the presence of NLOS conditions and the multipath propagation

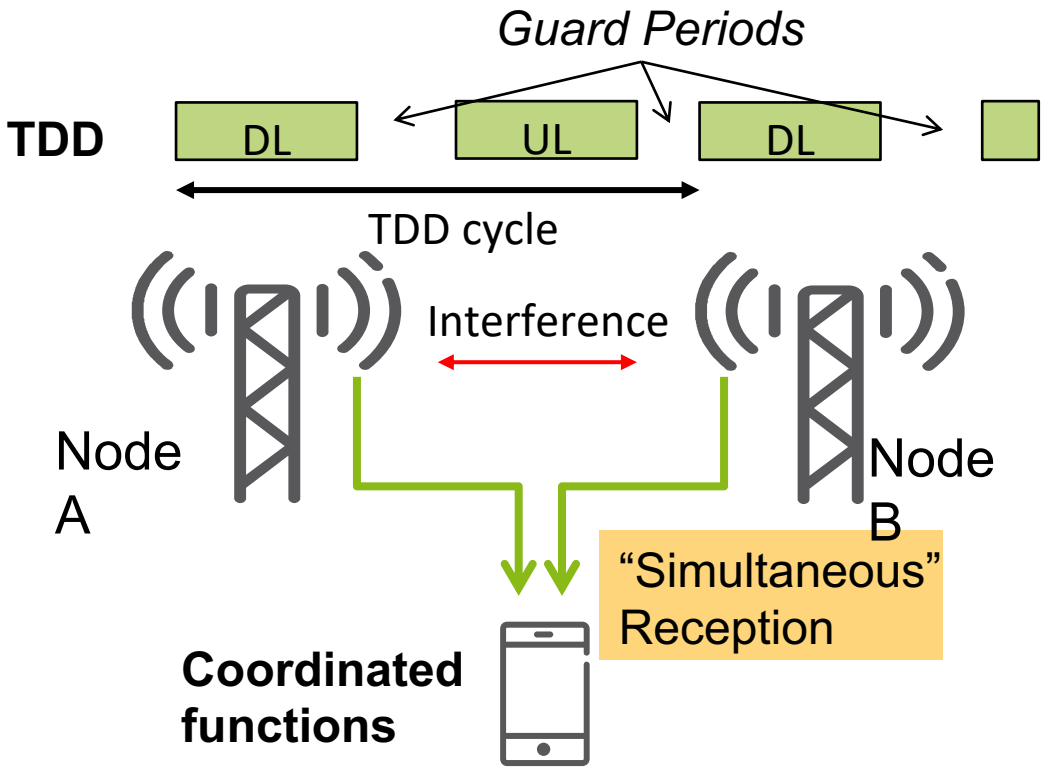


3GPP TR 37.857 "Study on indoor positioning enhancements for UTRA and LTE"

Why Synchronization in 5G

Radio frames are TDM (Time Division Multiplexing)

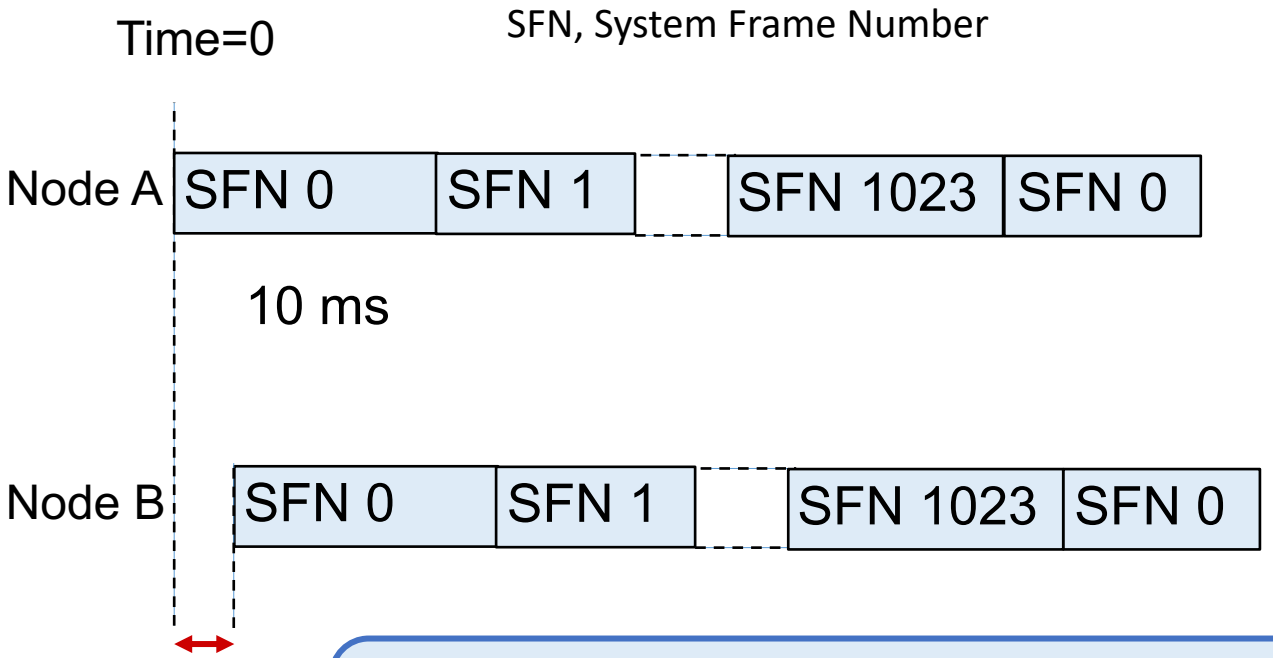


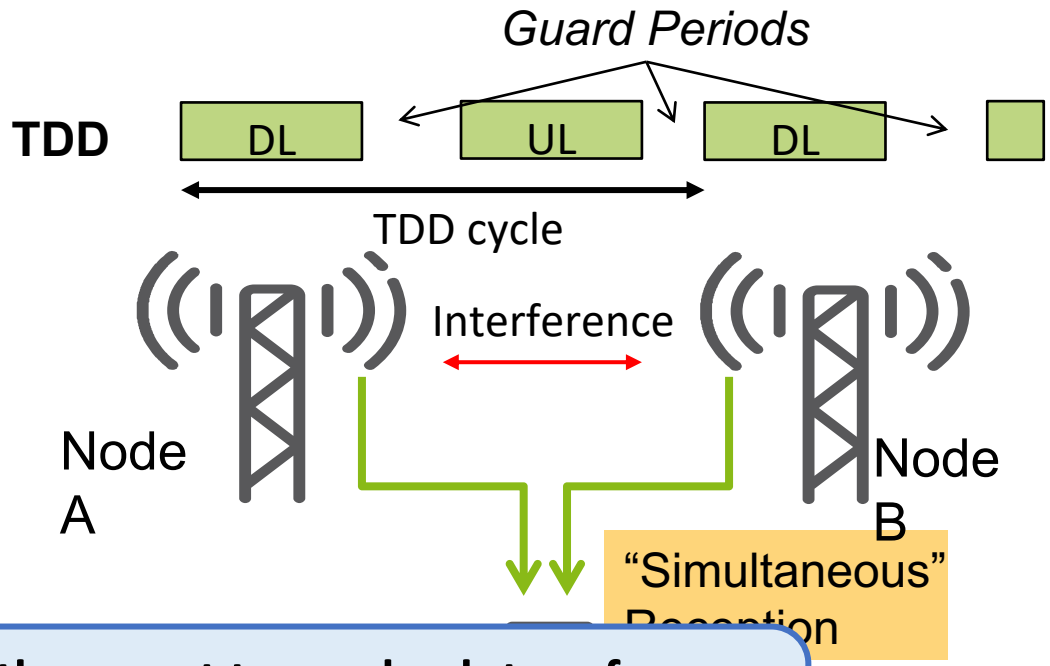


Sync for TDD, Carrier Aggregation, Dual Connectivity ...

Why Synchronization in 5G

Radio frames are TDM (Time Division Multiplexing)





Typical target requirement is about 1 us with respect to an absolute reference
In order to meet 3 us Cell Phase Synchronization
3GPP TS 38.133 "Requirements for support of radio resource management"

ctivity ...

The Project LOCUS (H2020)

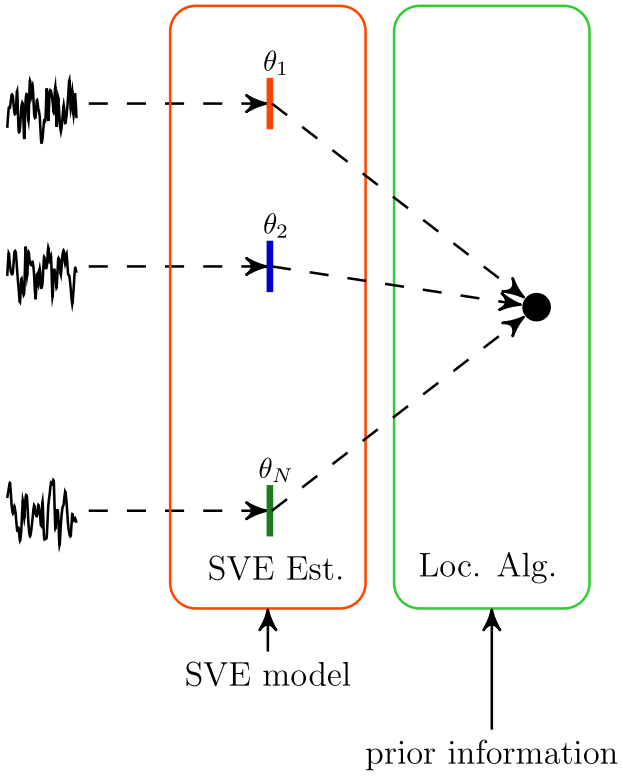
LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical applicationS

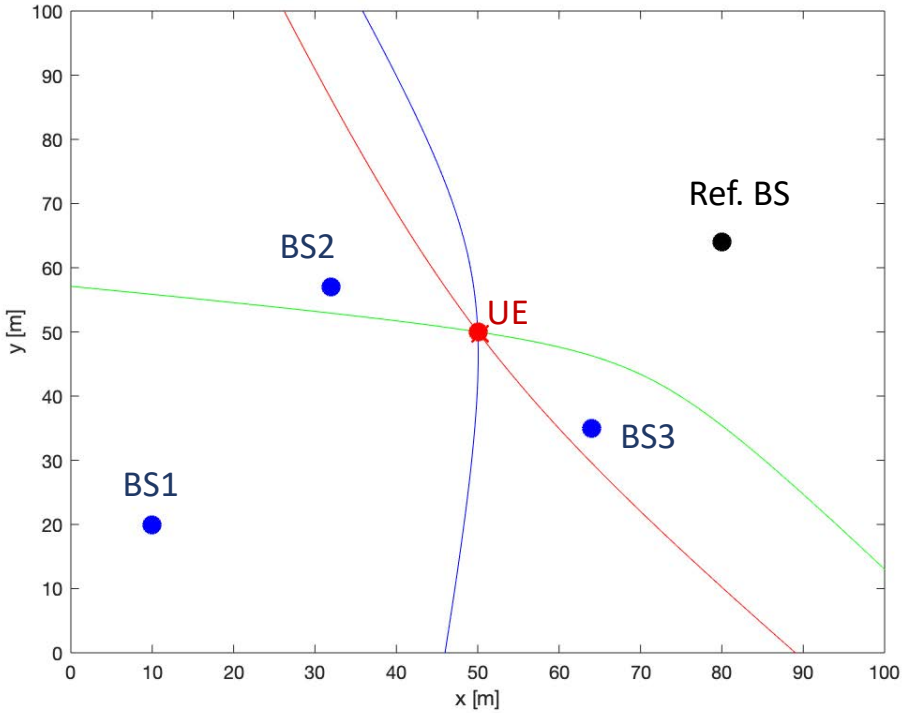
Consorzio Nazionale Interuniversitario per le Telecomunicazioni	IT
Ericsson AB	SE
Ericsson S.p.A.	IT
IBM	IE
NEC	DE
Orange	FR
OTE	GR
Samsung	UK
VIAVI	FR
Incelligent	GR
Nextworks	IT
IMDEA Networks	ES
University of Malaga	ES

- Enabling accurate and ubiquitous location information as a network-native service
- Derivation of complex features and behavioural patterns from raw location and physical events for application developers (location-based analytics)
- Localization of terminals for improving network performance and to better manage and operate networks

OTDOA-based localization

- Classic localization techniques rely on single value estimates (SVE), e.g. distance/angle, which are jointly used together with prior information by a localization algorithm

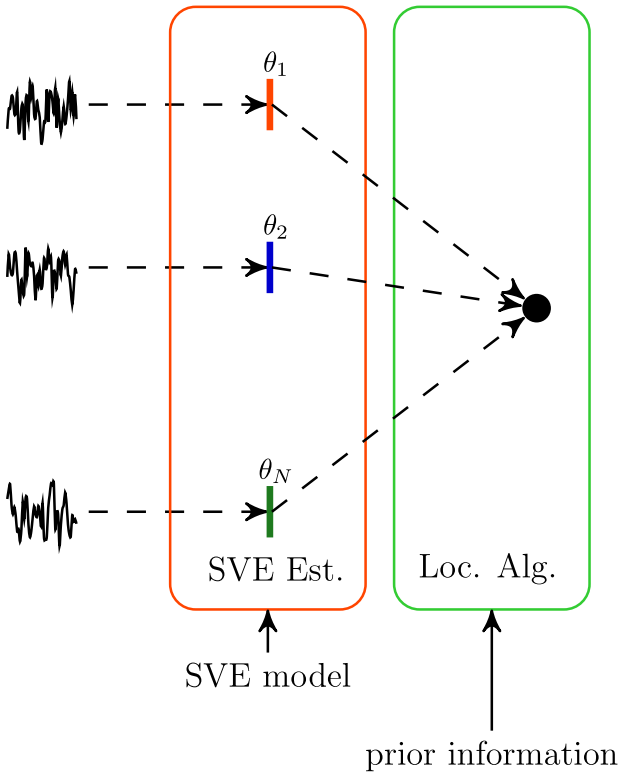


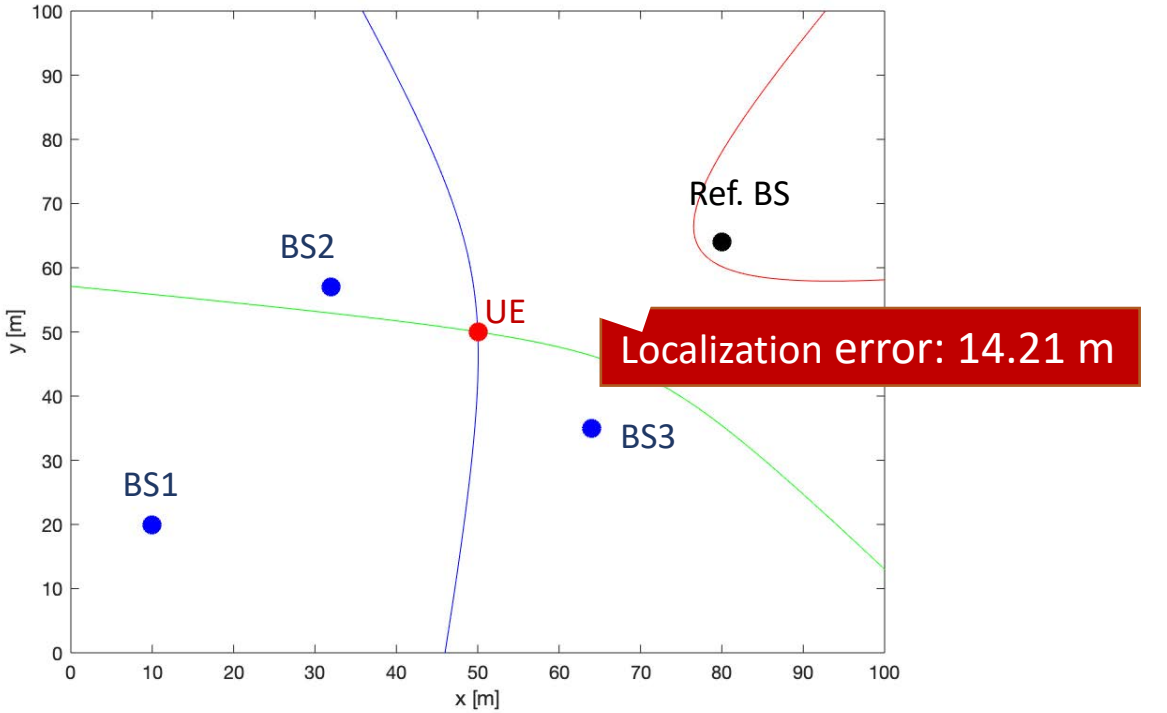


Example: accurate estimation, no synchronization errors

OTDOA-based localization

- Timing error

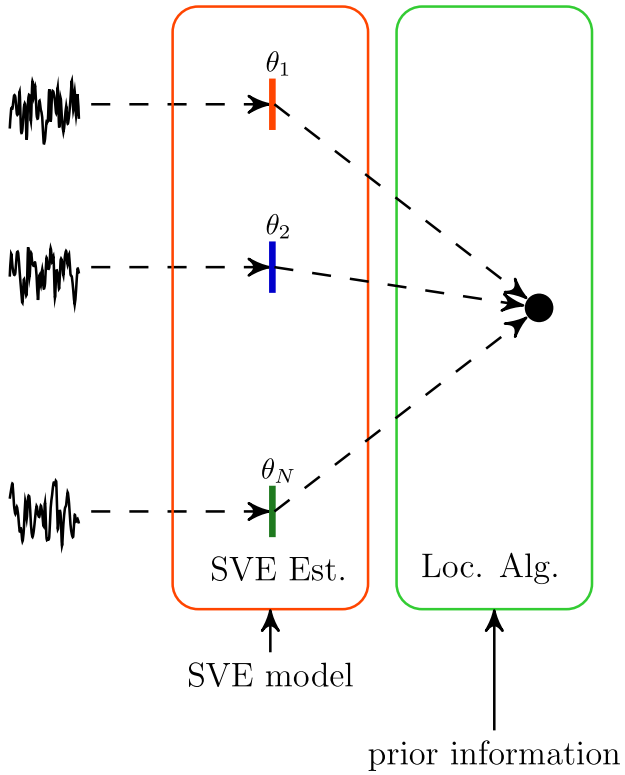




Example: a single time measurement from one of the base stations has 100 ns error

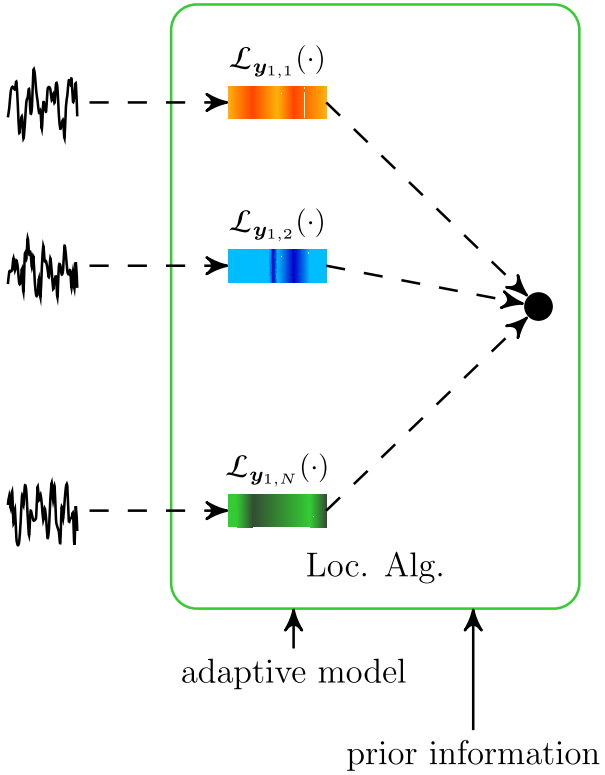
Soft Information for Localization

SVE-based localization



$$\{\boldsymbol{y}_{i,j}\}_{j\in\mathcal{N}} \longrightarrow \{\hat{\boldsymbol{\theta}}_{i,j}\} \longrightarrow \boldsymbol{p}_i$$

SI-based localization



$$\{\mathcal{L}_{\boldsymbol{y}_{i,j}}(\cdot)\}_{j\in\mathcal{N}} \longrightarrow \boldsymbol{p}_i$$

A. Conti et al., "Soft Information for Localization-of-Things," Proc. of the IEEE, May 2019

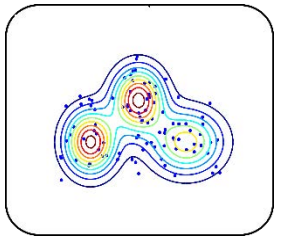
Methodology for Soft-Information

Training (Measurement Campaign)

TDoA, ToA, AoA, DoA, and RSS Measurement

Machine Learning for Density Estimation

Dataset of measurements given the BS-UE distance $\{\mathbf{y}^{(k)}, d^{(k)}\}_{k=1}^{N}$



$\widehat{f}(\psi(\mathbf{y}), d)$

Online

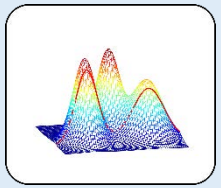
TDoA, ToA, AoA, DoA, and RSS Measurement

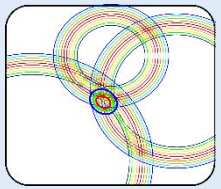
Pre-processing

Likelihood Calculation

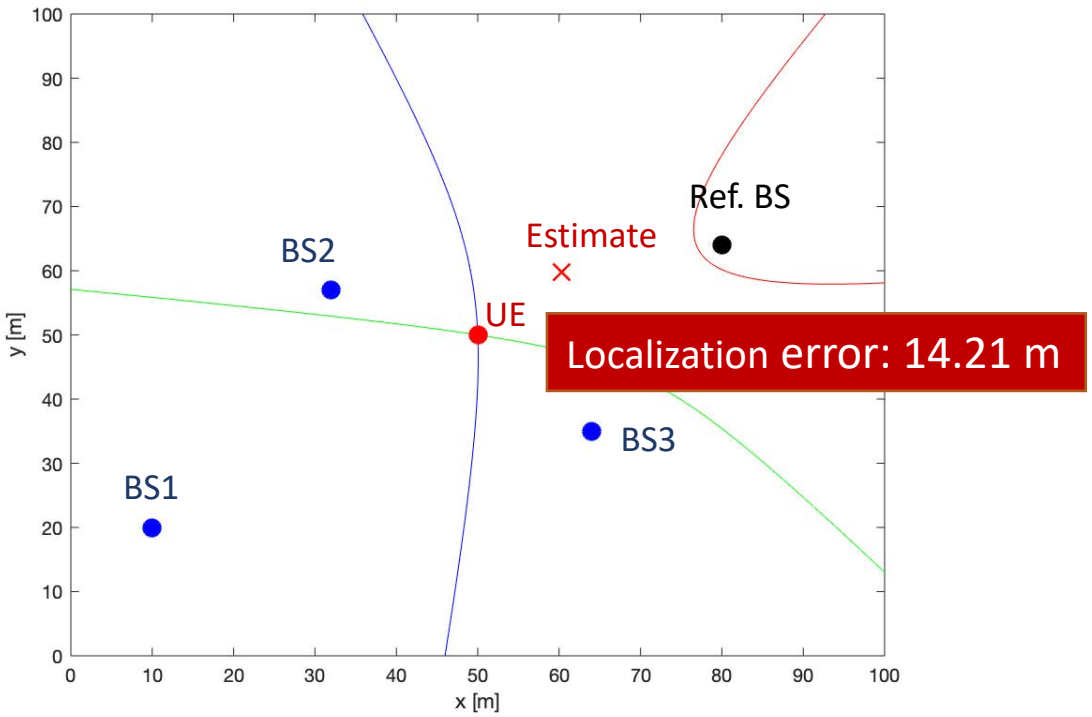
Localization

Online measurement, BS-UE distance unknown



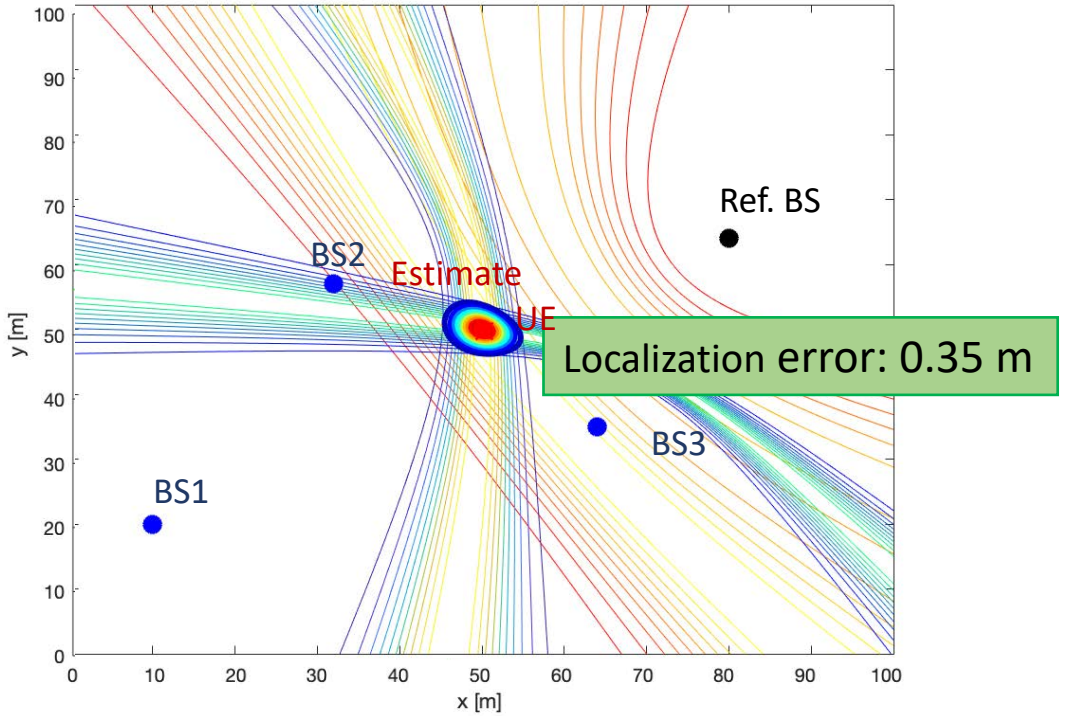


Example with OTDOA-based localization



Example: 100 ns error

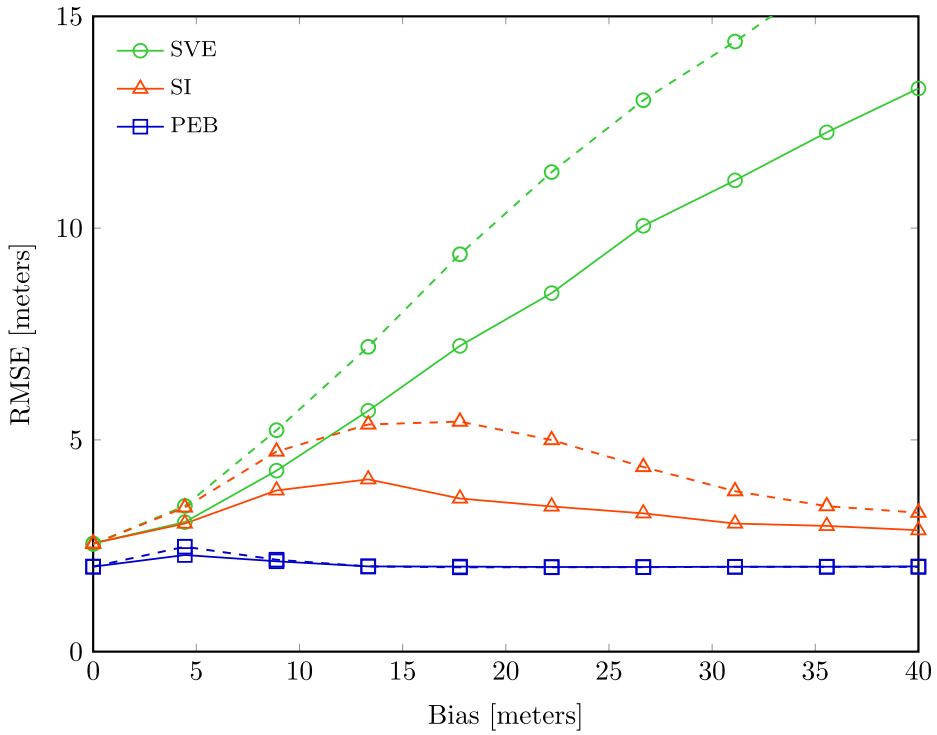
SVE-based



SI-based

Example Result

- 4 anchors in 100m X 100m: anchors and agents at random
- Probability of NLOS 0.4
- Measurements error with std 2m
- Detection error 0.1 (solid) and 0.2 (dashed)



Summary

- Positioning is a key enabler for a wide range of emerging applications in 5G scenarios
- The European Project LOCUS is aiming at improving localization accuracy, close to theoretical bounds and extend localization with physical analytics
- Synchronization and timing are vital for addressing accurate localization in critical scenarios
- Extremely accurate synchronization, for example in the order of a few ns could result in unreasonable cost for a network operator
- Soft-Information is a new paradigm for learning and exploiting location information and mitigate several error sources including synchronization and timing errors due to impaired wireless propagation

Thank you

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