Synchronization and Positioning

5G Critical Functions Supporting Various Applications

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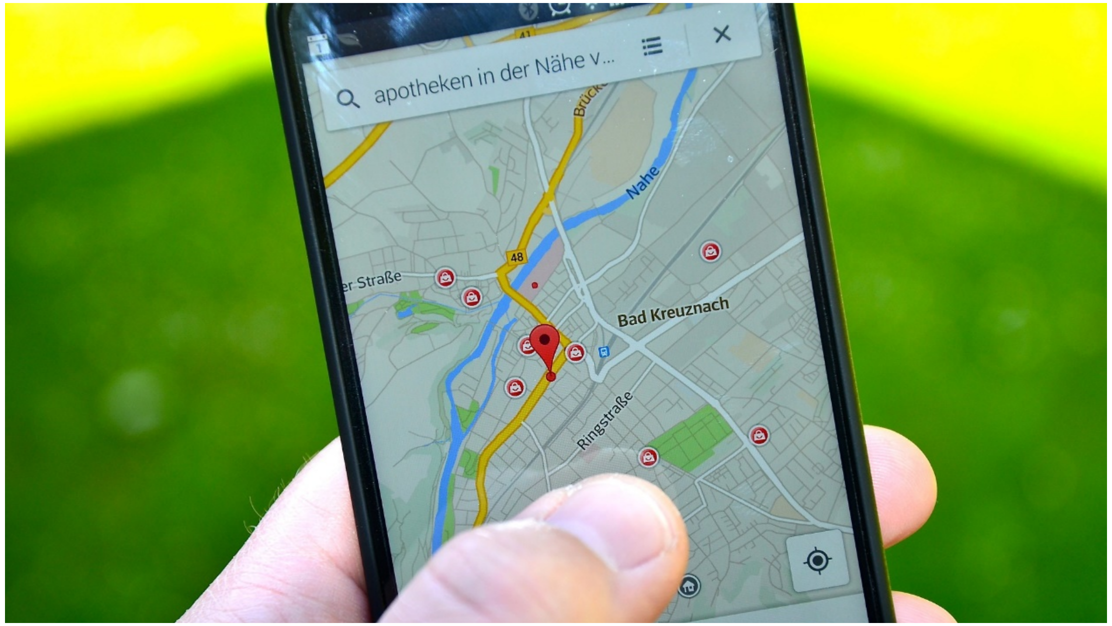
https://www.locus-project.eu/

Location Based Services

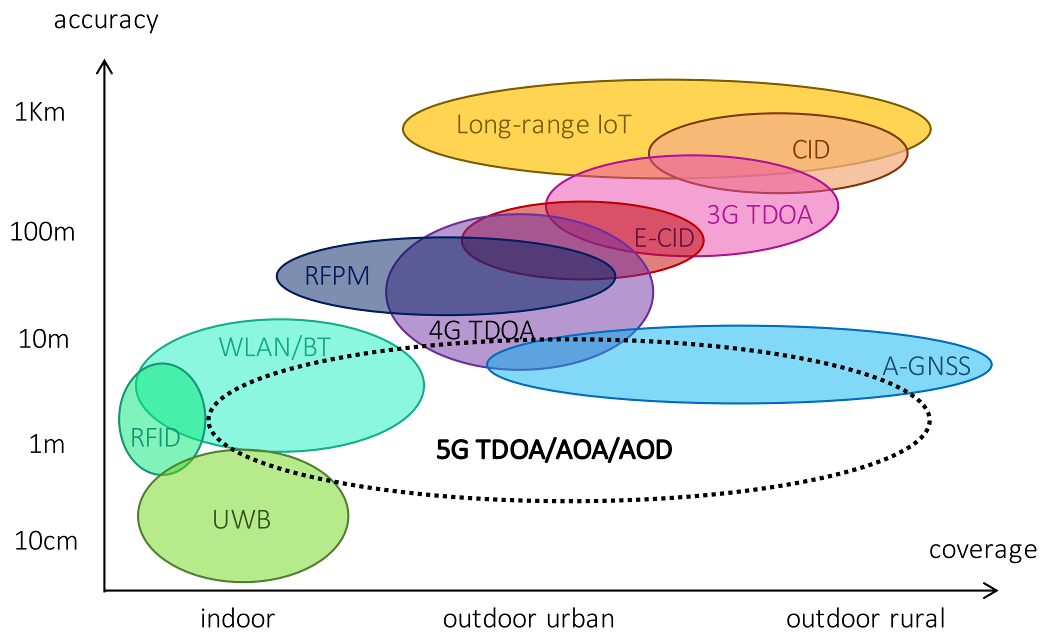
- LBS market from USD 16 billion in 2019 to USD 40 billion by 2024
- 60% of the global LBS revenues taken by very few leading players



- Global navigation satellite systems' 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*

Cellular Localization

Positioning technology		GPS (2G)	UMTS (3G)	LTE (R8) (3.9G)	LTE-A (R9) (4G)	LTE-A (R11)	LTE-A pro (R12) (4.5G)	LTE-A pro (R13)	3GPP NR (R16) (5G)
RAT-dependent	Cell-ID	X	X						X
	E-CID			X	X	X	X	X	X
	OTDOA	X	X		X	X	X	X	X
	UTDOA		X			X	X	X	X
	AOA/DOA								X
	RFPM						X	X	X
RAT-independent	A-GNSS	X	X	X	X	X	X	X	X
	TBS							X	X
	WLAN							X	X
	Bluetooth							X	X
	Barometer							X	X



“The 5G Italy Book 2019: a Multiperspective View of 5G,” CNIT, Dec. 2019

5G Location Service Levels

Serv. Lev.	Abs./Rel.	Accuracy		Avail.	Lat.	Coverage, environment of use and UE vel.		
		Hor. Acc.	Ver. Acc.			5G pos. ser. area	5G enh. pos. ser. area	
							Outdoor	Indoor
1	A	10m	3m	99%	1s	Indoor: up to 30 km/h; Outdoor (rural and urban): up to 500km/h (trains) and 250km/h (other veh.)	NA	Indoor:up to 30 km/h
2	A	3m	3m	99%	1s	Outdoor (rural and urban): up to 500km/h (trains) and 250km/h (other veh.)	Outdoor (dense urban): up to 60 km/h; Along roads up to 250 km/h and along railways up to 500 km/h	Indoor: up to 30 km/h
3	A	1m	2m	99%	1s	Outdoor (rural and urban): up to 500km/h (trains) and 250km/h (other veh.)	Outdoor (dense urban): up to 60 km/h; Along roads up to 250 km/h and along railways up to 500 km/h	Indoor: up to 30 km/h

Service requirements for the 5G system, 3rd Generation Partnership Project 3GPP™ TS 22.261

5G Location Service Levels

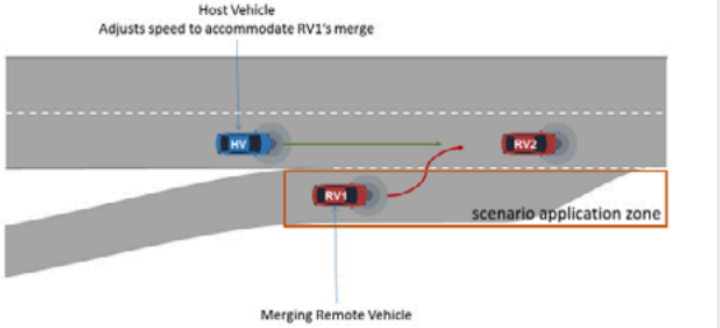
<table>
<tr><th rowspan="3">Serv. Lev.</th><th rowspan="3">Abs./Rel.</th><th colspan="2">Accuracy</th><th rowspan="3">Avail.</th><th rowspan="3">Lat.</th><th colspan="3">Coverage, environment of use and UE vel.</th></tr>
<tr><th rowspan="2">Hor. Acc.</th><th rowspan="2">Ver. Acc.</th><th rowspan="2">5G pos. ser. area</th><th colspan="2">5G enh. pos. ser. area</th></tr>
<tr><th>Outdoor</th><th>Indoor</th></tr>
<tr><td>4</td><td>A</td><td>1m</td><td>2m</td><td>99.9%</td><td>15 ms</td><td>NA</td><td>NA</td><td>Indoor: up to 30 km/h</td></tr>
<tr><td>5</td><td>A</td><td>0.3m</td><td>2m</td><td>99%</td><td>1s</td><td>Outdoor (rural): up to 250km/h</td><td>Outdoor (dense urban): up to 60 km/h; Along roads up to 250 km/h and along railways up to 500 km/h</td><td>Indoor: up to 30 km/h</td></tr>
<tr><td>6</td><td>A</td><td>0.3m</td><td>2m</td><td>99.9%</td><td>10 ms</td><td>NA</td><td>Outdoor (dense urban): up to 60 km/h</td><td>Indoor: up to 30 km/h</td></tr>
<tr><td>7</td><td>R</td><td>0.2m</td><td>0.2m</td><td>99%</td><td>1s</td><td colspan="3">Indoor and outdoor (rural, urban, dense urban): up to 30 km/h; rel. pos. is between two UE (within 10m apart) or one UE and 5G pos. node (within 10m apart)</td></tr>
</table>

Service requirements for the 5G system, 3rd Generation Partnership Project 3GPP™ TS 22.261

Examples of Safety-critical Applications: eV2X

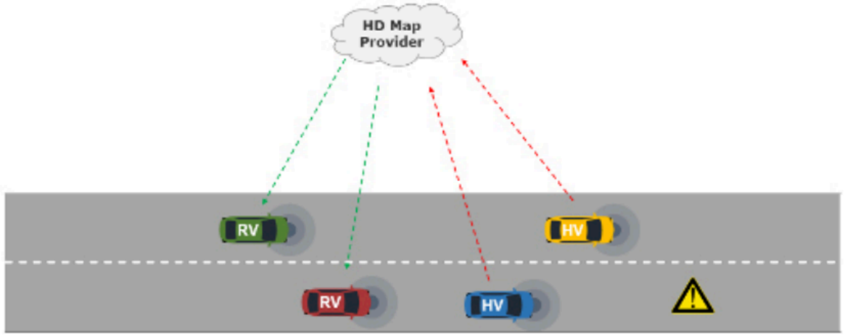
Advanced Driving allowing vehicles to coordinate their trajectories or maneuvers (**maneuver coordination**)

Positioning [m] 1.5 (3σ)



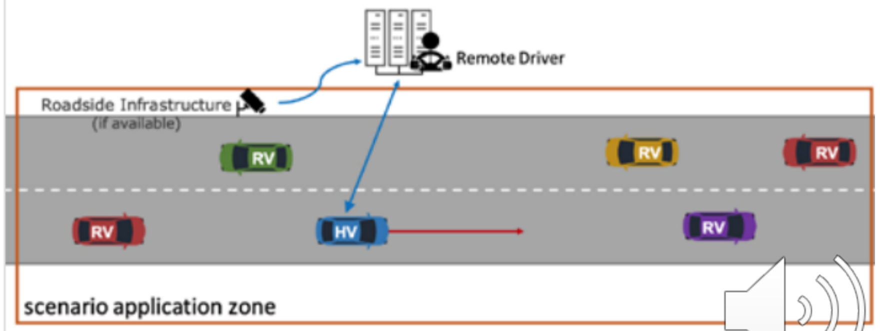
Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data

Positioning [m] 0.1m~0.5 m (3σ)



Remote Driving enables a remote driver or a V2X application to operate a remote vehicle

Positioning [m] 0.1 (3σ)*



5G; Service requirements for enhanced V2X scenarios" (3GPP TS 22.186 version 16.2.0 Release 16, Nov 2020)

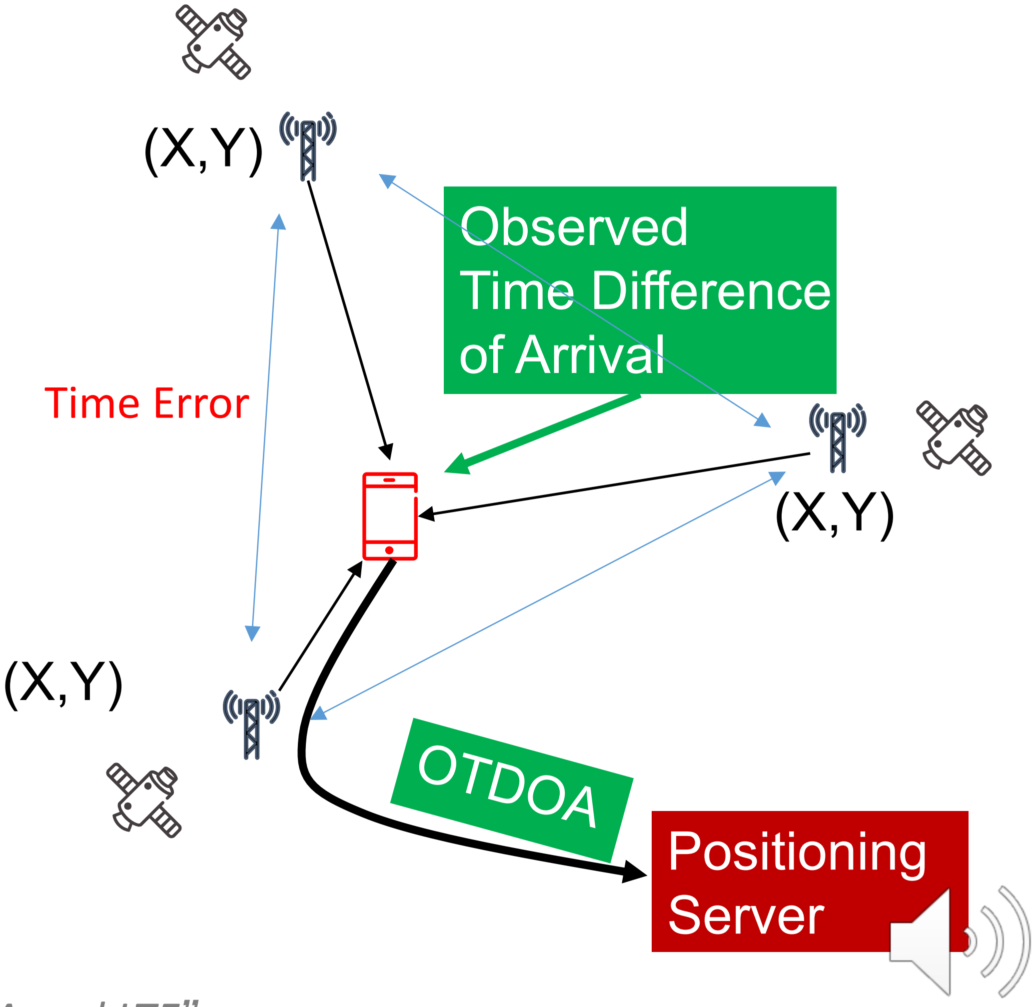
*5GAA Whitepaper, C-V2X Use Cases Volume II: Examples and Service Level Requirements

3GPP Positioning and Synchronization

- 5G Localization methods rely on accurate timing (e.g., OTDOA, Observed Time Difference of Arrival)

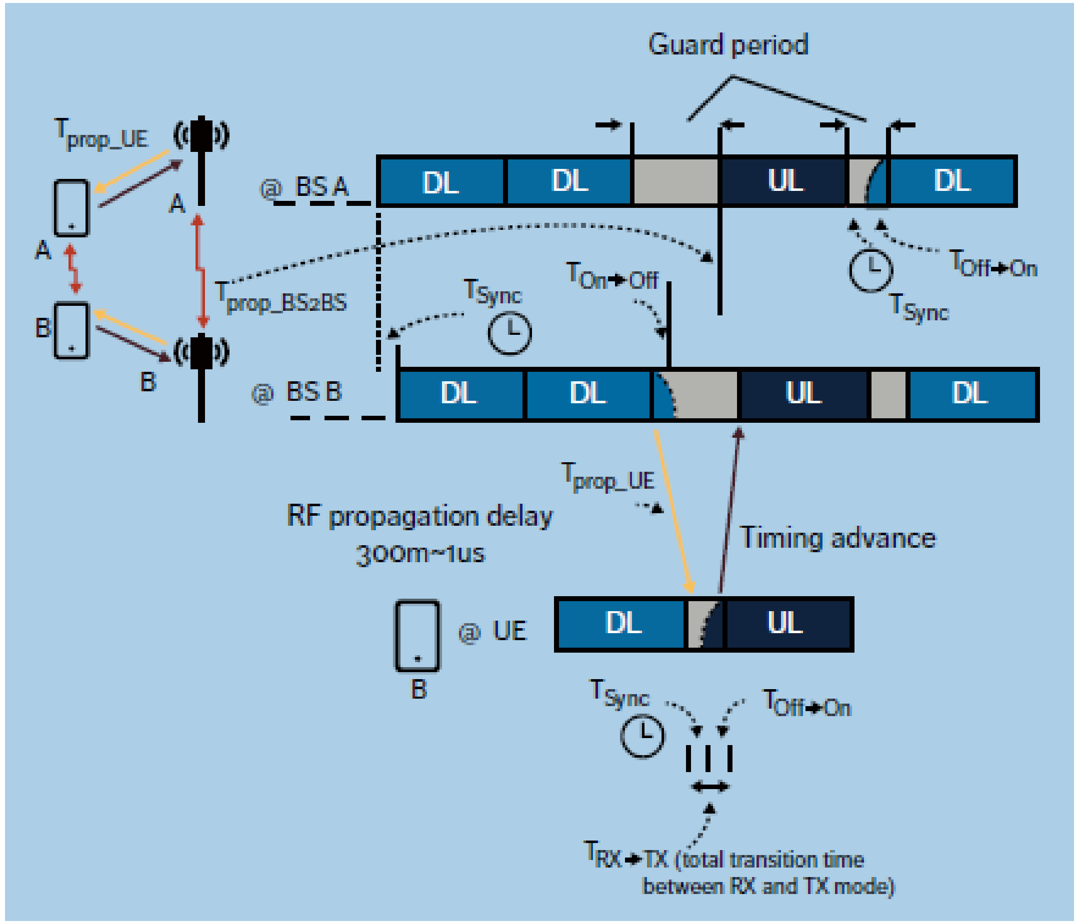
- The synchronization requirements depends on the location accuracy requirements:
  - As an example, to achieve a location accuracy of 40-60m, a relative time error less than 200 ns is required.

- Other source of timing errors are the presence of NLOS conditions and the multipath propagation



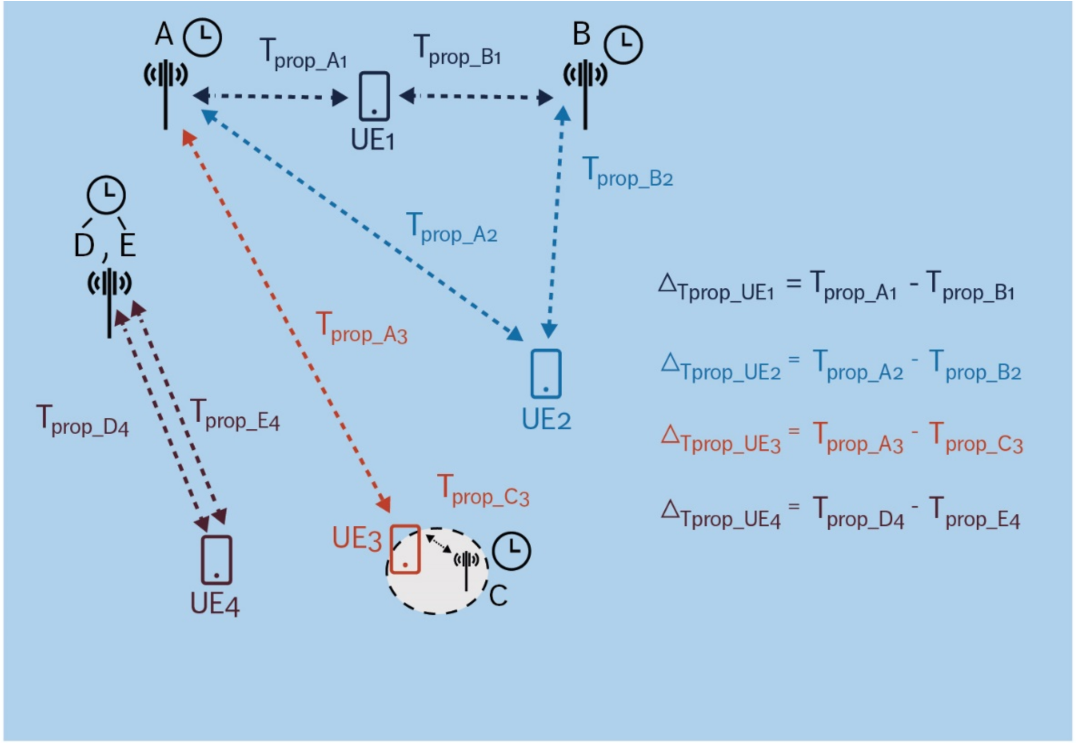
3GPP TR 37.857 "Study on indoor positioning enhancements for UTRA and LTE"

Why Synchronization in 5G



Sync is required for

- controlling interferences in TDD
- combining radio signals in Carrier Aggregation, Dual Connectivity



Typical target requirement is about 1 us with respect to an absolute reference
In order to meet 3 us Cell Phase Synchronization

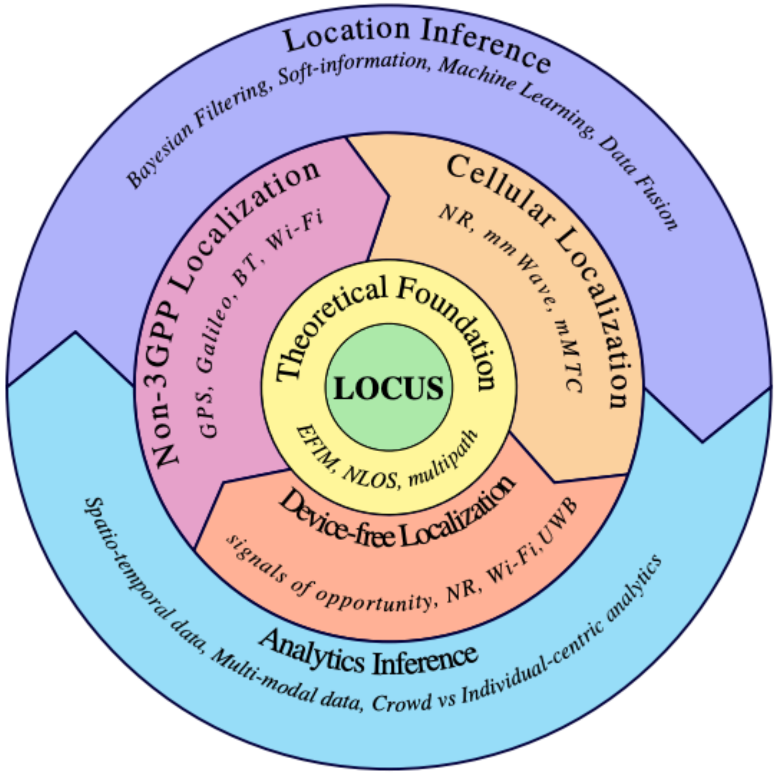
ΔT_{prop_UE1} and $\Delta T_{prop\_UE4} < \Delta T_{prop\_UE2} < \Delta T_{prop\_UE3}$

For same delay spread → UE1 and UE4 can tolerate larger TAE than UE2 and UE3. For colocated D and E, $TAE_{D\text{-}E}$ generally < $TAE_{A\text{-}B}$

The Project LOCUS (H2020)

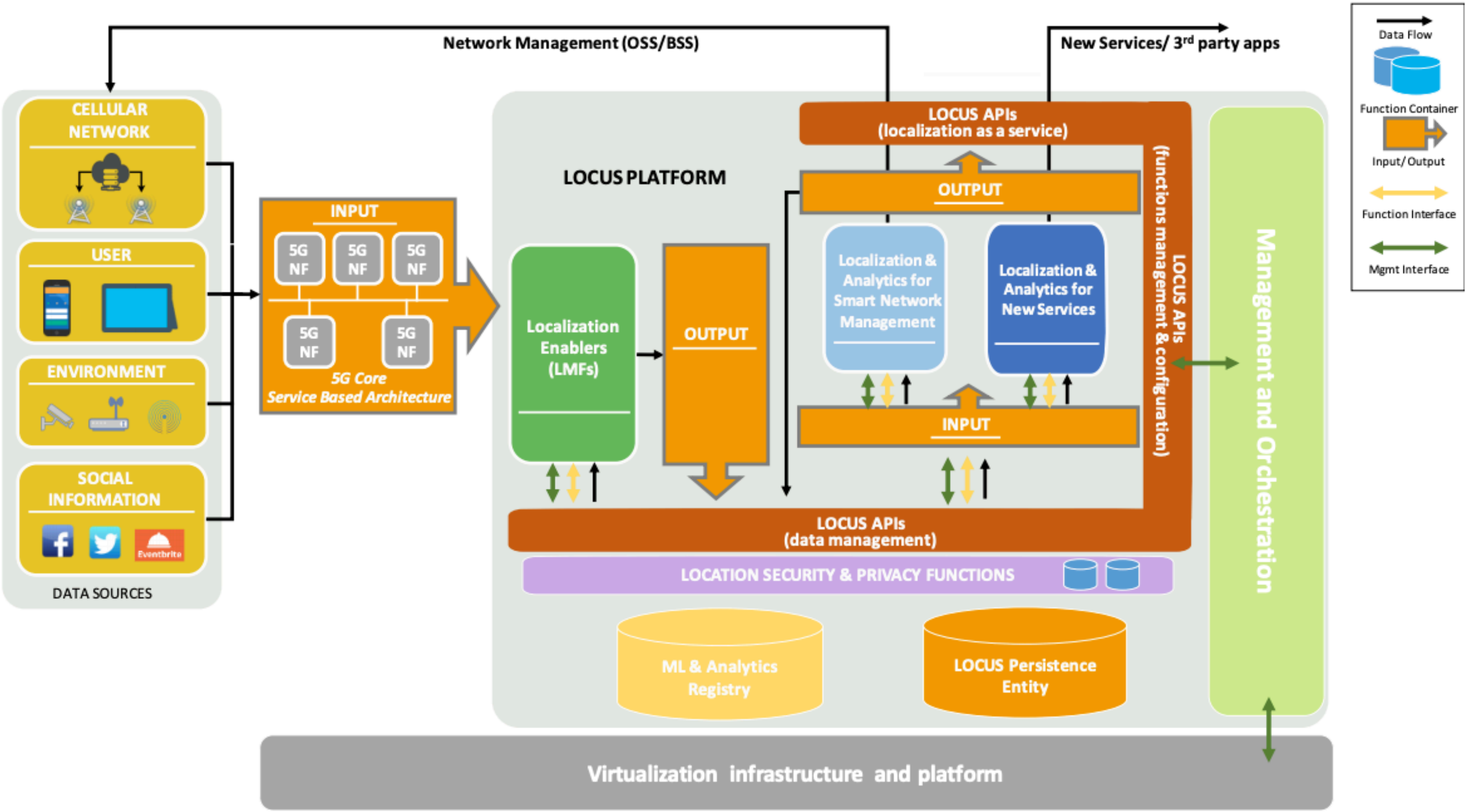
LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical applicationS

- 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



LOCUS Consortium: CNIT, Ericsson AB, Ericcson S.p.A., IBM, NEC, Orange, OTE, Samsung, VIAVI, Incelligent, Nextworks, IMDEA Networks, University of Malaga.

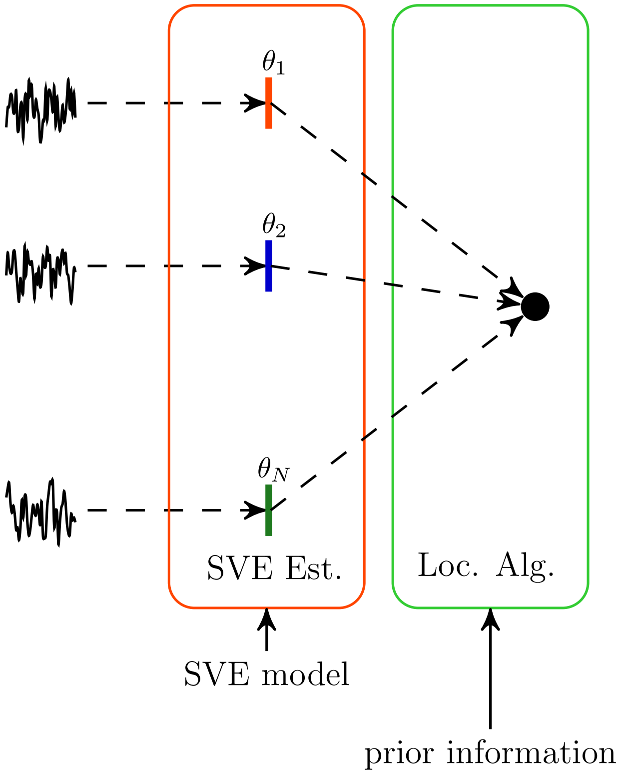
The Project LOCUS (H2020)

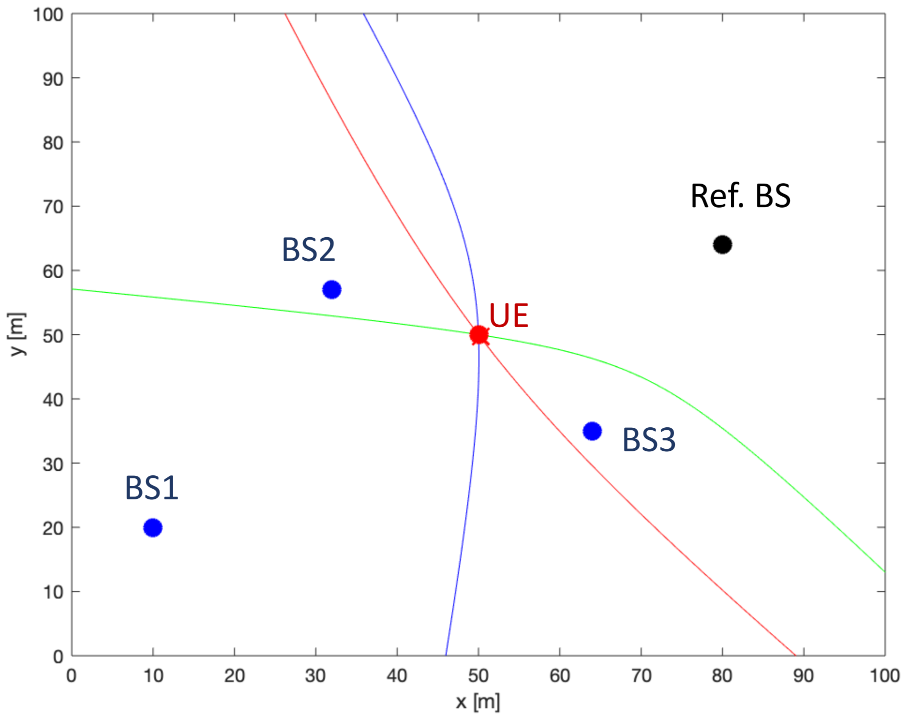


N. Blefari-Melazzi *et al*., "LOCUS: Localization and analytics on-demand embedded in the 5G ecosystem," *2020 European Conference on Networks and Communications (EuCNC)*, Dubrovnik, Croatia, 2020, pp. 170-175.

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

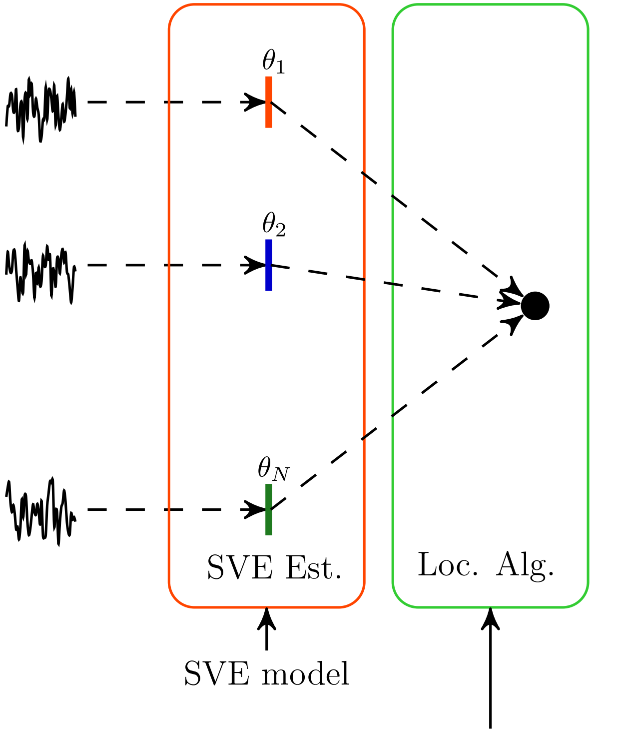


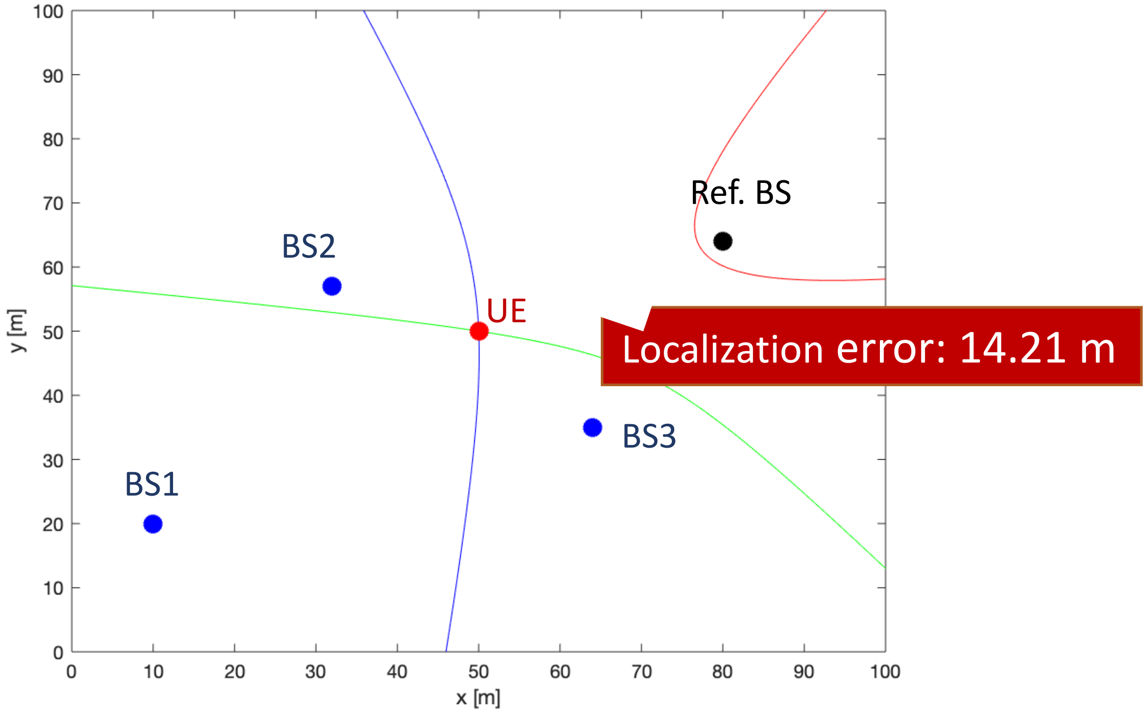


Example: accurate estimation, no synch errors

OTDOA-based localization

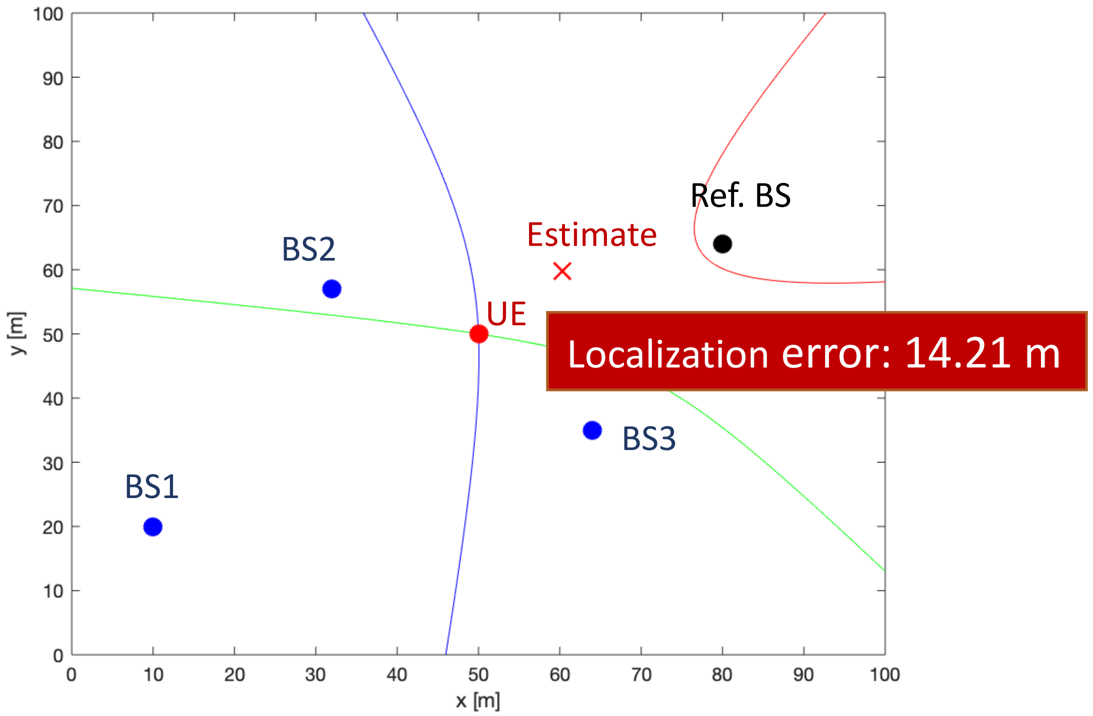
- Timing error

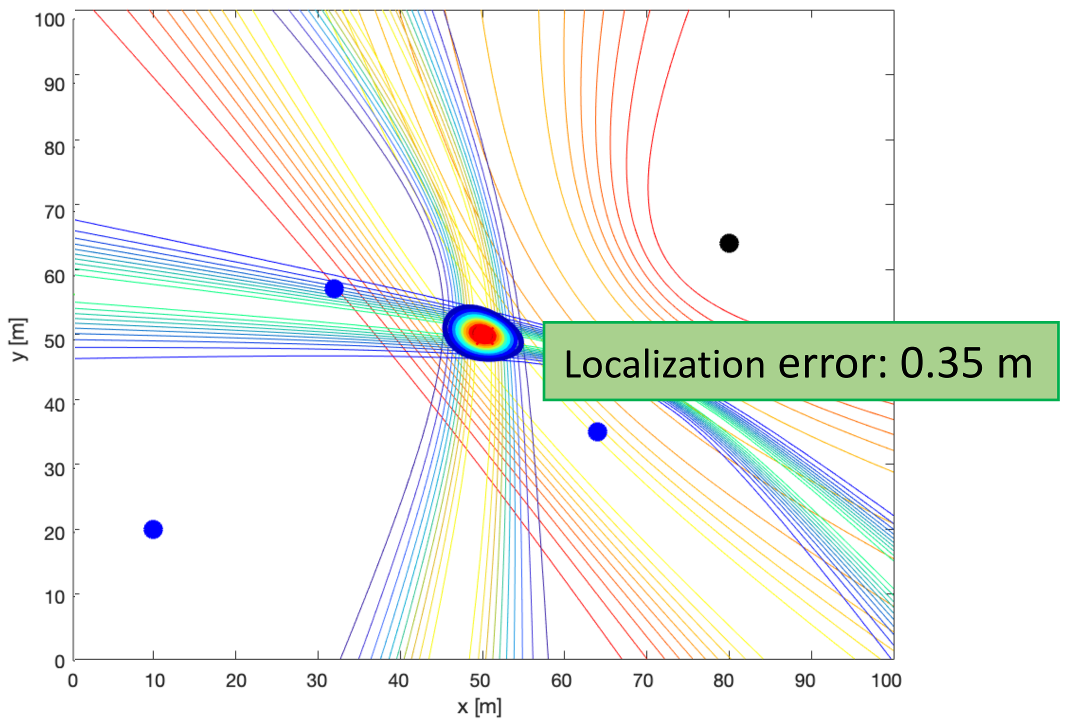




Example: one time measurement from a base stationn has 100 ns error

Example with OTDOA-based localization





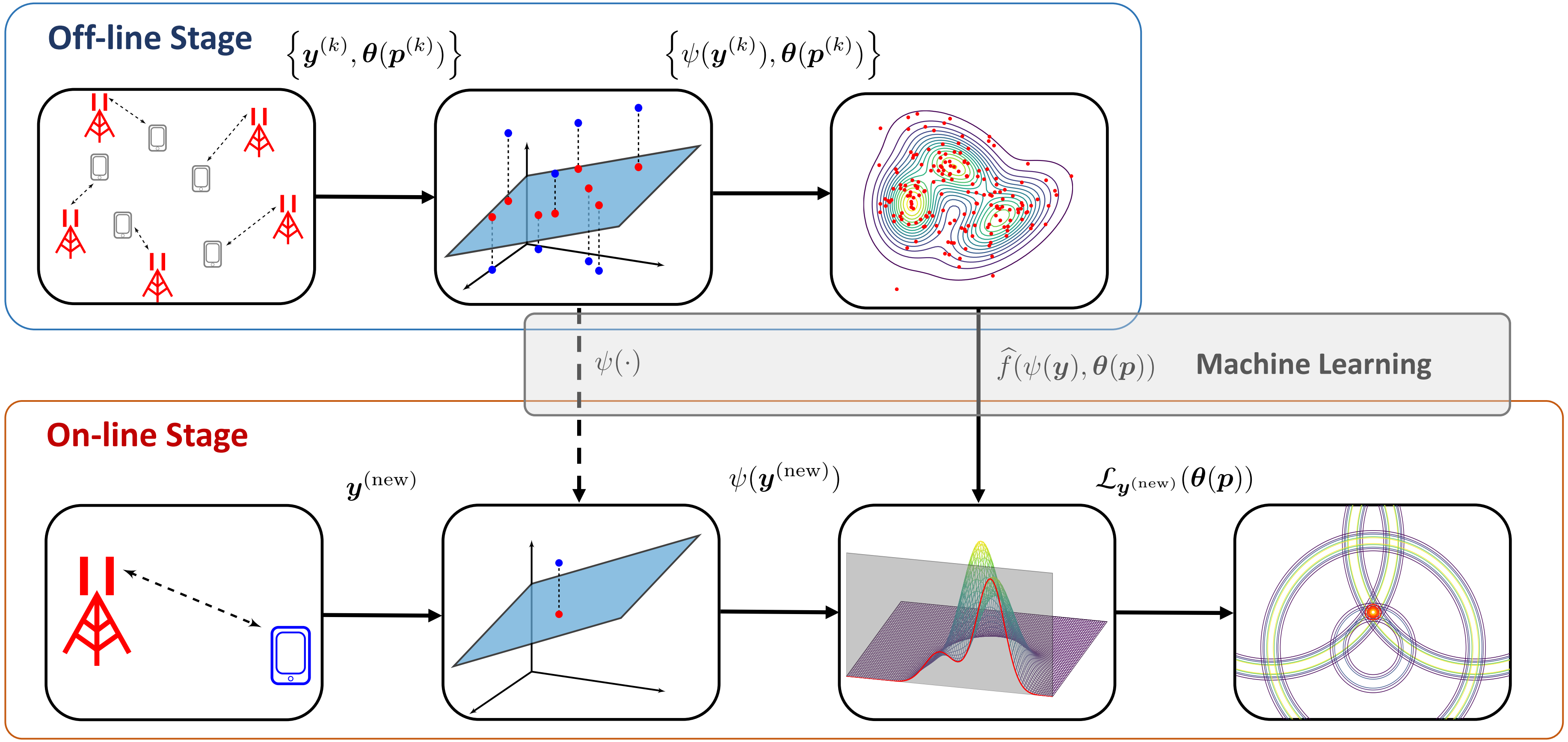
Example: 100 ns error

SVE-based

SI-based

A. Conti, S. Mazuelas, S. Bartoletti, W. C. Lindsey, and M. Z. Win, “Soft information for localization-of-things,” *Proc. IEEE*, Nov. 2019.

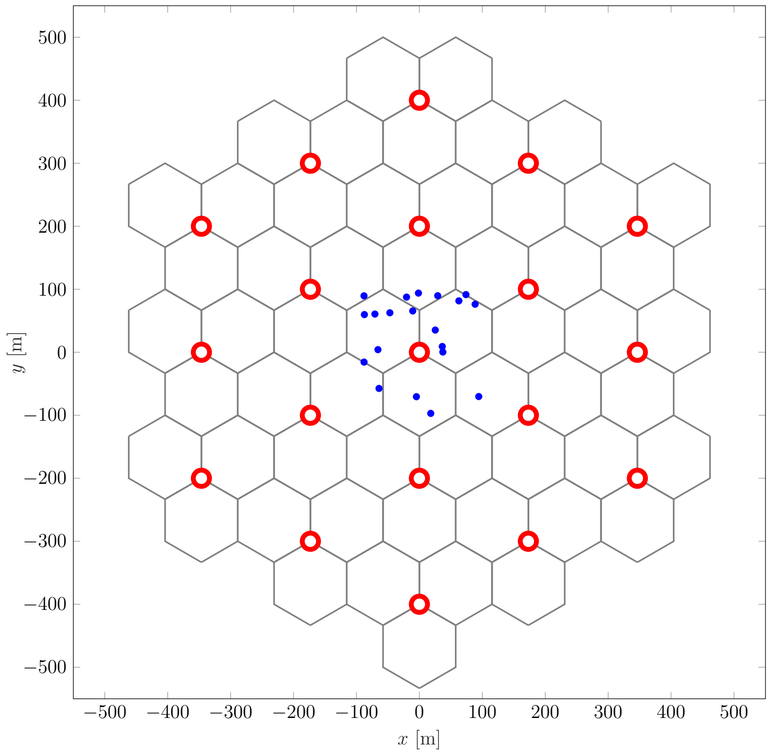
Methodology for Soft-Information

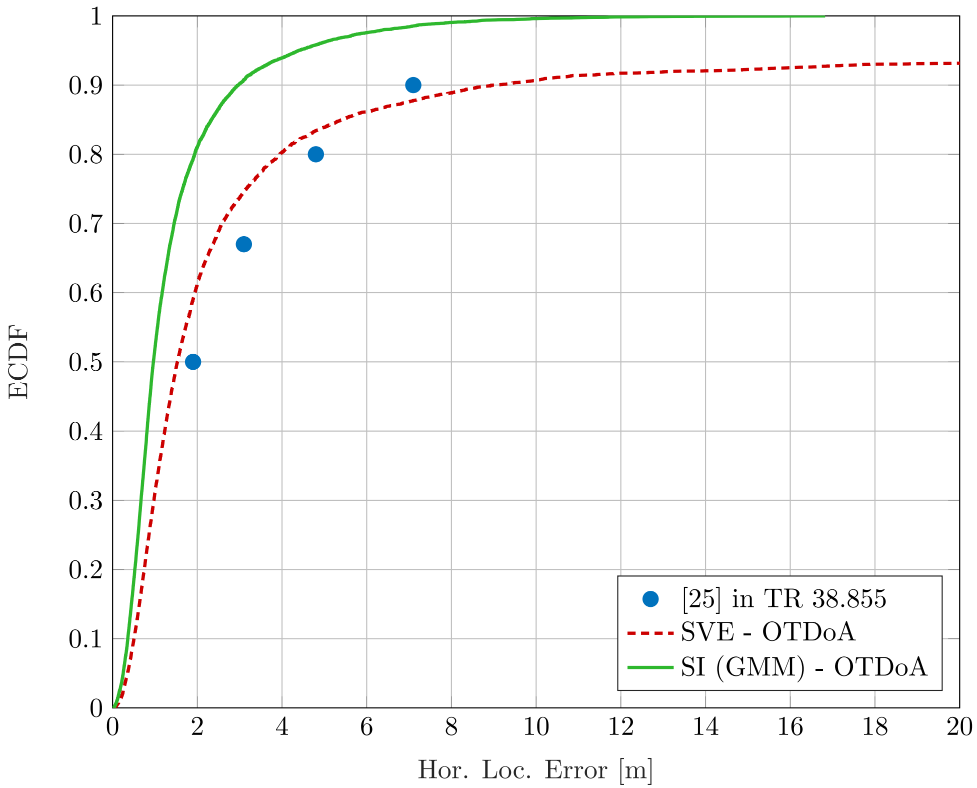


A. Conti, S. Mazuelas, S. Bartoletti, W. C. Lindsey, and M. Z. Win, "Soft information for localization-of-things," *Proc. IEEE*, Nov. 2019.

SI-based 5G localization

- **H2020 LOCUS project:** Localization and analytics on-demand embedded in 5G ecosystem, for ubiquitous vertical applications





Courtesy of the University of Ferrara/CNIT: preliminary results within the LOCUS project

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, e.g. safety-critical ones
- Extremely accurate synchronization 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; preliminary results show SI to outperform SOA localization methods

Thank you

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