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A Hybrid Localization Method for Mobile Station Location Estimation

C. Fritsche[#], A. Klein[#], H. Schmitz[*], M. Pakulski[**]

[#] TU Darmstadt, Institute of Telecommunications, Communication Engineering Lab, Merckstr. 25, 64283 Darmstadt, Germany
E-mail: [a.klein,c.fritsche]@nt.tu-darmstadt.de

[*] Nokia Siemens Networks GmbH & Co. KG, Siemensdamm 62, 13627 Berlin, Germany

[**] Nokia Siemens Networks GmbH & Co. KG, ul. Strzegomska 46A, 53-611 Wroclaw, Poland
E-mail: [heiko.schmitz,maciej.pakulski]@nsn.com

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Motivation (1)

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Mobile station localization

	Accuracy in m	Availability	
		Outdoor	Indoor / Dense Urban
Cellular Radio Network	50 – 550	✓	✓
Global Positioning System	5 – 100	✓	✗

Problem in indoor and dense urban scenarios

- Number of available GPS satellites is <u>not sufficient</u> for 3-D or even 2-D position fix with GPS
- Cellular radio network-based localization methods are almost everywhere available, but do not reach the accuracy of GPS

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Motivation (2)

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Idea

- The signal the mobile station (MS) receives from each GPS satellite provides information about the position of the MS
- Position information from each GPS satellite can be combined with position information available from the cellular radio network

Benefit

- Improved accuracy compared to cellular radio network-based localization methods

→ **Hybrid Localization Method**

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Outline

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- Problem of Combining Measured Values
- Hybrid Localization Principle
- Simulation Scenario
- Examples for Probability Density Functions
- Simulation Results
- Conclusion & Outlook

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Problem of Combining Measured Values

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Radio-based measured values	Satellite-based measured values
• Received Signal Strength (RSS) • Cell Global Identifier (CGI) • Timing Advance (TA) • Enhanced observed time difference (E-OTD)	• Time of Arrival (ToA)

Problem

$$\mathrm{RSS} + \mathrm{CGI} + \mathrm{TA} + \mathrm{E\text{-}OTD} + \mathrm{ToA} \neq \text{Position of mobile station}$$

- RSS: power
- CGI: object
- TA: integer
- E-OTD: time difference
- ToA: time
- Position of mobile station: (x,y,z)

→ Direct combination of measured values is not possible !

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Hybrid Localization Principle (1)

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Idea

Represent each measured value by its (conditional) probability density function ⟶ *Bayesian estimation approach*

Properties of probability density function

+ Gives the probability with which the MS is located at a certain position in a 2-D or 3-D space
+ Takes into account the different distributions of errors each measured value is affected with
+ Can be determined for any kind of measured value
+ Combination of different measured values is a simple multiplication of their conditional probability density functions

⟶ **Promising approach for a hybrid localization method**

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Hybrid Localization Principle (2)

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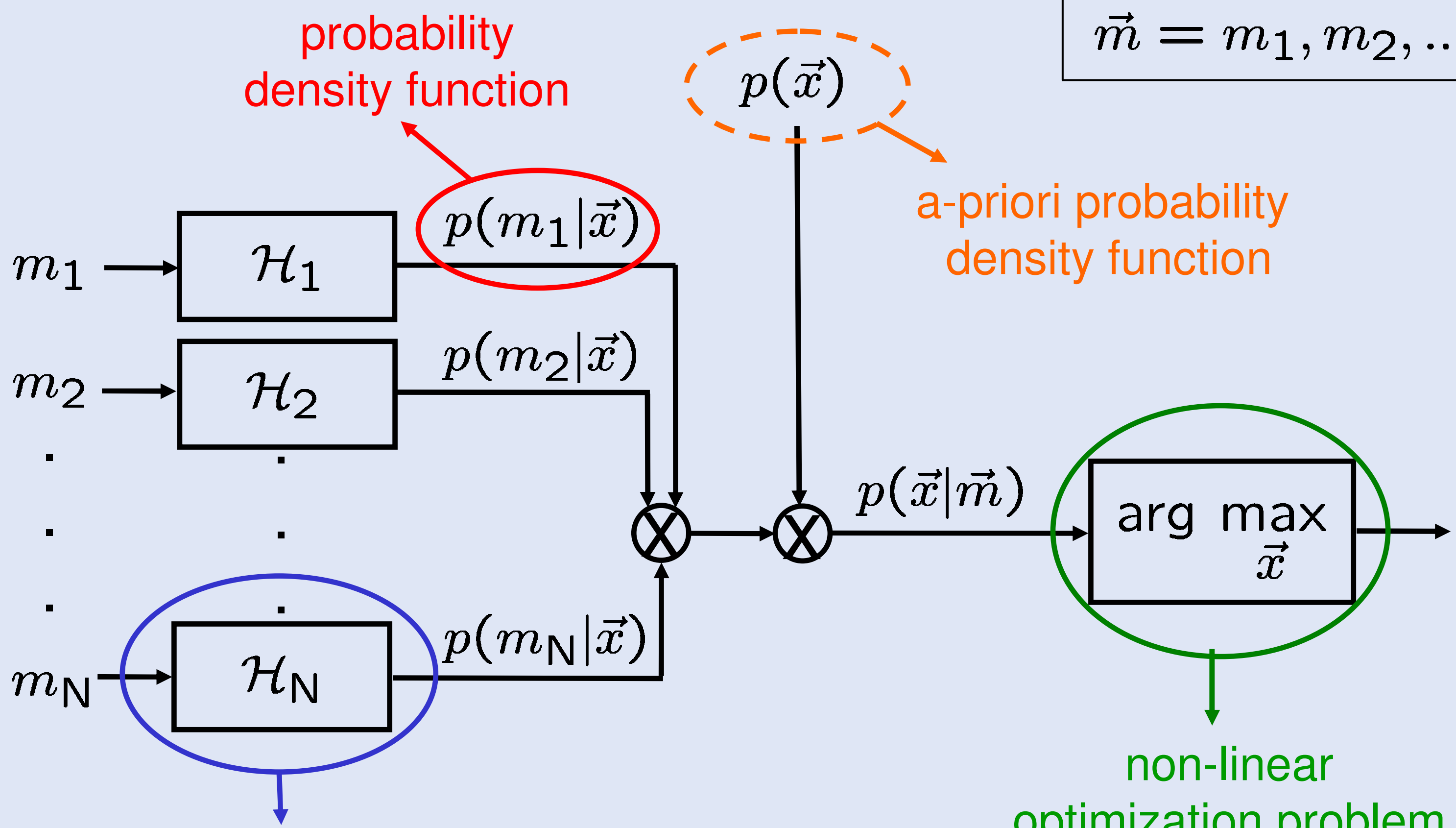
Maximum a-posteriori (MAP) estimator

$\vec{x}$ =possible MS position
$\hat{\vec{x}}$ =estimated MS position
$\vec{m} = m_1, m_2, ..., m_N$



- Functional relationship between measured value and location of MS
- Probability density function of errors

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Simulation Scenario (1)

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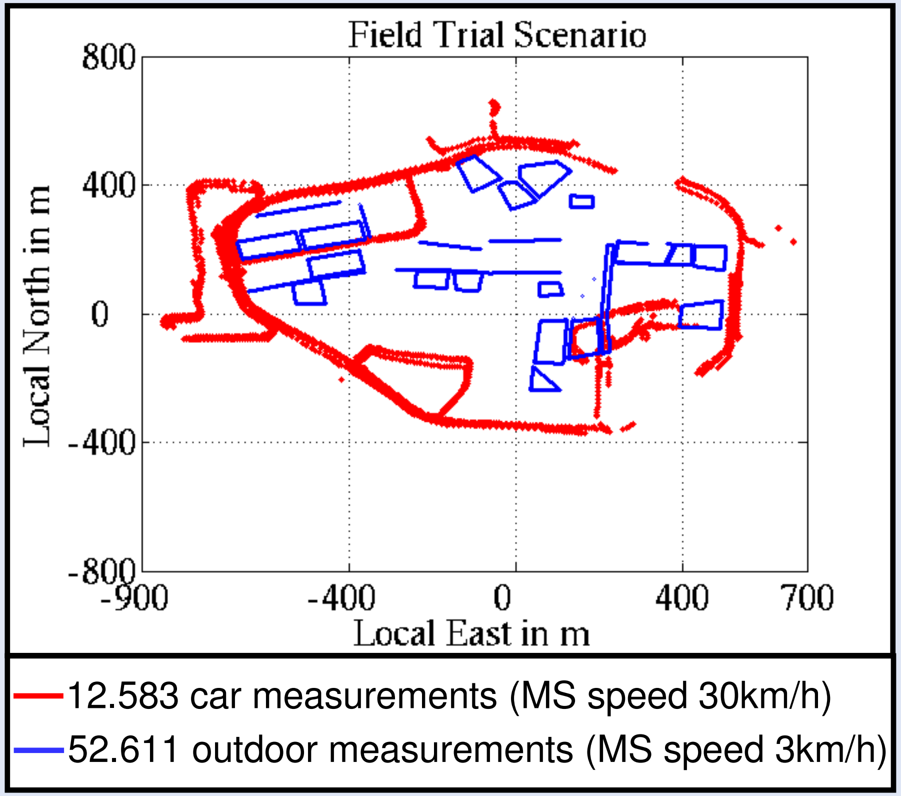
GSM network

- Field trial data available (car, outdoor)
- Dense urban scenario
- Base stations equipped with omni-directional or directional antennas
- GSM data reporting period: ≈ 0.5 s

GPS network

- No field trial data available
- Satellite positions are taken from real satellite constellation (GPS Almanac)
- GNSS simulator generates synthethic measured values (LOS or NLOS)
- GPS data is adjusted to reporting period of GSM field trial data



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Simulation Scenario (2)

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Combinations of measured values

- Timing Advance (TA) and Received Signal Strength (RSS) from serving base station (BS) and between one and six RSS values from neighbouring BSs (**GSM**)

- TA and RSS from serving BS and between one and six RSS values from neighbouring BSs and one Time of Arrival (ToA) measured value from one satellite (**Hybrid 1**)

- TA and RSS from serving BS and between one and six RSS values from neighbouring BSs and one ToA measured value from each of a total of two satellites (**Hybrid 2**)

- One ToA measured value from each of a total of two satellites (**2 Satellite**)

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Simulation Assumptions

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- Fixed local Cartesian East-North-Up coordinate system
- Uniform a-priori probability density function
- MS is time-synchronized to GPS
- Error distributions of statistical model for RSS, TA and ToA measured values are Gaussian:

i	μ_i	σ_i
RSS	0 dB	6-10 dB
TA	depends on TA value	2 µs
ToA	0 µs	0.027 µs

user equivalent range error

- 2-D MS location is estimated
- Snapshot-based evaluation of algorithm

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Examples for Probability Density Functions (1)

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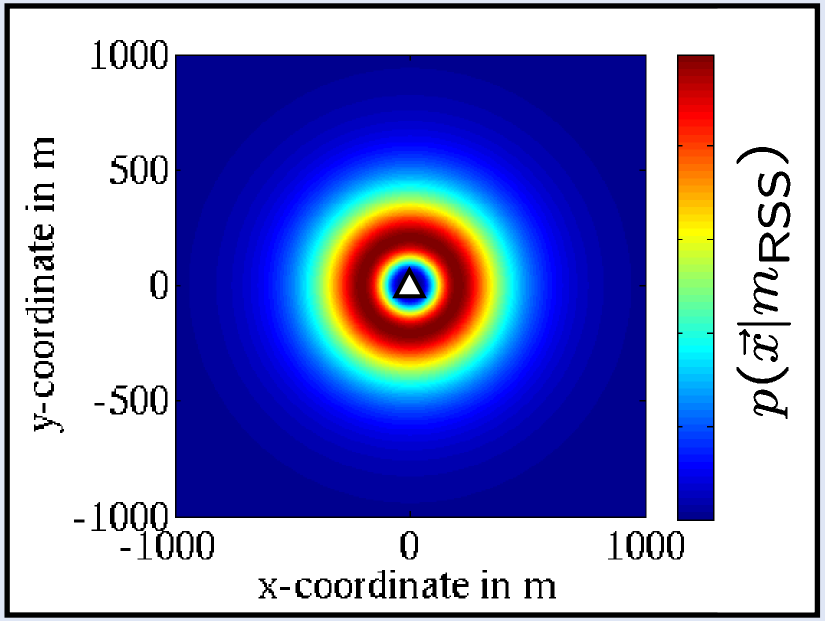
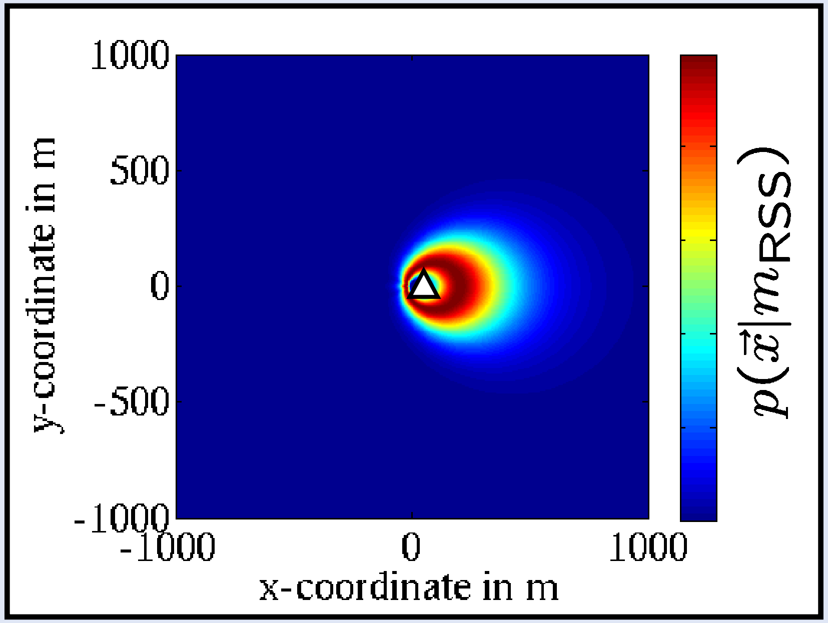
Received Signal Strength



omnidirectional antenna



sectorized antenna

△ Base station

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Examples for Probability Density Functions (2)

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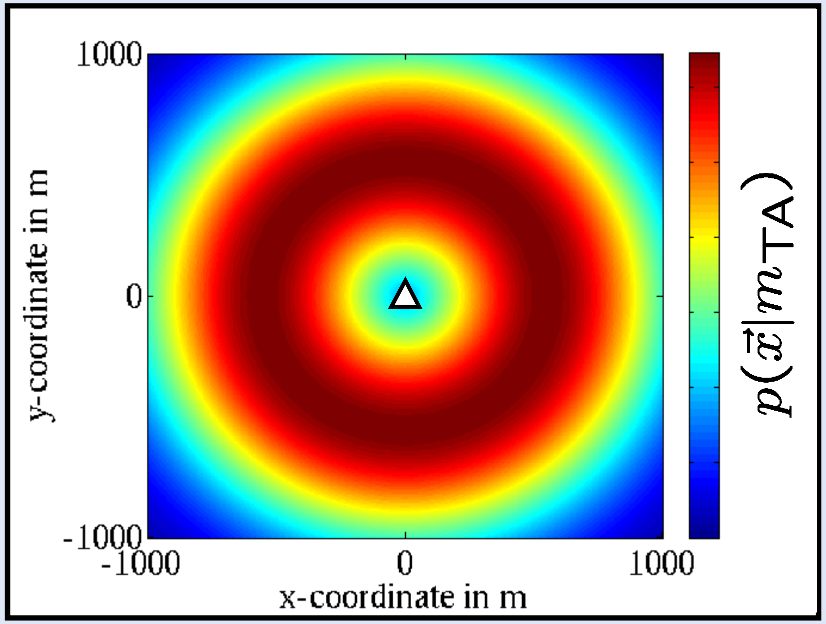
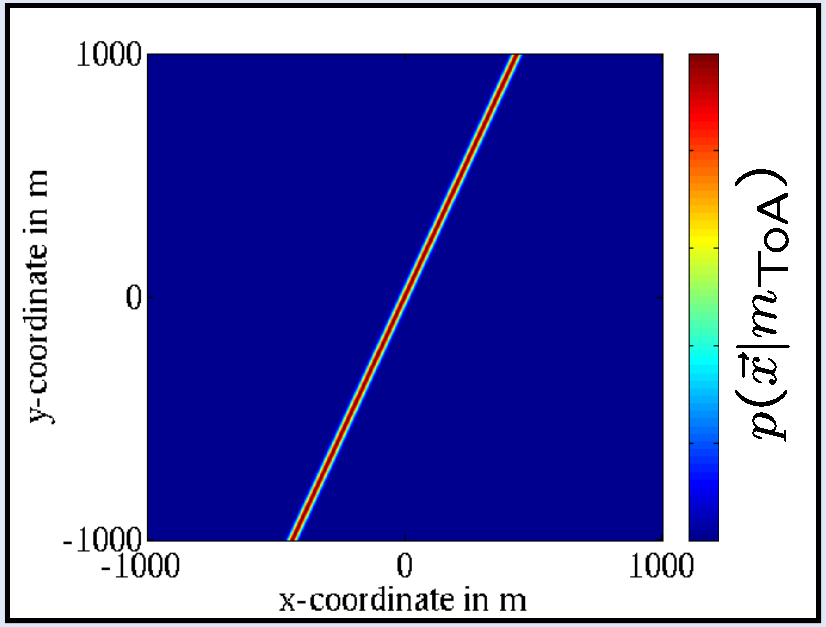
Timing Advance



Time of Arrival



△ Base station

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Simulation Results (1)

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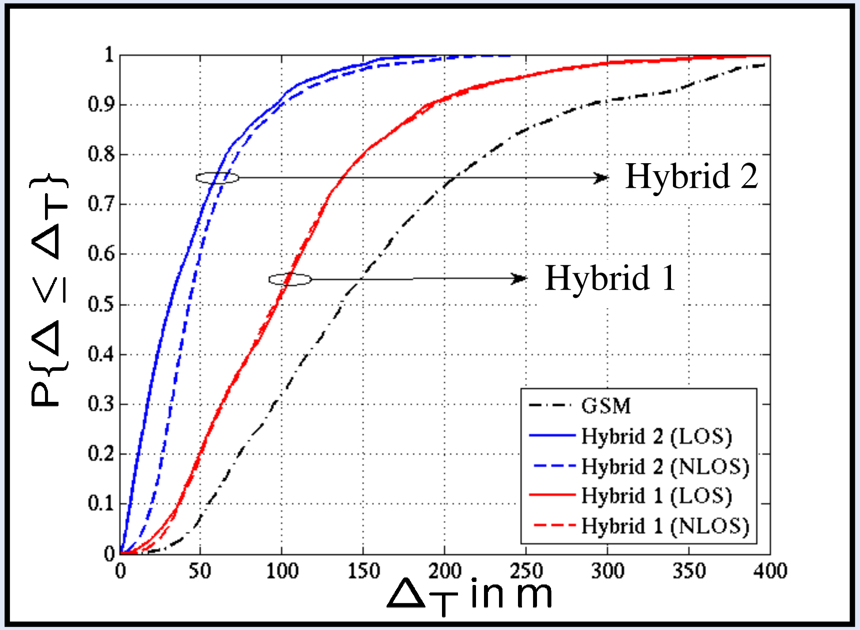
Localization error $\Delta = ||\vec{x} - \hat{\vec{x}}||_2$

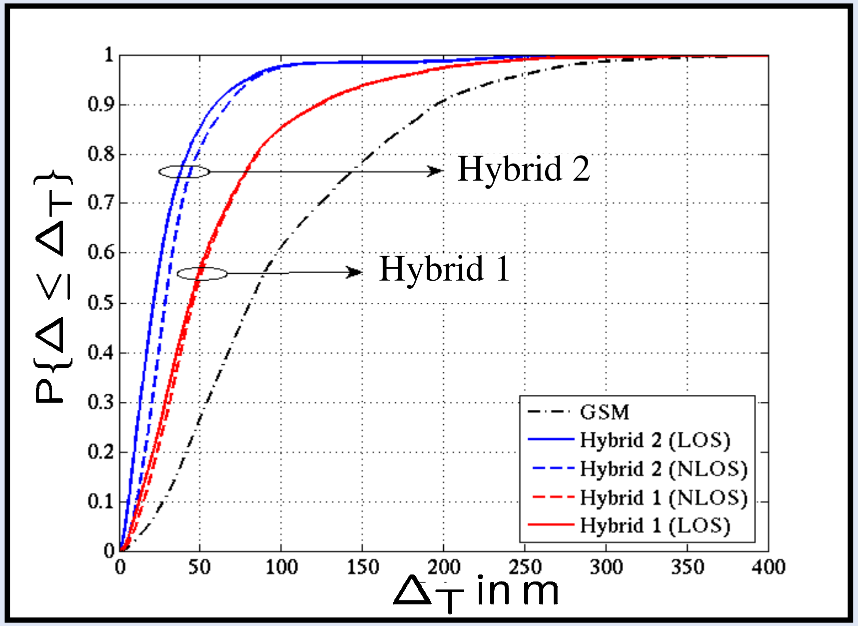
Δ = distance between true and estimated MS location

$P\{\Delta \leq \Delta_T\}$ = Probability that the localization error Δ falls below the threshold Δ_T

Car field trial



Outdoor field trial



➡ **Incorporation of satellite measured value significantly improves the localization accuracy**

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Simulation Results (2)

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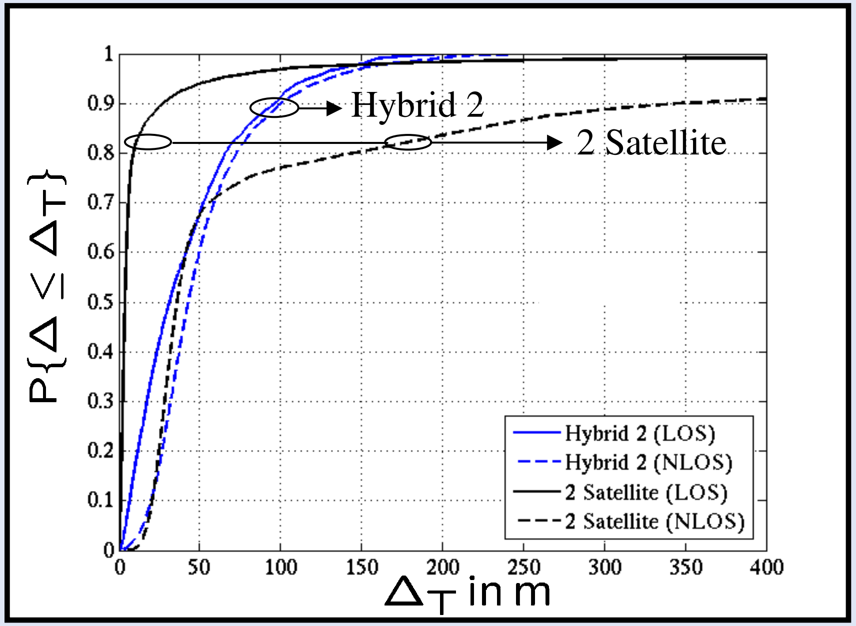
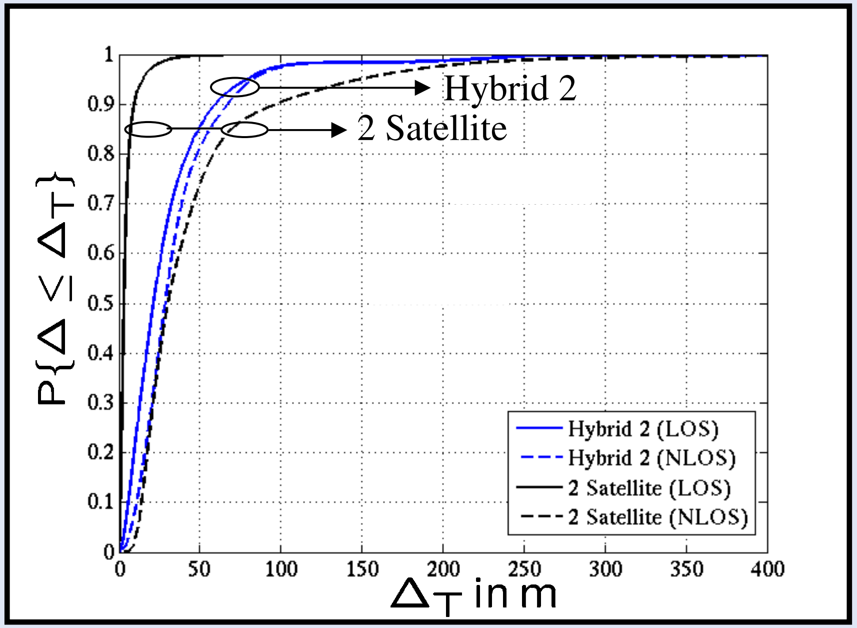
Hybrid 2 method vs. 2 Satellite method

Car field trial



Outdoor field trial



→ **In LOS situations, the 2 Satellite method outperforms the Hybrid 2 method**

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Conclusion & Outlook

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- Hybrid localization method significantly improves the localization accuracy
- Hybrid localization method is easily extendable to other measured values (e.g. E-OTD, AoA)
- Implementation of hybrid localization method into mobile terminals possible in the near future
- Hybrid localization method can be easily applied to measured values of other systems (e.g. UMTS, WLAN or UWB)
- Enhance hybrid localization method by continously estimating the mobile station location (e.g. Extended Kalman Filter, Particle Filter)

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Thank you for your attention