P2P Positioning

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    a. GNSS + ranging between users

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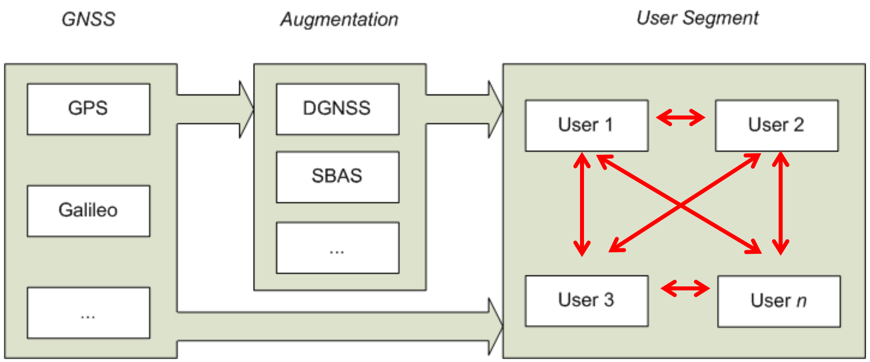
Introduction P2P Positioning (1 of 2)



- Traditionally, GNSS uses a one-directional flow of signals/data to users
- In P2P Positioning, GNSS-users exchange signals/data
- Goal P2P Positioning:

Improved navigation in difficult environments (e.g. indoor, interference, …)

Introduction P2P Positioning (2 of 2)

1. Benefits P2P Positioning:
    - Limited costs compared to augmentations (e.g. no reference stations required)
    - Very high number of GNSS-users → High density peers

      (http://www.isuppli.com: Q4 2011: ± 80% of mobile phones incorporates GPS)
    - Environments of nearby peers almost identical

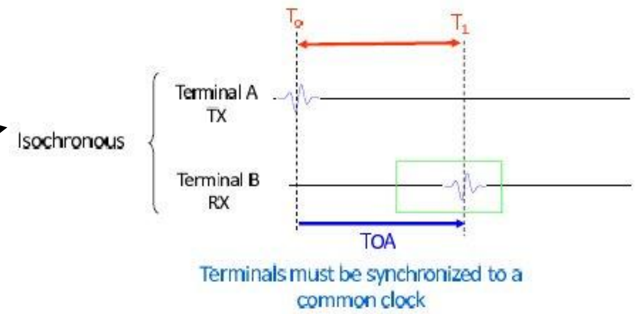
- Categories of P2P Positioning:
  1. Exchange of data and signals for <u>ranging between users</u>
  2. Exchange of <u>GNSS-data only</u>

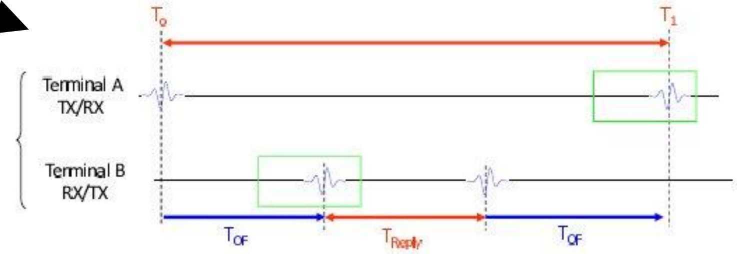
     (i.e. without ranging between users)

Exchange of data and signals for ranging between users

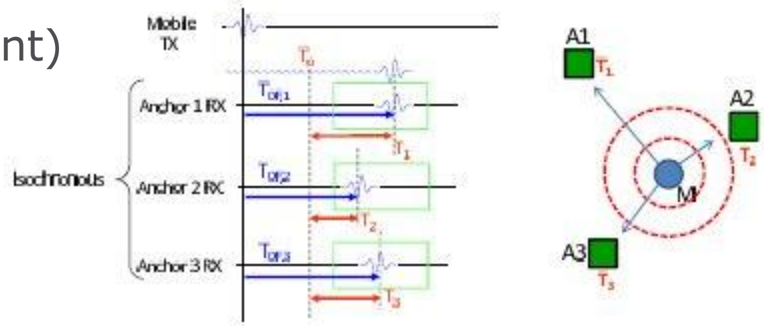
Terrestrial ranging

1. Techniques:
   a. Received Signal Strength
   b. Time Of Arrival:
      – One-way Ranging
      – Two-way Ranging
   c. Time Difference of Arrival
   d. Angle of Arrival
   e. Interferometry

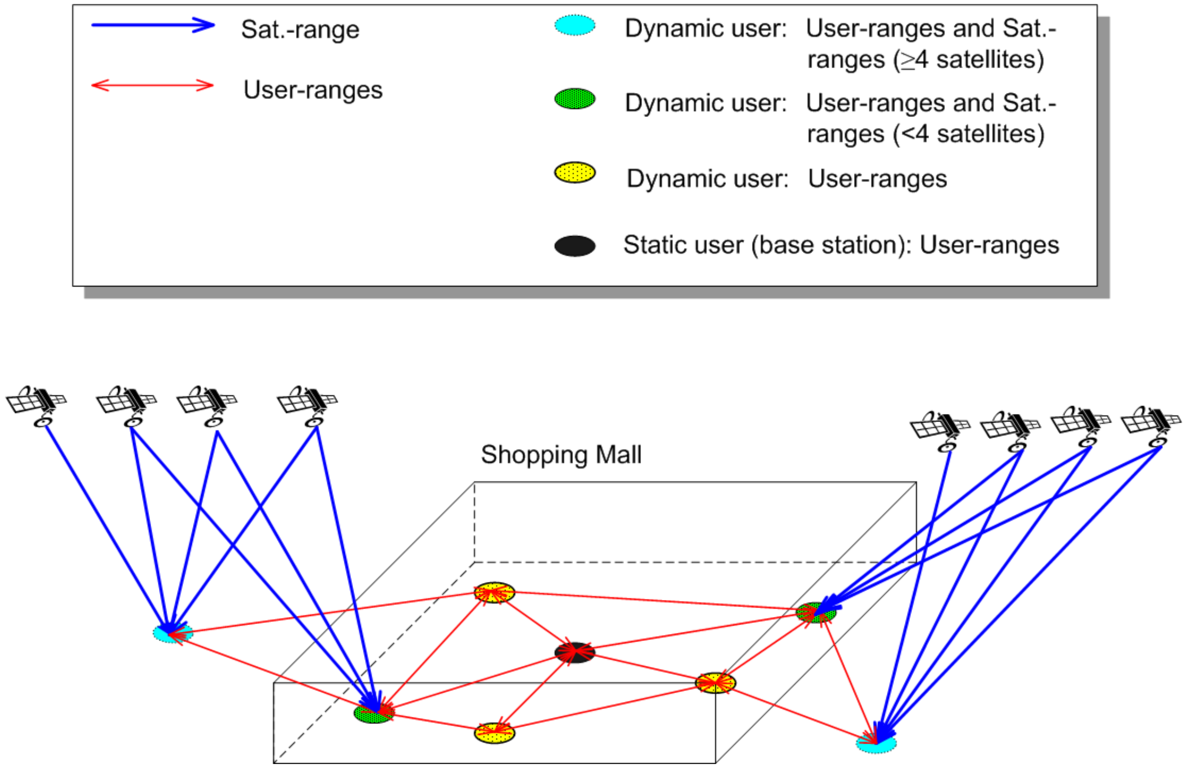




2. Systems:
   a. UWB
   b. WAVE
   (Wireless Access in Vehicular Environment)
   a. WLAN
   b. Bluetooth
   c. Etc.



Hybrid P2P scenario



Given a certain geometry, accuracy of pseudo-ranges and terrestrial ranges:

What are the optimal distributed algorithms ?

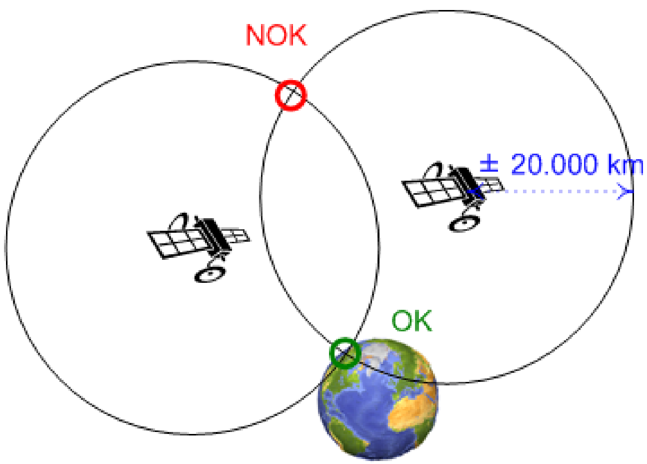
(Optimising convergence, accuracy, and availability, minimising data traffic)

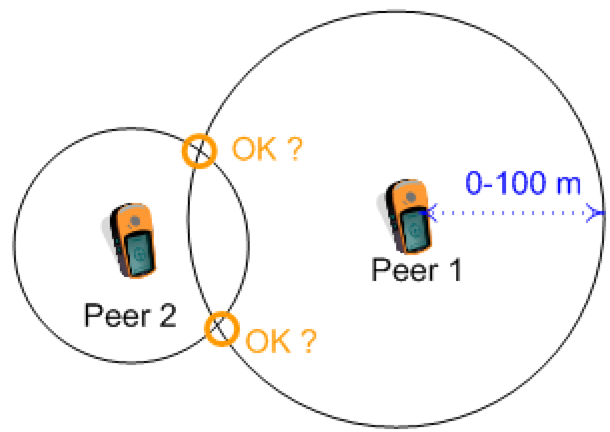
Algorithm: Least Squares

For GNSS, Iterative Linearized Least Squares is the default positioning algorithm

However, Least Squares may not be optimal for the P2P-scenario:

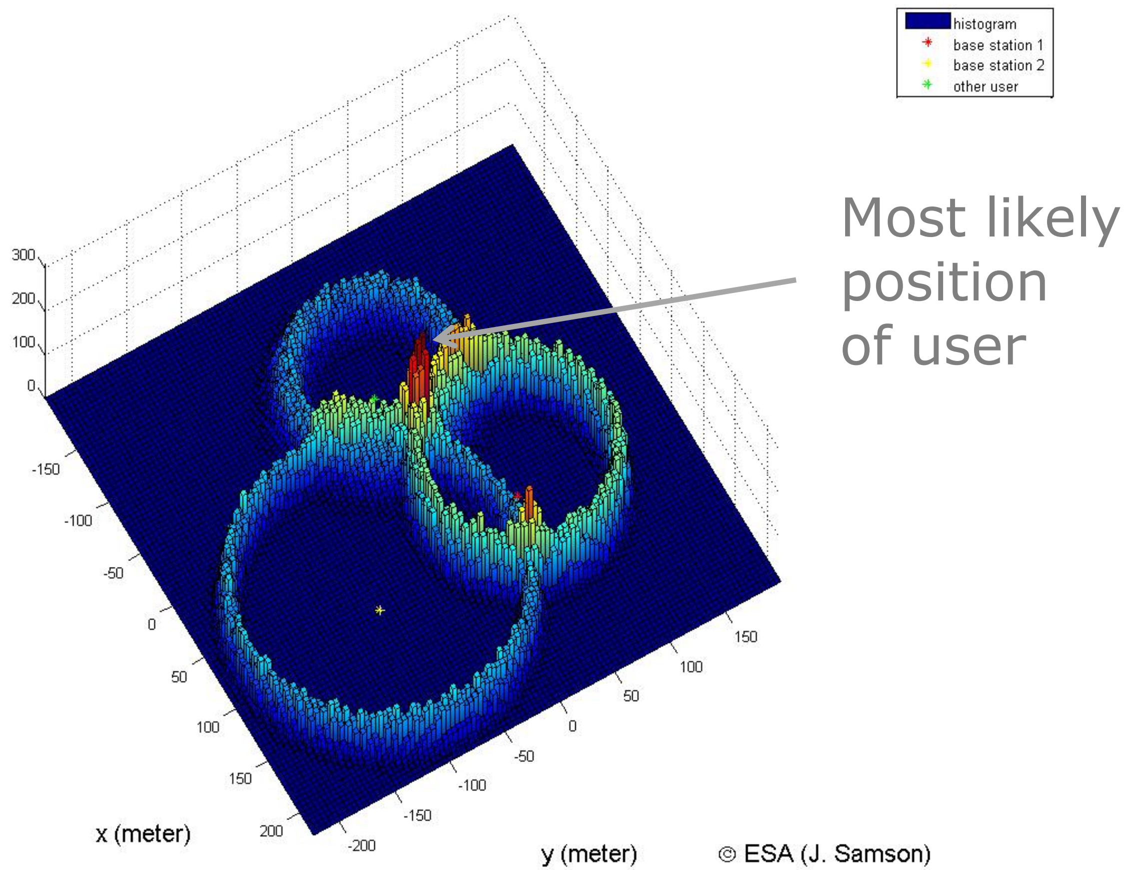
1. Usually, For P2P, we do not always have a good a-priori position
   (For GNSS, we can always assume we are near the earth surface)
1. For P2P, we have short ranges → linearization may be an issue
   (For GNSS, equidistance circles to satellites may be approximated by straight lines at the earth surface)





Algorithm: Probabilistic approach (1/2)

1. Range measurements to:
    a. base station 1
2. Range measurements to:
    a. base station 1
    b. base station 2
3. Range measurements to:
    a. base station 1
    b. base station 2
    c. other user



Algorithm: Probabilistic approach (2/2)

1. Pdf's exchanged in Messages:
   a. Temporal (user mobility):

$$\mathcal{M}_{f_m \to m}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) := \mathcal{N}_{\tilde{\boldsymbol{x}}_m^{(t)}}\left(\boldsymbol{\mu}_{\tilde{\boldsymbol{x}}_m^{(t)}}, \Sigma_{\tilde{\boldsymbol{x}}_m^{(t)}}\right).$$

   b. Satellite-ranges:

$$\mathcal{M}_{g_{sm} \to m}^{(t)}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) := \mathcal{V}_{\tilde{\boldsymbol{x}}_m^{(t)}}\left(\rho_{sm}^{(t)}, \boldsymbol{x}_s^{(t)}, \sigma^2_{\rho_{sm}^{(t)}}\right)$$

   c. Ranges between peers:

$$\mathcal{M}_{h_{nm} \to m}^{(t)}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) := \mathcal{C}_{\tilde{\boldsymbol{x}}_m^{(t)}}\left(r_{nm}^{(t)}, \boldsymbol{\mu}_{\boldsymbol{x}_n^{(t)}}, \sigma^2_{r_{nm}^{(t)}} + \operatorname{tr}\Sigma_{\boldsymbol{x}_n^{(t)}}\right)$$

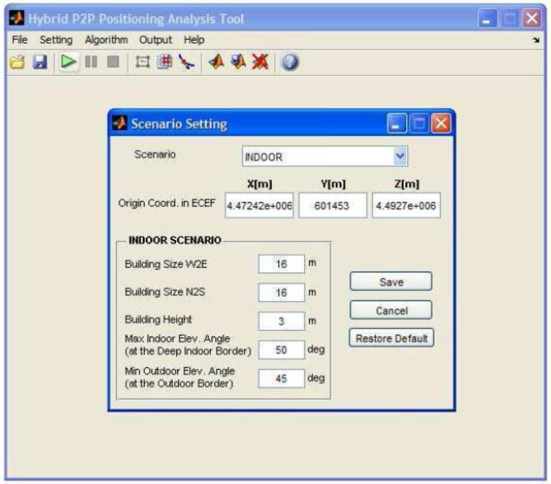
2. Pdf of User Position computed by Message Multiplication:

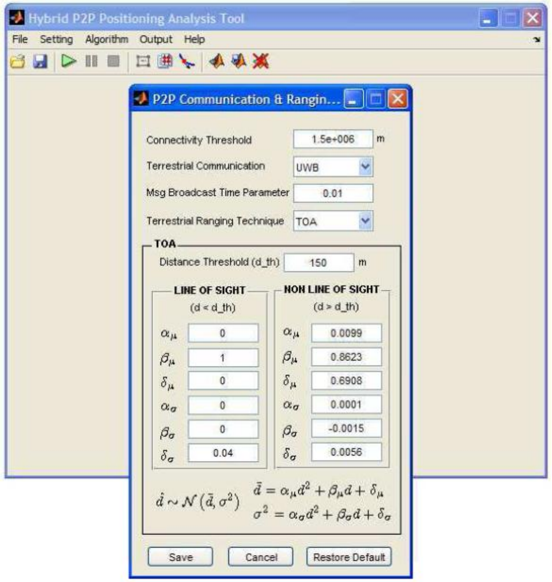
$$\hat{p}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) \propto \mathcal{M}_{f_{\tilde{\boldsymbol{x}}_m} \to \tilde{\boldsymbol{x}}_m^{(t)}}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) \prod_{s \in \mathcal{S}_m^{(t)}} \mathcal{M}_{g_{sm} \to \tilde{\boldsymbol{x}}_m^{(t)}}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right) \prod_{n \in \mathcal{M}_m^{(t)}} \mathcal{M}_{h_{nm} \to \tilde{\boldsymbol{x}}_m^{(t)}}\left(\tilde{\boldsymbol{x}}_m^{(t)}\right)$$

P2P Simulator

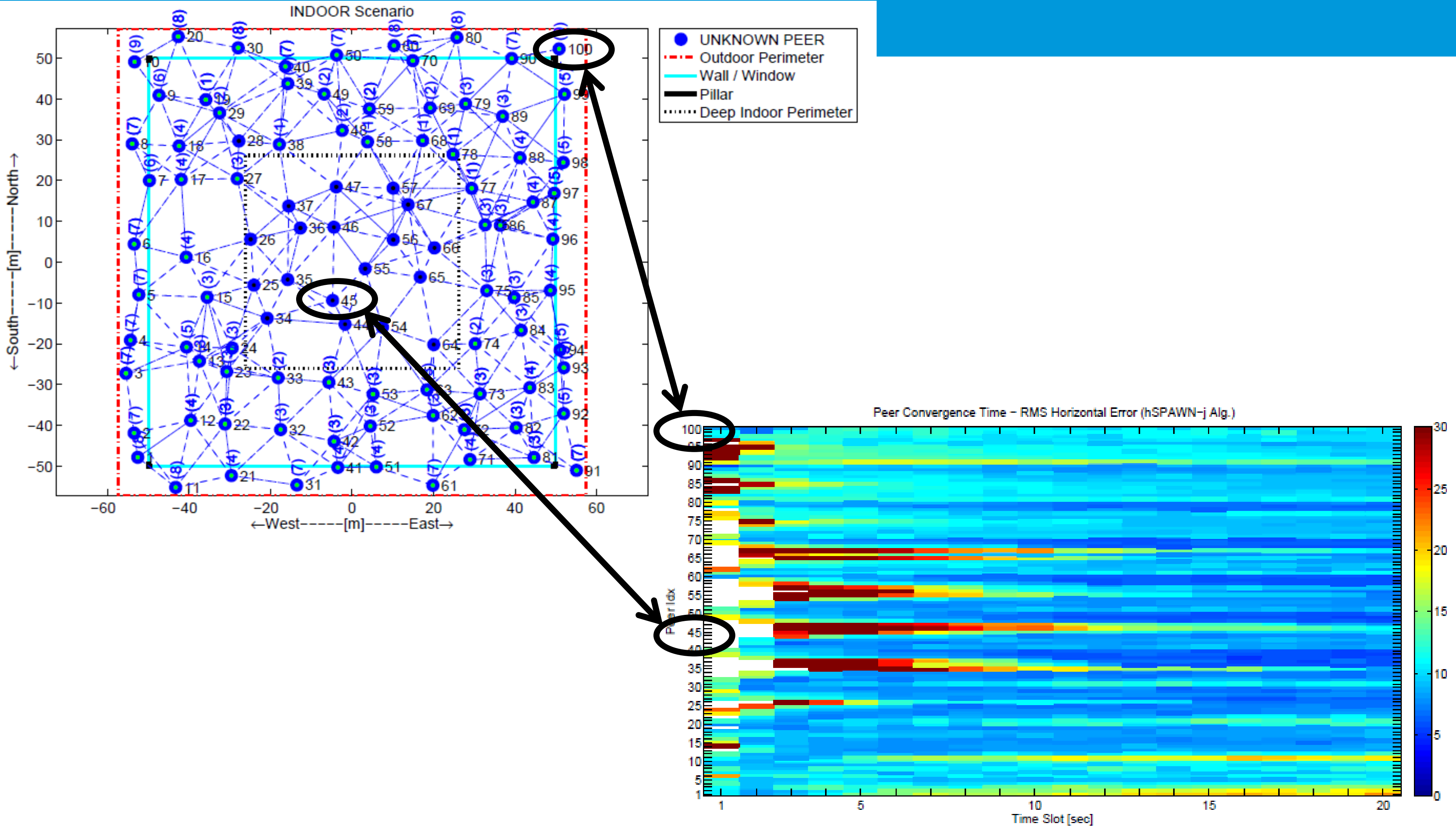
Settings:

1. Scenario (indoor / urban)
2. Network (nr. of peers / anchors)
3. Radio com. (UWB / WAVE)
4. Ranging parameters
5. Connectivity
6. Mobility (static / pedestrian / vehicle)
7. Algorithm:
    a. Sum-Product Algorithm over a Wireless Network
    b. Kalman Filter
    c. Particle Filter
    d. Least Squares





P2P Simulator: results



Exchange of GNSS-data only

Exchange of GNSS-data only

Aiding	Concept
Interference detection and mitigation	High-end RX’s provide information on interference to nearby low-end RX’s
Altitude Aiding	Nearby users share information on altitude; 3 instead of 4 satellites needed for positioning
Acquisition Aiding	Discussed in the next sheets

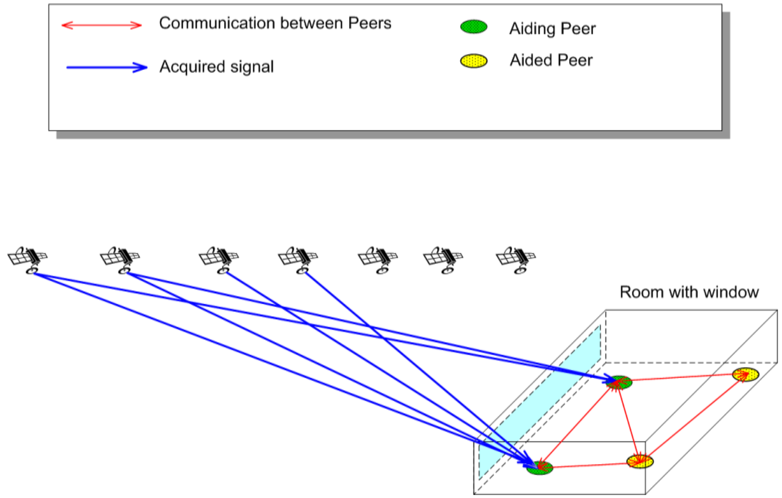
P2P Acquisition Aiding – Description

1. Scenario description

a. Cluster of ***N*** peers:
   - ***M*** aided peers (acquisition still to be performed), ***M* < *N***
   - ***N* - *M*** aiding peers (acquisition already performed)

b. Aiding peers sharing satellite information for aided acquisition

c. Reference signal: Galileo E1C (Mass Market Rx)



P2P Acquisition Aiding – Strategy (1 of 2)

1. **Physical layer: sharing of satellite information**
   1. **Doppler frequency shift** ($f_{d,m}$) estimated by aiding peers
   2. **Secondary code delay** ($t_{S,m}$) w.r.t. current time
   3. **Carrier-to-Noise ratio** ($C/N_{0,m}$) measured by aiding peers

$$\bar{g}_{LI} = \sum_{m=1}^{N_{pr}-1} \alpha_m \hat{g}_m$$

Weighted average of data coming from aiding peers, useful for aided acquisition ($\bar{g}_{LI}$)

Generic satellite information from the aiding peers ($\hat{g}_m$)

Weights, depending on the reliability of aiding information (α_m)

P2P Acquisition Aiding – Strategy (2 of 2)

- **Shared by peers for improving acquisition performance:**

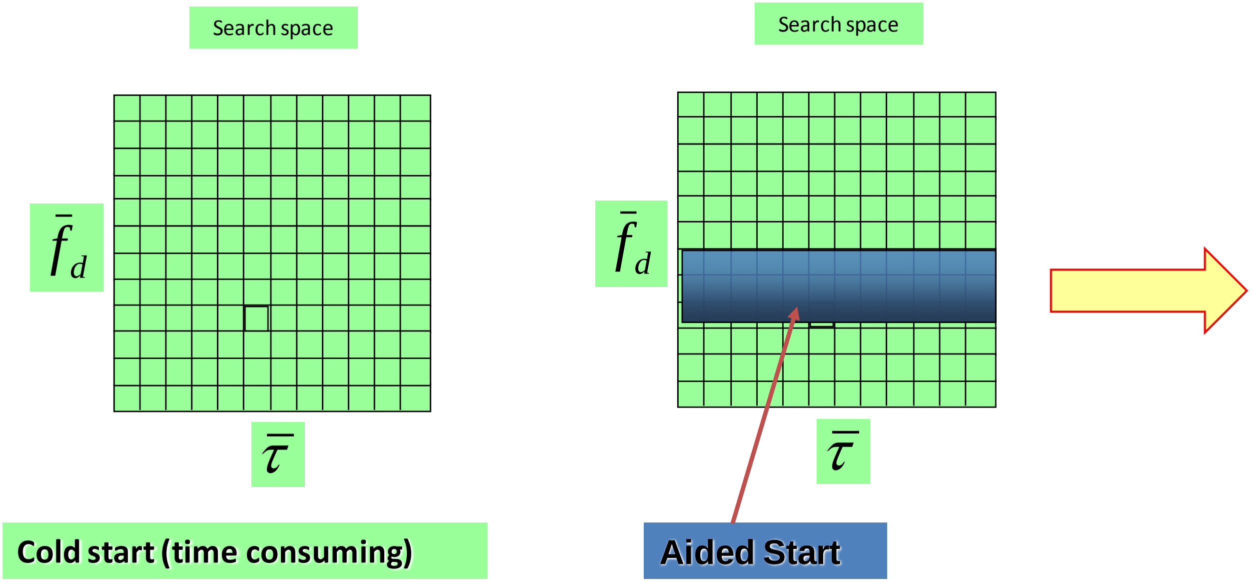
a. Exploit information from peers for reducing the Doppler uncertainty
b. Wiping off the secondary code and reduce the search space size
c. Start acquiring satellites with higher expected C/N_0 values
d. Increase the integration time in case of low expected C/N_0

Comparison to AGNSS context:

- Doppler:
  In AGNSS-standard, beneficial
- Secondary code delay:
  Not in standard, could be beneficial
- C/N0:
  In standard, not beneficial

Aiding parameter 1: Doppler aiding

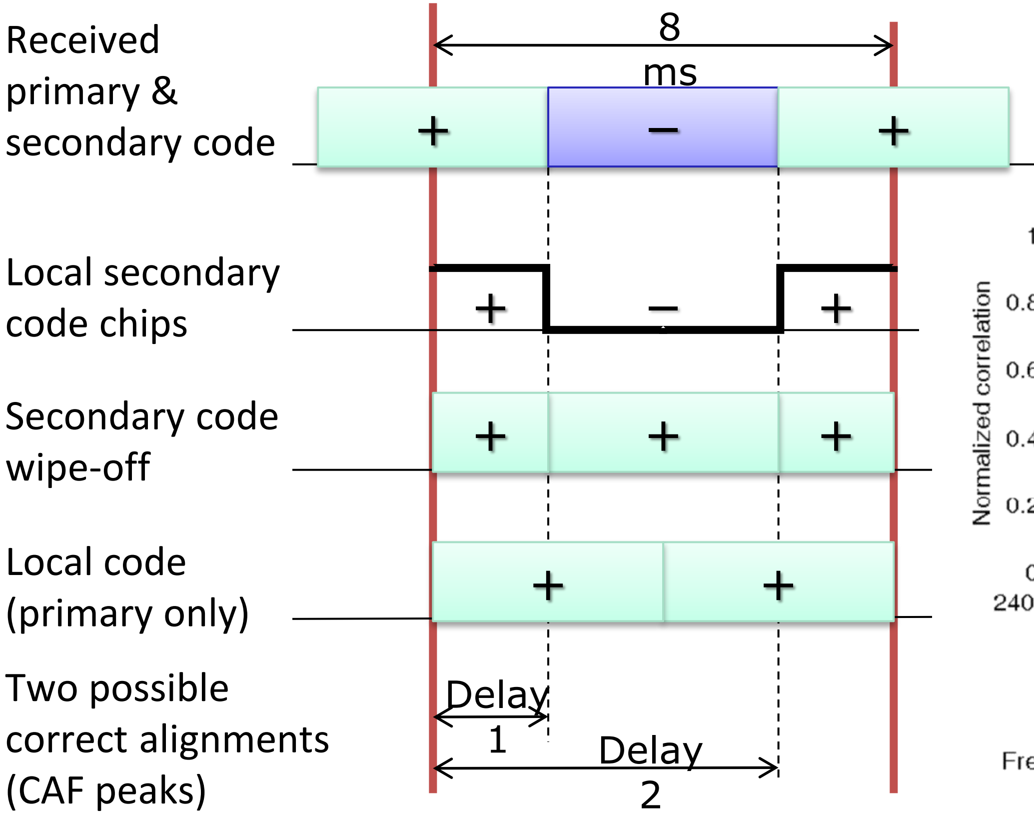
1. **Doppler aiding for signal acquisition**
    a. Cross-ambiguity Function (CAF) computed only in few frequency bins
    b. Reduction of the size of search space for the aided peer



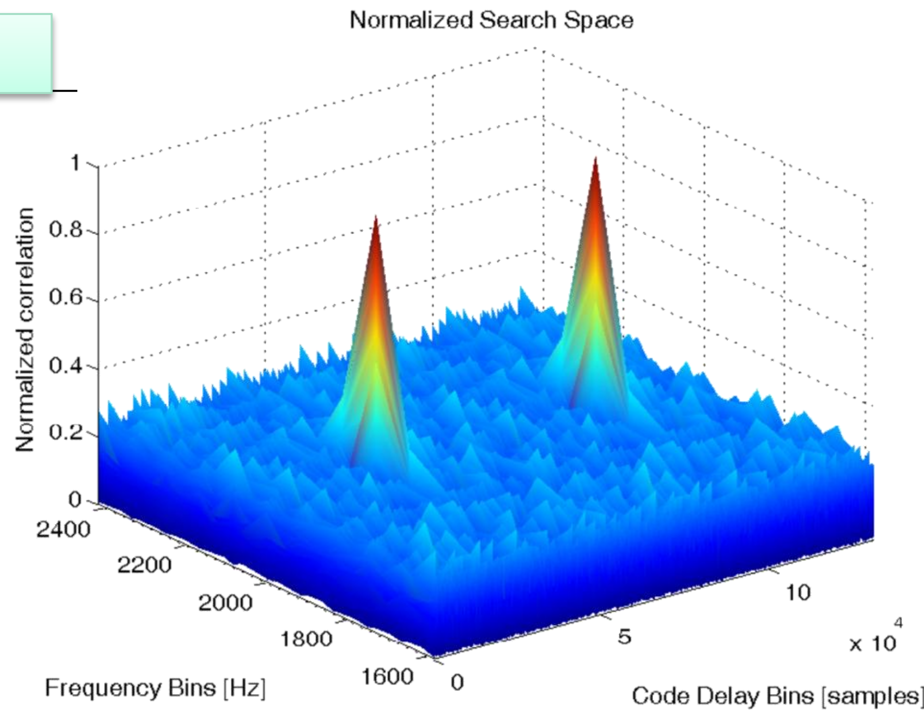
Decrease of 'Mean Acquisition Time' (MAT)

Aiding parameter 2: Secondary Code Wipe-off

- **Parallel FFT acquisition with secondary code wipe-off**
  a. **Tailored to Galileo E1 pilot channel**



Cross-Ambiguity Function (CAF)



Aiding parameter 3: C/N0 aiding (1 of 3)

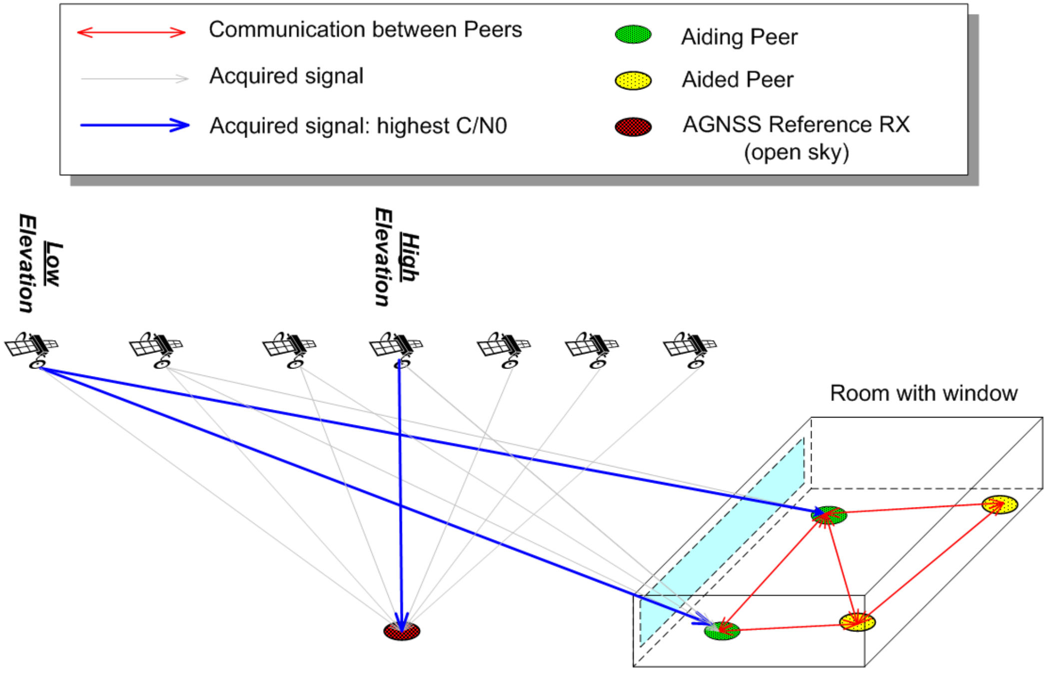
1. **C/N0 aiding for signal acquisition**
    a. A peer can **average C/N0 values** estimated by other peers
    b. Start acquiring satellites with **higher expected C/N0**
    c. Select an **adequate number of coherent and non-coherent integrations**

⬇

- **Decrease of MAT w.r.t. AGNSS case**

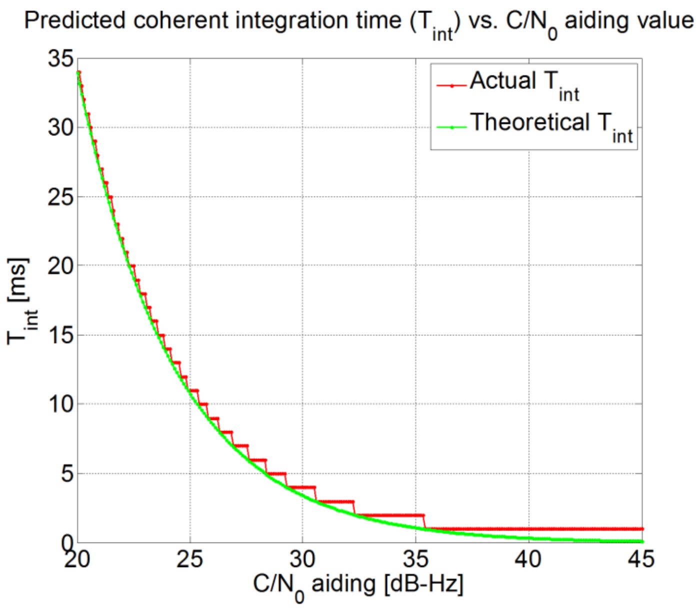
Aiding parameter 3: C/N0 aiding (2 of 3)

1. Start acquiring the 4 satellites with highest expected C/N0 → Faster TTFF (reduced initial accuracy)



Aiding parameter 3: C/N0 aiding (3 of 3)

1. **Setup of coherent integration time depending on:**
   - SNR_C at correlator output
   - RX front-end bandwidth *B*
   - Estimated C/N_0
   - Non-coherent accumulations *(L)*



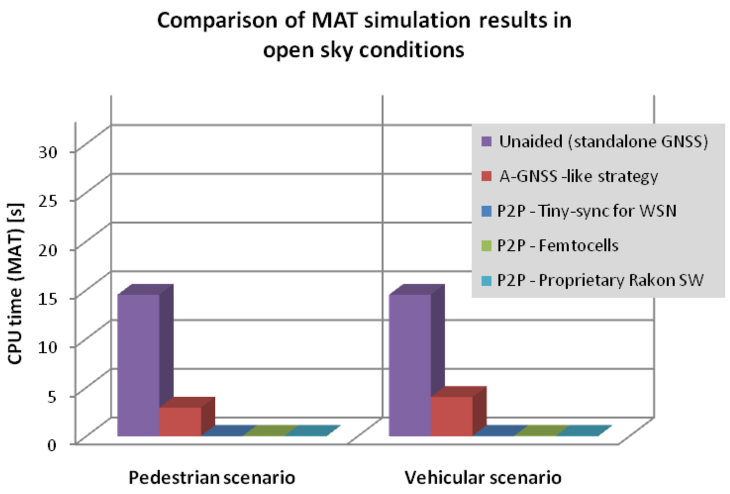
Comparison results to AGNSS

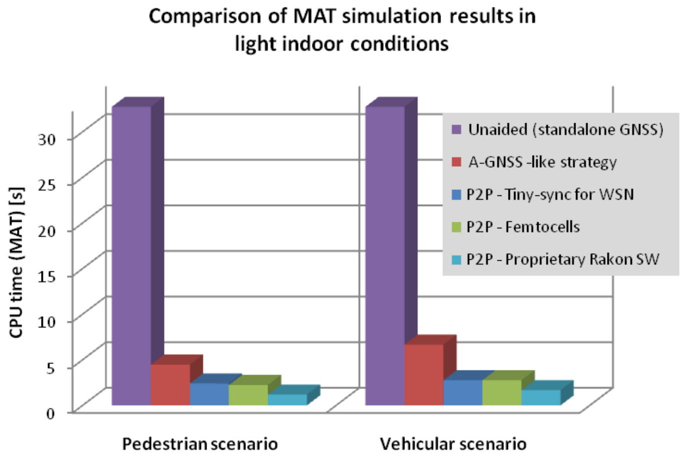
- Results in in **open sky conditions** (C/N_0 = 45dBHz) and **light indoor conditions** (C/N_0 = 32dBHz)

- Results obtained by using real data collected from GIOVE-A satellite in a **P2P experimental setup** and post-processed in order to simulate **pedestrian or vehicular scenarios**

- **Mean Acquisition Time** (MAT) estimated in terms of CPU time by means of MATLAB simulations

- **Unaided** (Standalone GNSS) vs **A-GNSS-like** approach vs **P2P aided acquisition strategy** (considering 3 different synchronization techniques)





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Thank you, Any questions?