Seamless Outdoors-Indoors Navigation for the Internet of Everything

Focus on RF SIGNALS ISSUES!

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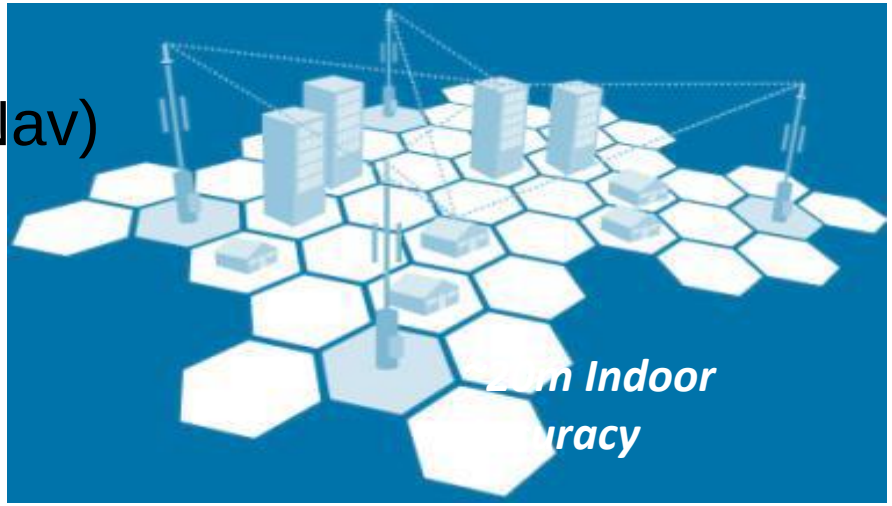
Outline

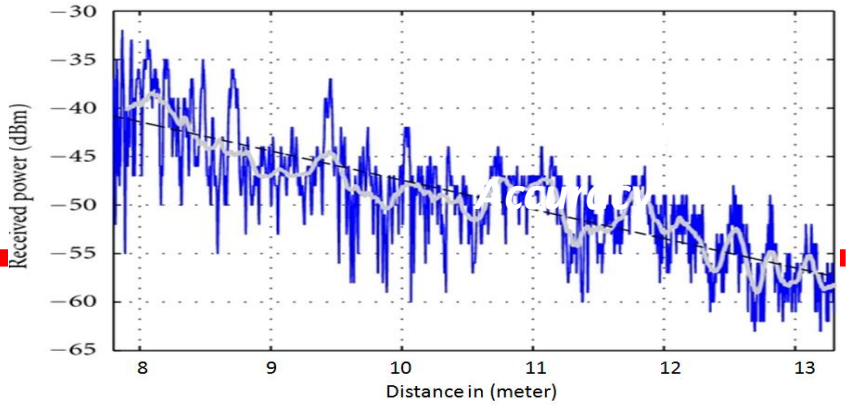
- Will WiFi & Bluetooth plus GNSS help locate indoors?
  - Status of current indoors localization
  - Cooperative localization may help for infrastructure-less solutions?
- Our proposed SILS (Seamless Indoors Localisation Scheme)
  - Forming Smartphones network via Bluetooth
  - Sync WAPs clock-time with GNSS to estimate their location
  - Locate participating Smartphones indoors
- SILS Implementation and results:
  - Range measurement using Bluetooth hop-synchronization & GNSS time
  - Switching Master/Slave & Permutation references for better accuracy
- Conclusions and future work

Status of current indoors localization solutions

- Time-based Solutions (eg. NextNav)
  - Need sub-nano-second resolution
  - LOS
  - Poor geometry due to DOP

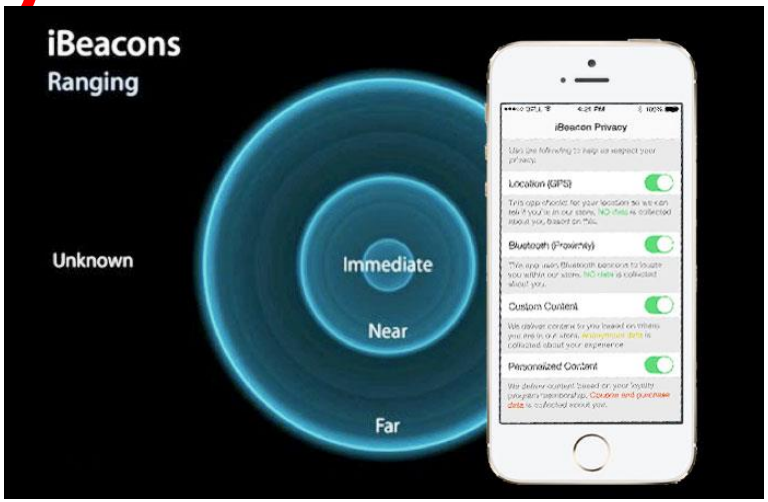


- RSS Solutions (eg. Skyhook)
  - Non-uniform shadowing



Indoors WAPs/SN anchors give better accuracy

- eg. BLE-iBeaconing
  - Calculate estimated Pseudo ranges to BLE anchor sensors using RSSI (Immediate, Near, Far, Unknown)
  - 1-2 meter accuracy

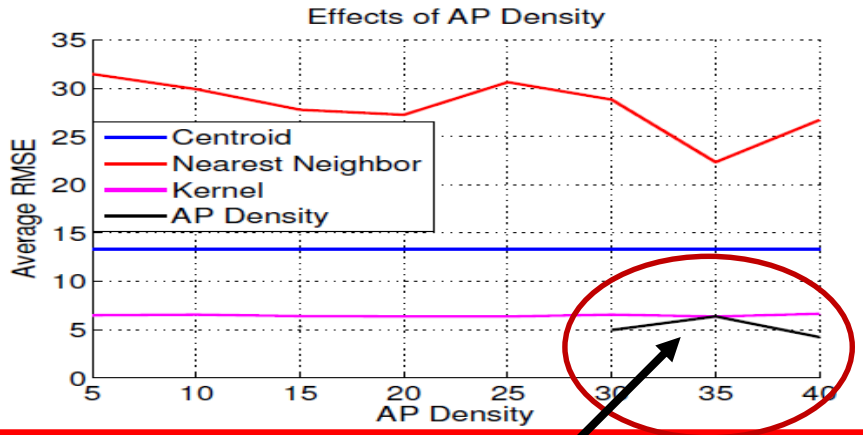


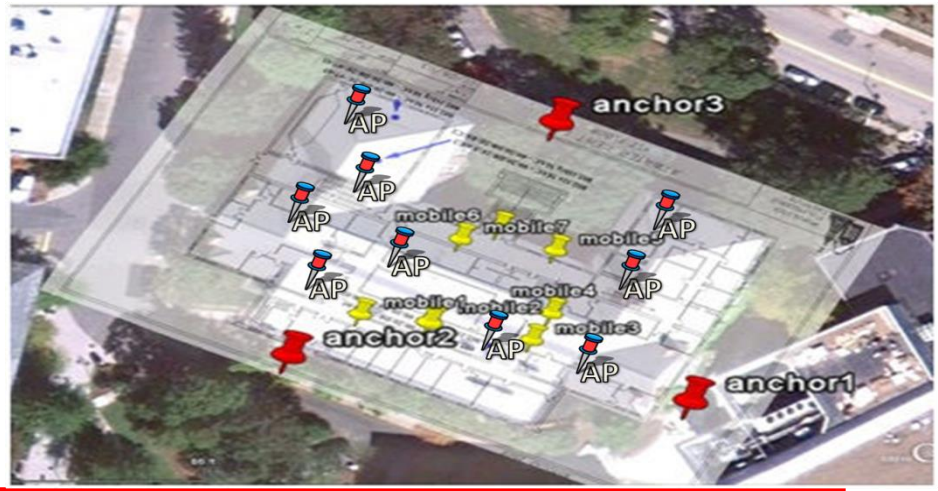
- Deploying large number of sensors does incurs huge cost

Cooperative SPs localization Solutions

- eg. Using dedicated database/server
  - Improving onboard GNSS SP position via neighbouring SPs cooperation using server

- Offering good SP localization accuracy
  - Accuracy is up to 5 meter, when indoors based on probabilistic methods





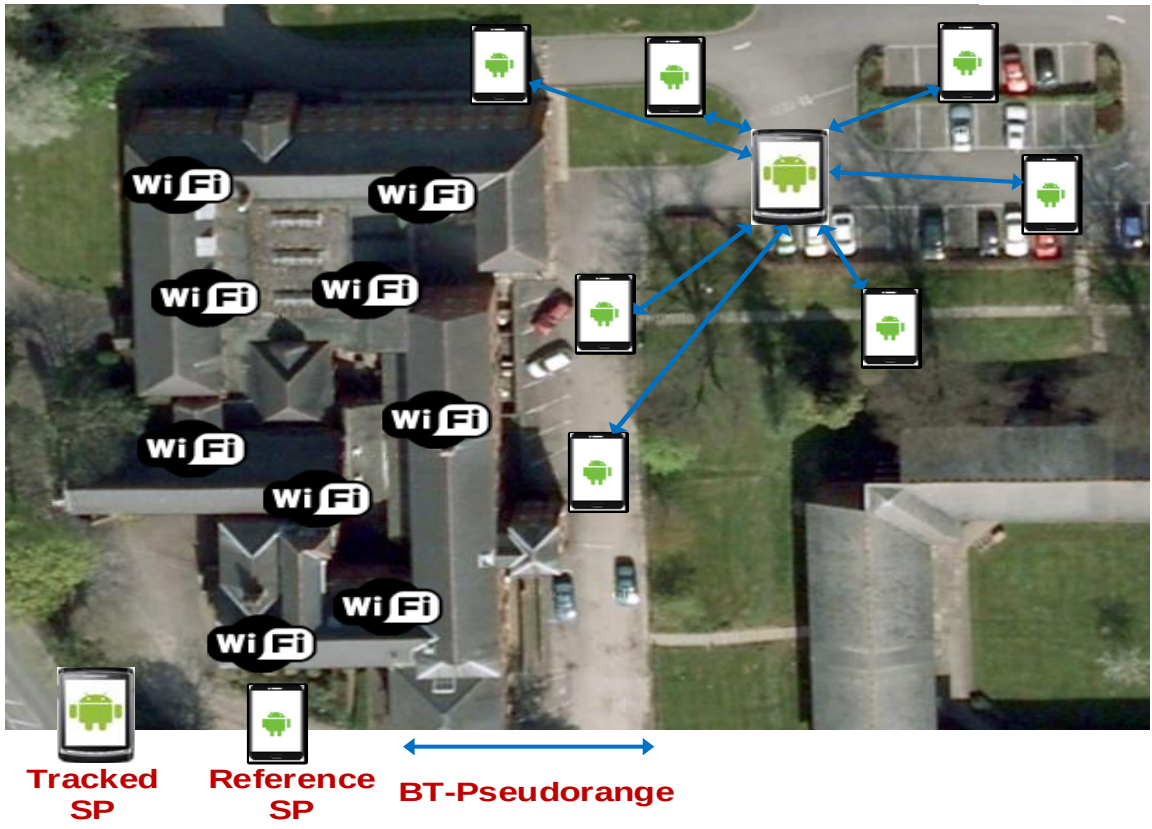
reference points anchors measurements

SILS started as a student's study of:

- RSS vs. Time accuracy of pseudo-ranging/position measurements?
  - For WiFi and BT
  - And indoors?
- What MAC layer API functions available for all wireless sensors on SPs?
  - And at what resolutions?
- Time was chosen as being more challenging and potential
  - Albeit knowing that 1usec of time error = 300 meters inaccuracy

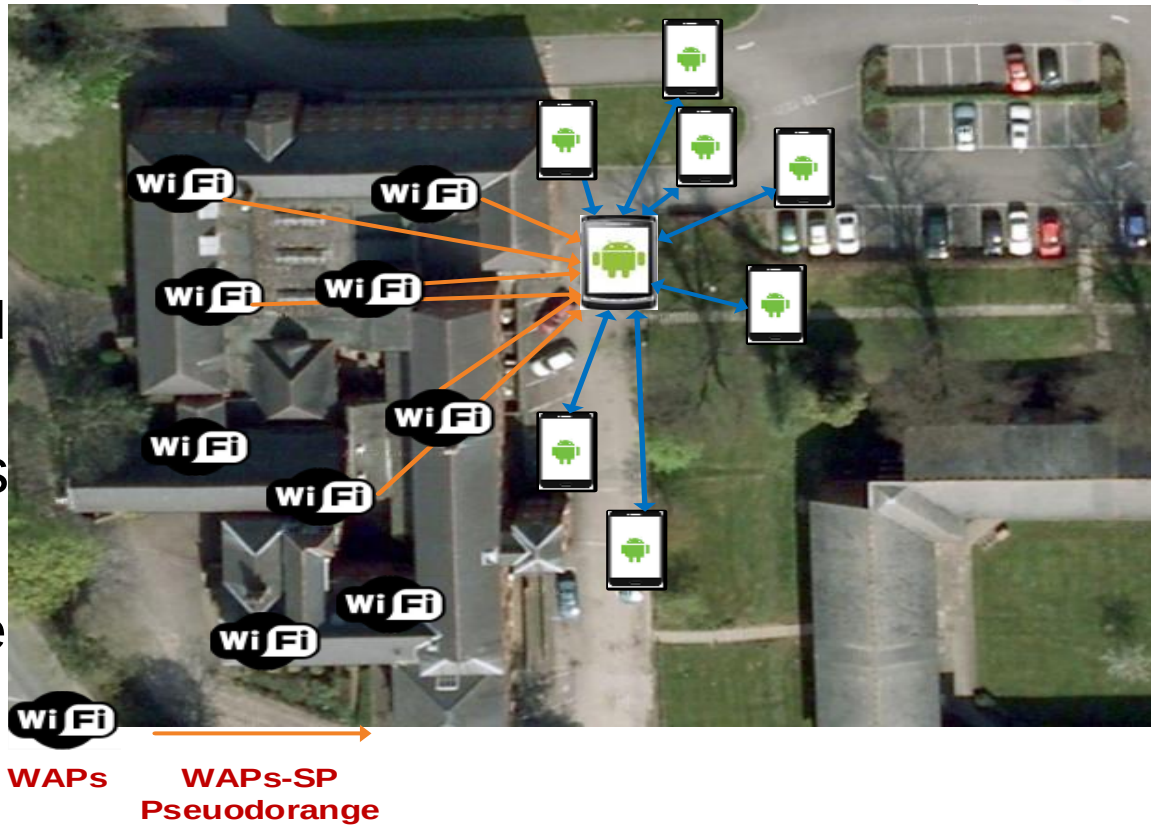
step 1 of 4: SILS forms on-the-go BT Piconet with SPs in the vicinity

- Assumptions:
  - All SPs are cooperative
  - Google's Map matching, or similar, is used on Android offering 1 meter GNSS accuracy



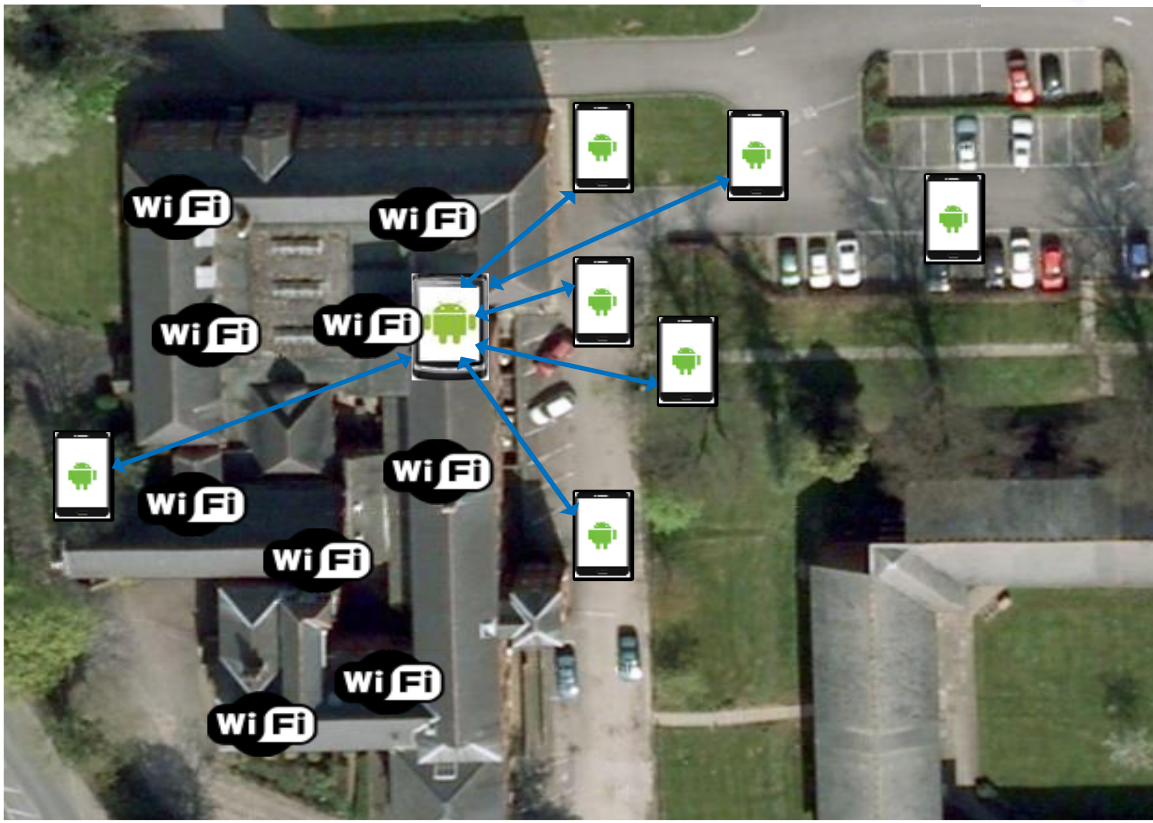
step 2 of 4: SILS Sync WAPs clock time to GNSS time and estimate their locations cooperatively within the network

- All SPs estimate WAPs positions
  - based on the sync'ed GPS time offset calculated from received Beacon signals
- Algorithm narrow WAPs position error
  - based on all cooperative SPs estimates
- Published in 2012



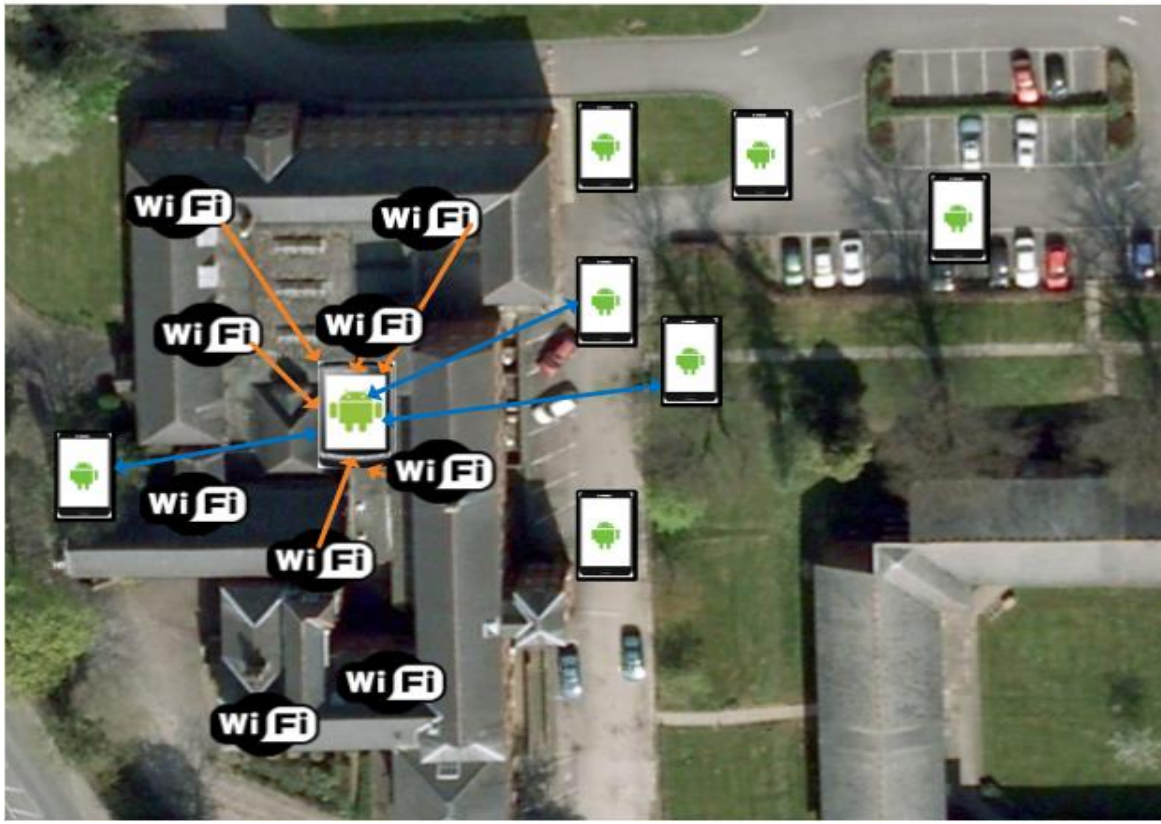
step 3 of 4: SILS Calculates the position of the Tracked SP based on BT-ranging & TOA

- BT-to-BT pseudo-range measurements
  - Using HOP count & Sharing location database (DB)
- Switching BT master-slave role
  - To reduce error in the pseudo-ranging measurements
- Permutation reference points
  - To enhance tracked-SP calculated position

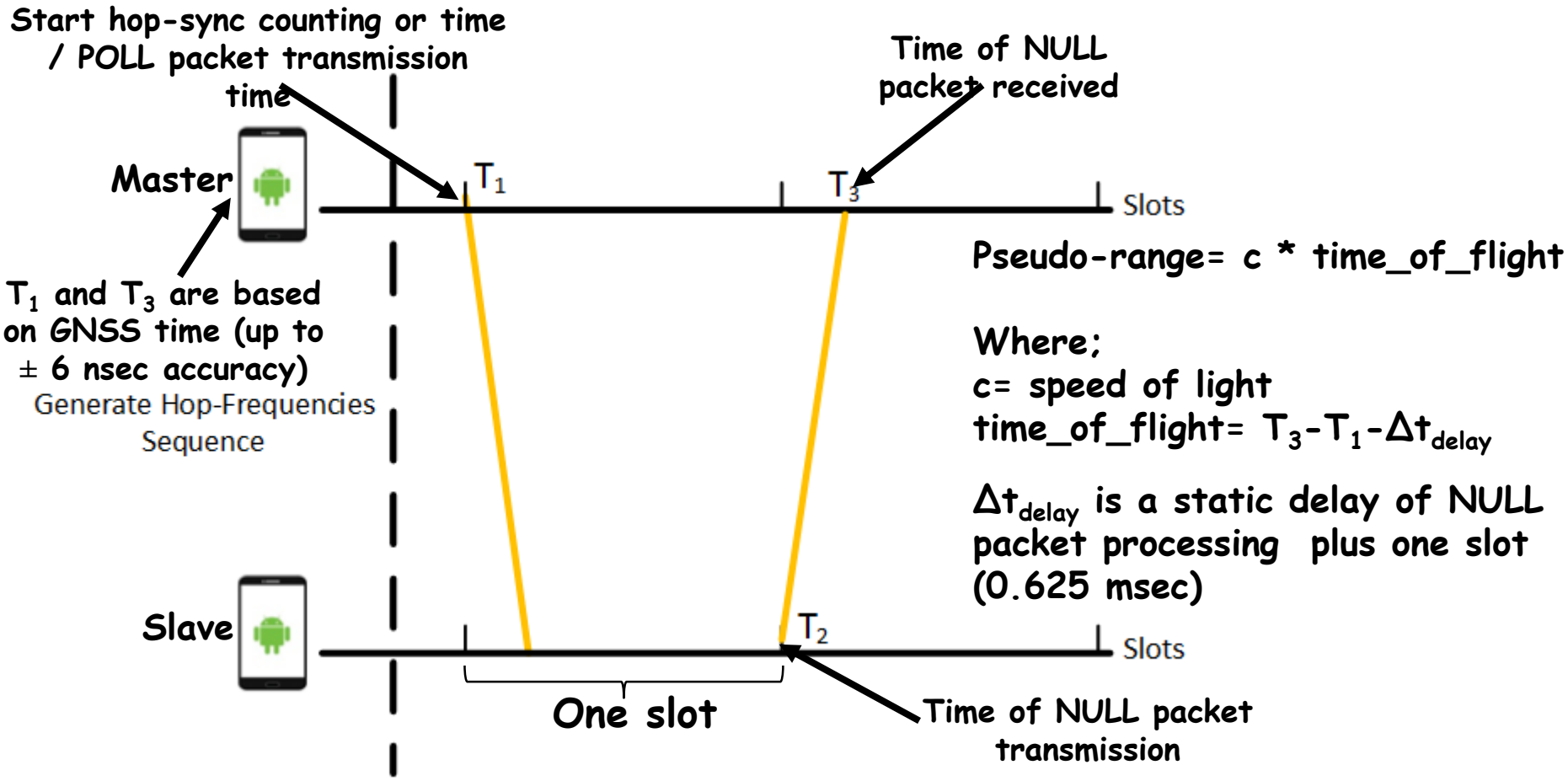


step 4 of 4: SILS also uses synched WAPs to locate an SP when at deep indoors situations

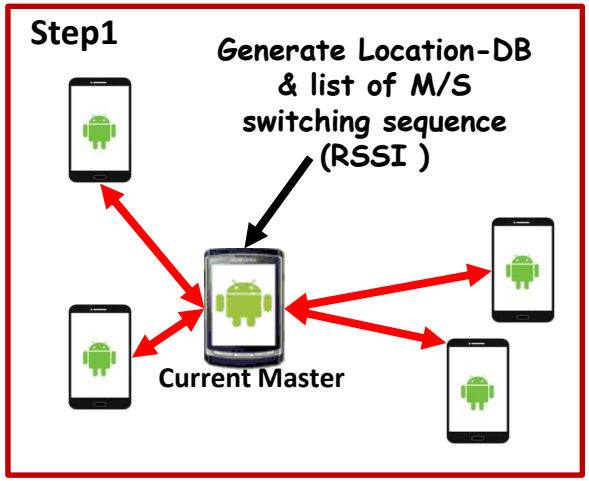
- WAPs used only if < 4 SPs are present in the Piconet
  - Deep indoors
- Pseudo-ranges between tracked-SP and WAPs is calculated using time- sync'ed beacon signals in SP monitor mode

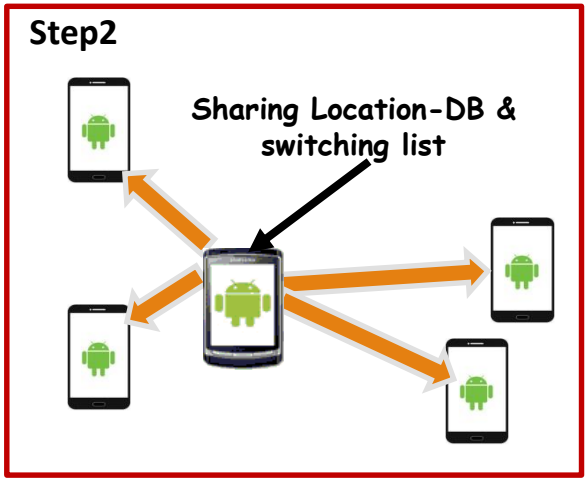


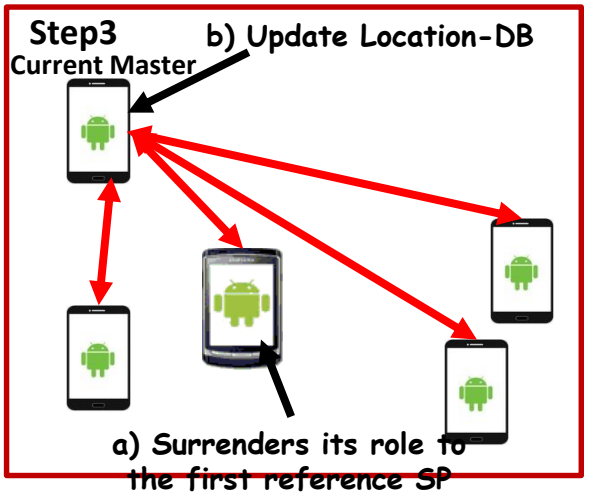
Pseudo-range measurement using BT hop-synchronization with GNSS time

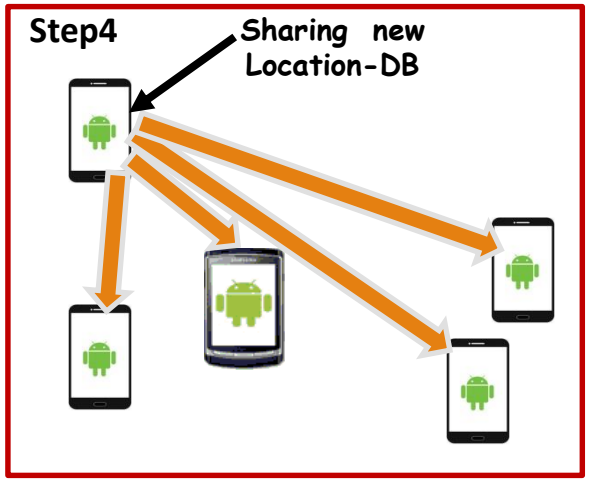


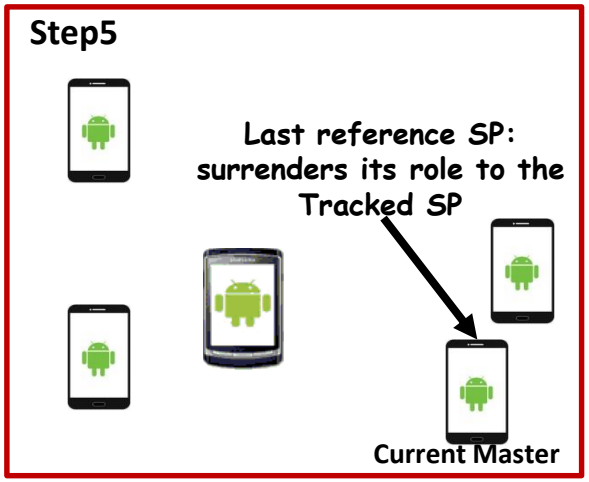
BT switching master/slave role

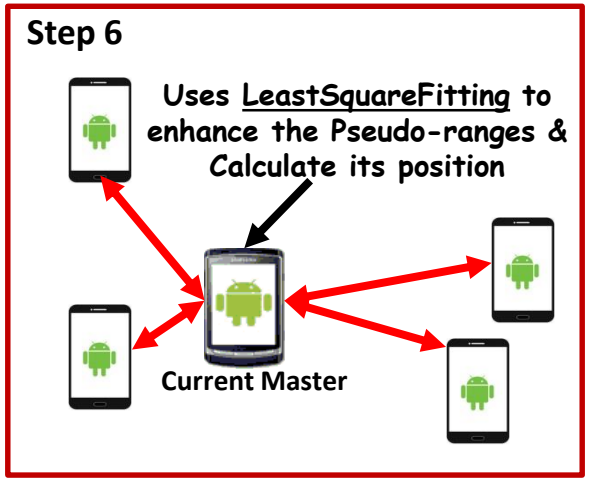




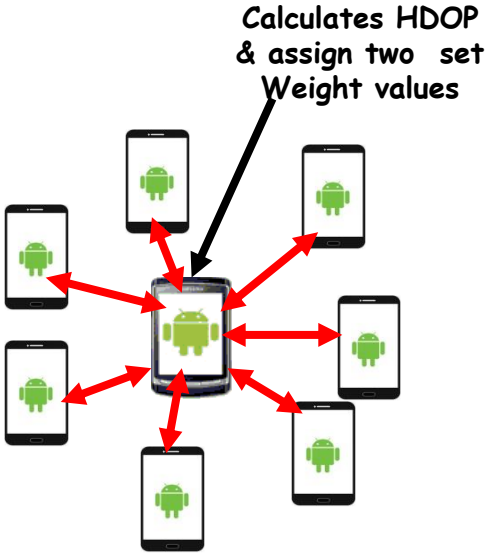




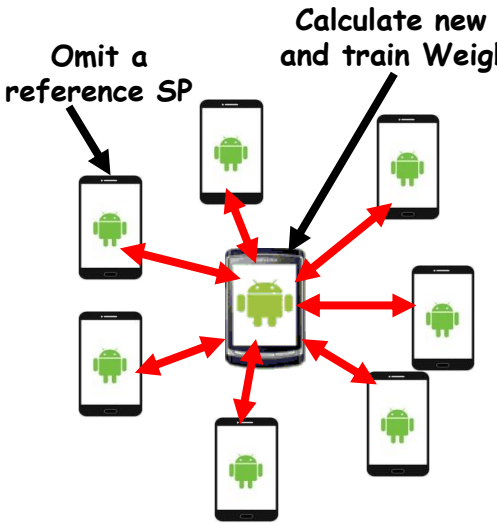




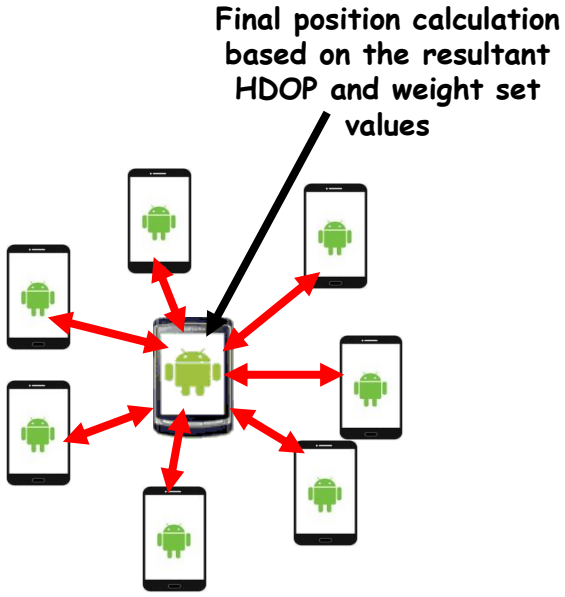
Piconet permutation reference algorithm



Step 1



Step 2
repeated for all SPs

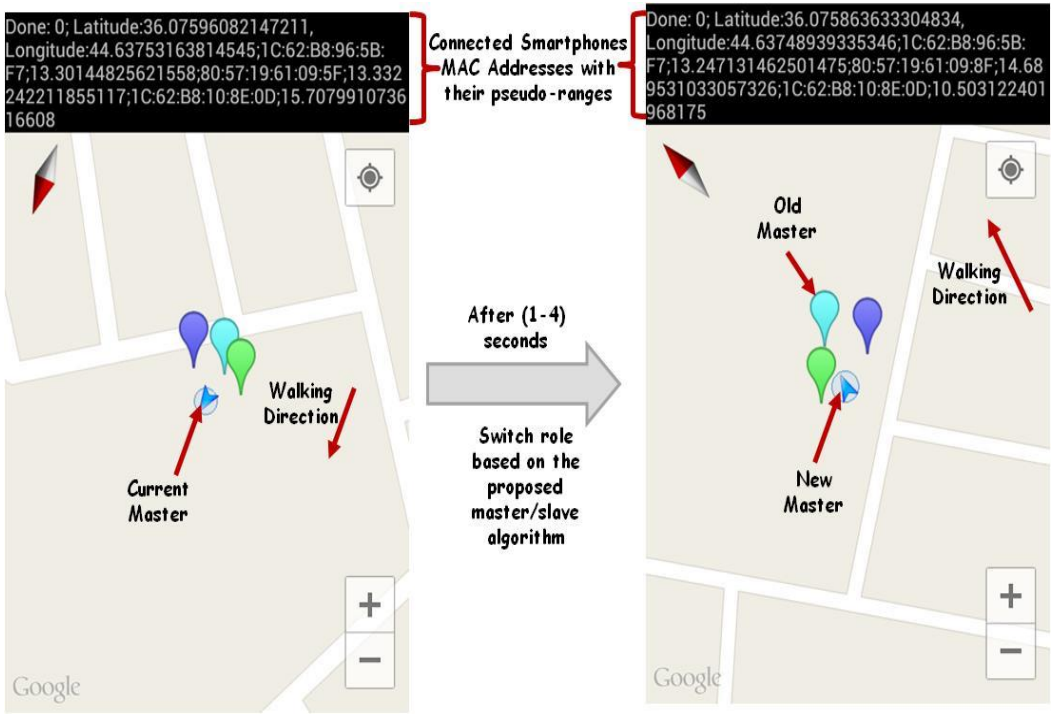


Step 3

SILS pseudo-ranges enhancements

- Trials of pseudo-ranges enhancement in comparison to basic hop-synchronization measurements

Trial number	Pseudo-range measurements		
	Actual	Hop-sync (only)	Hop-sync with Switching Master/Slave role
1	58.83	62.94	55.91
2	50.75	48.34	49.35
3	52.39	49.99	51.67
4	60.09	63.3	59.95
5	73.09	75.07	74.32
6	97.18	99.22	96.5



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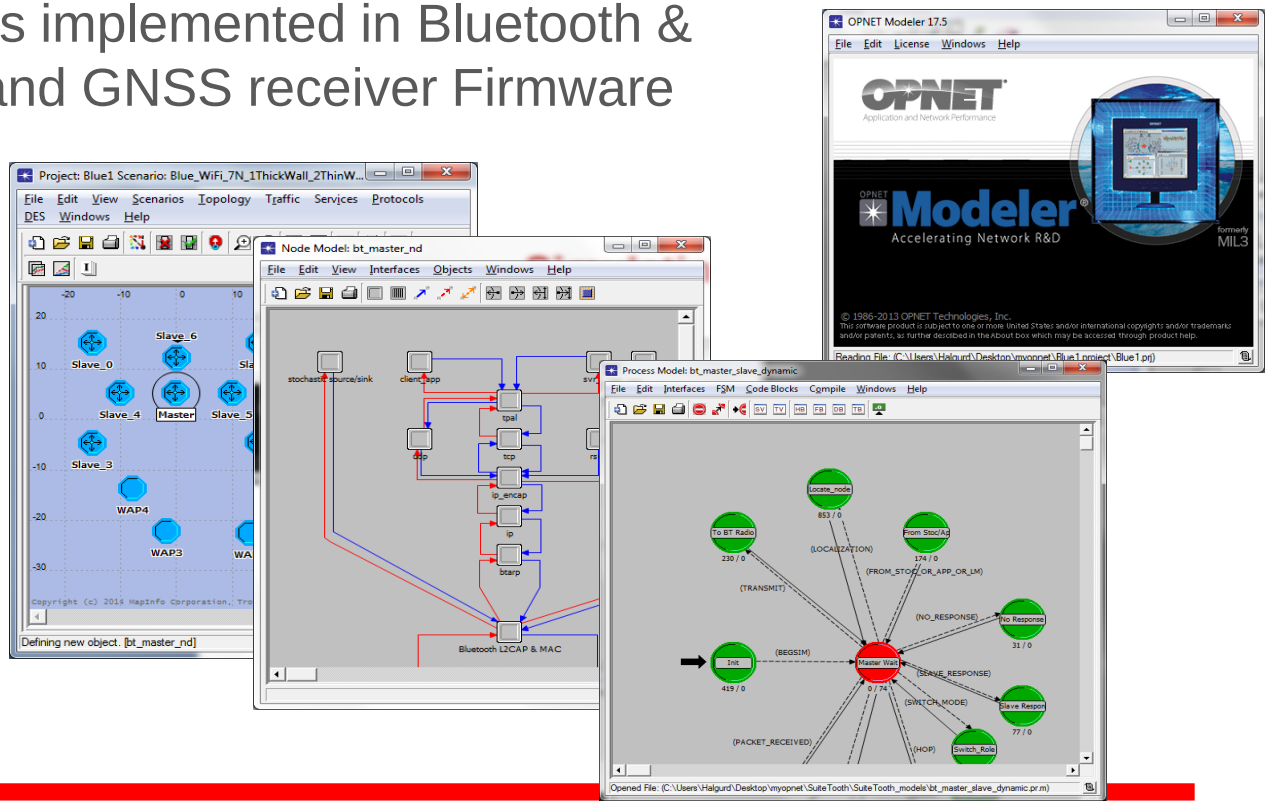
SILS Implementation

- Implementing the scheme on Android-based Smartphones has many challenges
  - Accessing functions implemented in Bluetooth & WiFi transceivers and GNSS receiver Firmware
- Therefore shifted Focus on proving the scheme based on OPNET simulation



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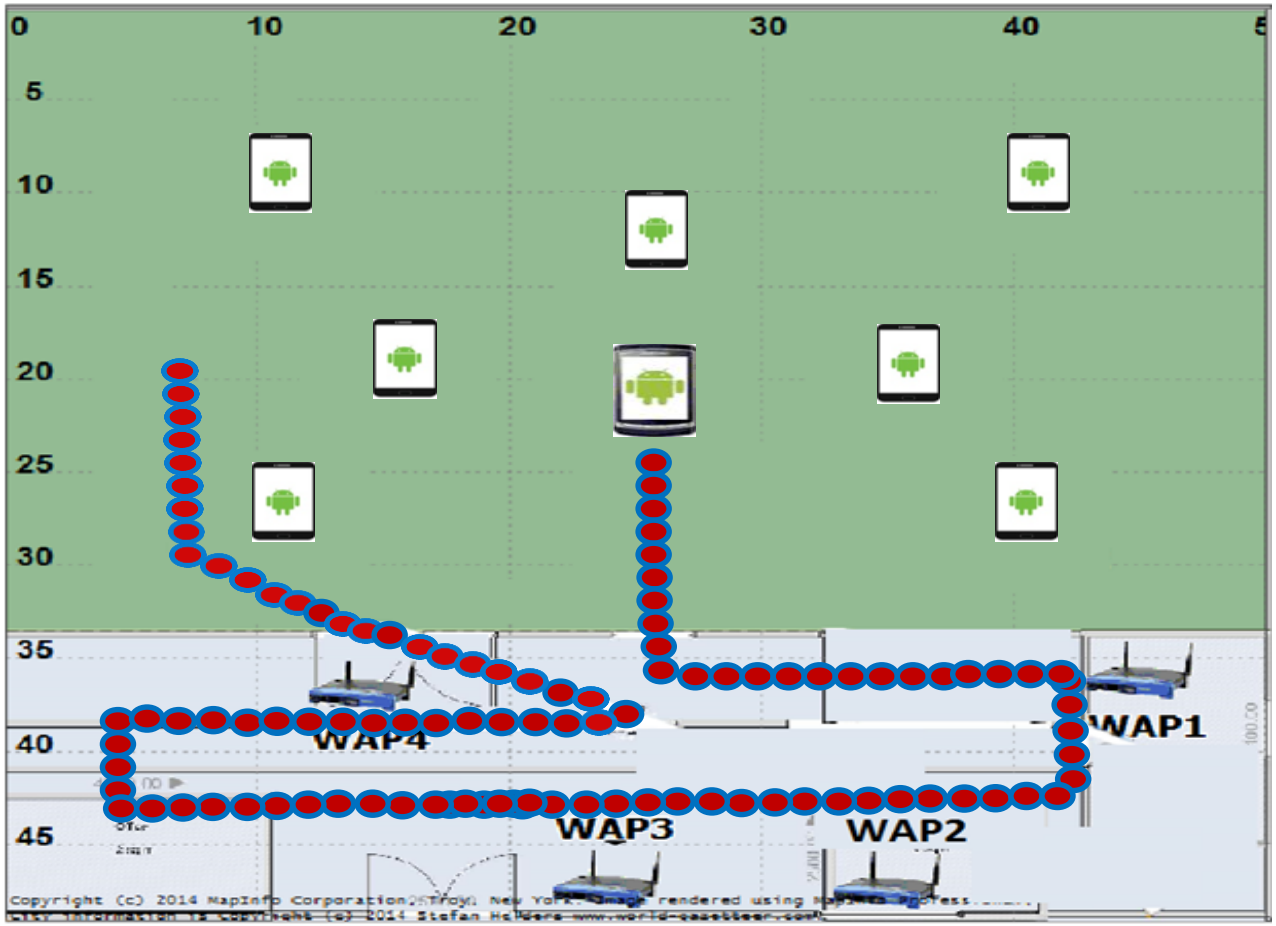
Example Test Scenario

Tracked-SP moved from outdoors to indoors



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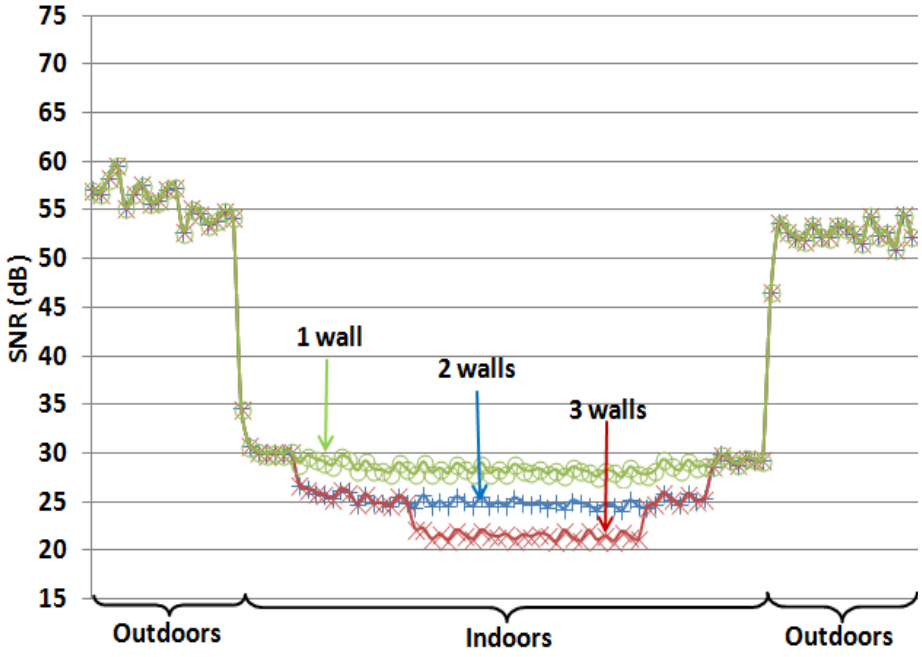
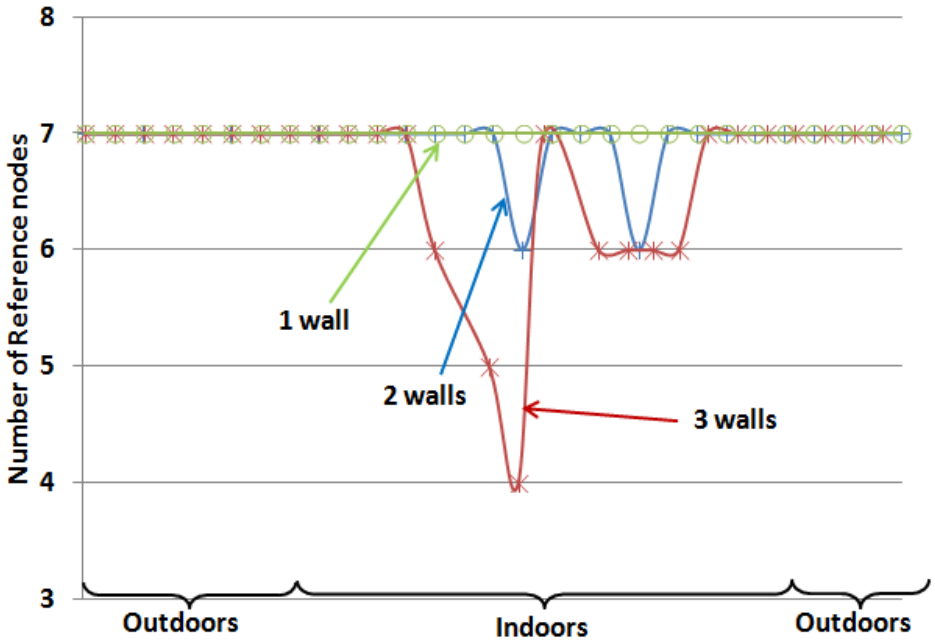
Measured SNR and size of Piconet of test scenario as the tracked-SP moves indoors

- SNR measurements from outdoors to indoors

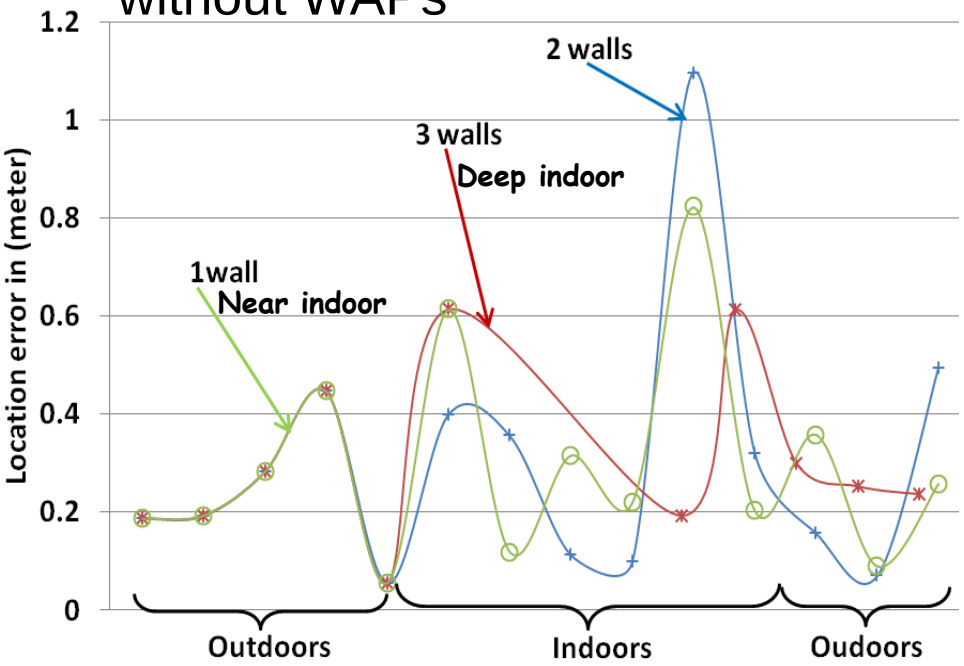


- Number of SPs connected in the BT network

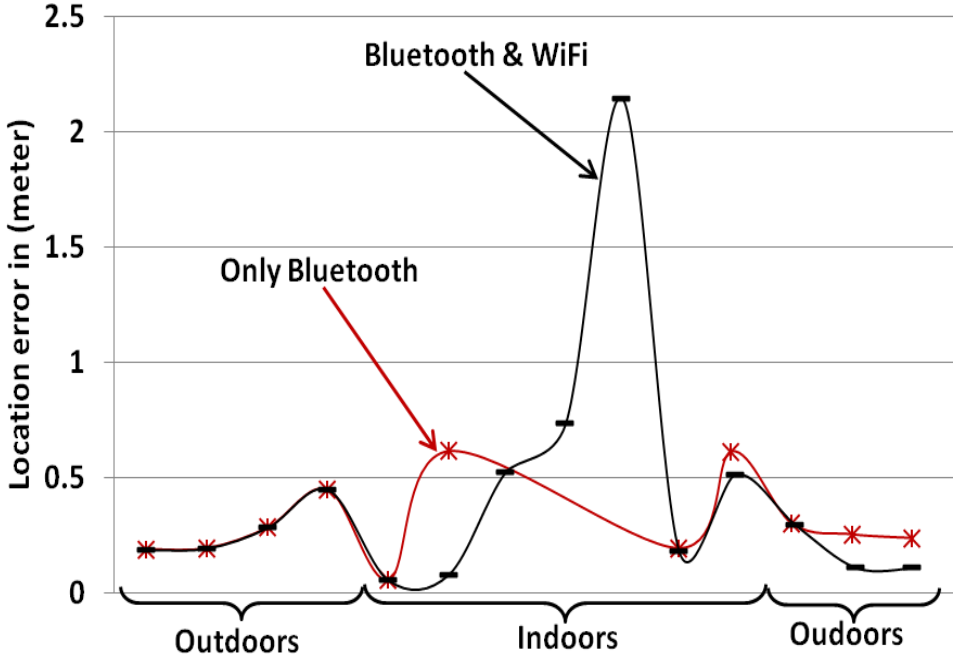


Achieved location accuracy for this test scenario

Location error during development (with switching master-slave role & permutation algorithm) of the SILS without WAPs



Location error for full SILS functionality



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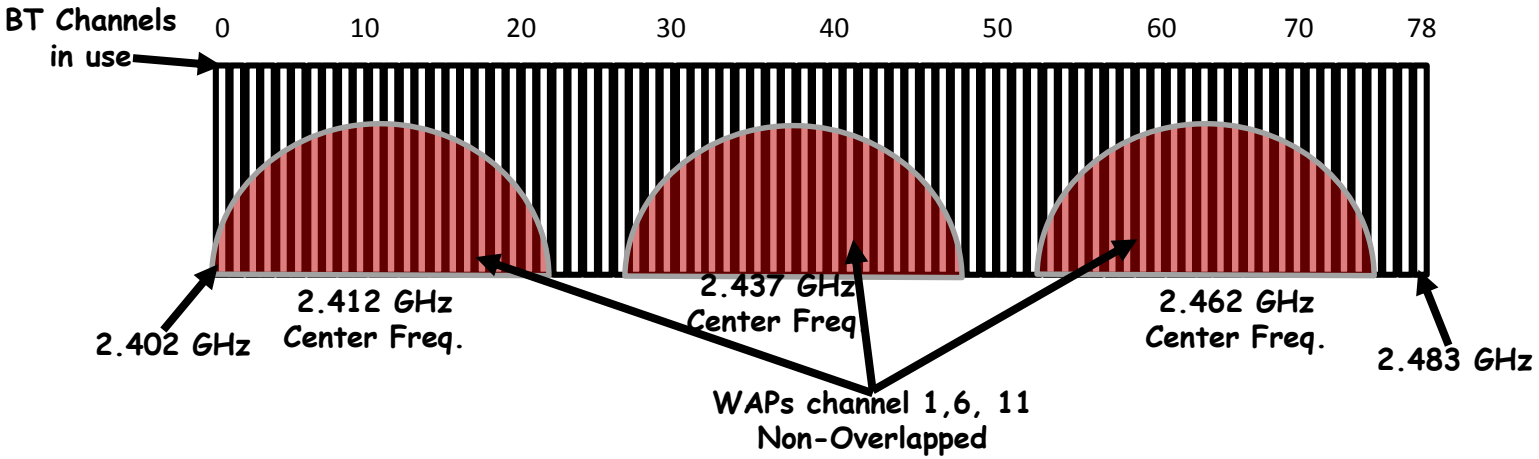
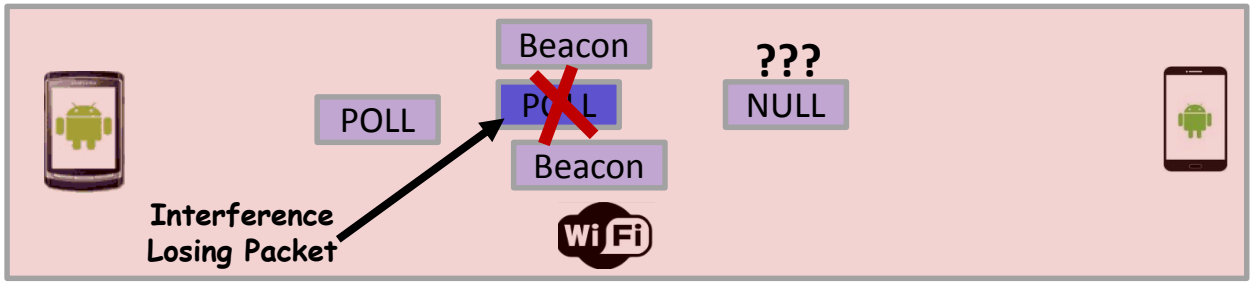
Conclusions

- SILS offers seamless outdoors-indoors SPs positioning with good accuracy
  - Via hybridization of onboard GNSS+Bluetooth+WiFi
  - On-the-go without the need for pre-installed infrastructure or prior geographic surveying
    - i.e. low cost solution for various LBS
  - Hop-sync with GNSS time can be used as an accurate method to measure time of flight between BT nodes
  - Role switching & permutation algorithms helped to improve location accuracy

Future work

- Future work focuses on overcoming the signal interference





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Thank you for your time and attention