PerfLoc Prize Competition Webinar

NIST

May 18, 2017

Welcome

- Introduction to NIST experts
- Background on NIST and PerfLoc
- Overview of the PerfLoc Prize Competition Rules
- Review of Technical Requirements
- Discussion of Technical Corrections
- Q&A

NIST Experts on Today's Webinar:

Nader Moayeri
Technical Lead for PerfLoc

Nader Moayeri has been with NIST since 1997, where he founded the Wireless Communications Technologies Group and managed it for 11 years. His research interests are in wireless networking, indoor localization and tracking, sensor networks, IoT, Cyber Physical Systems, and cognitive radio networks.

Heather Evans
NIST Challenge Coordinator

Heather Evans is a Senior Analyst in the NIST Program Coordination Office. She founded the NIST-wide Community of Interest in Prizes and Challenges and supports the implementation of prize competitions across NIST.

Technical Experts:

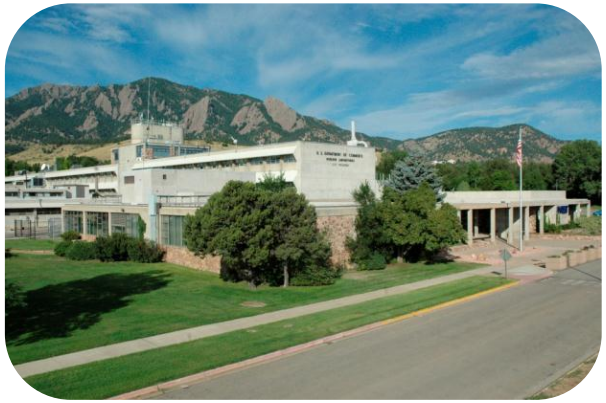
Lu Shi
NIST Research Associate

Chang Li
NIST Research Associate

NIST

The National Institute of Standards and Technology, NIST, is a non-regulatory agency of the United States Department of Commerce.

Founded in 1901, NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.



Two main sites in Gaithersburg, MD and Boulder, CO

The purpose of the PerfLoc Prize Competition is to advance app-based indoor localization and tracking technologies, using NIST's extensive smartphone data repository

Key Info

Dates:

- Competition Testing Period: open now through 5 PM, EDT (UTC-05:00), August 17, 2017
- Announcement of Finalists: August 18, 2017
- Finalist App Demo Days at NIST: August 24-25, 2017
- Announcement of Cash Prize Winners: August 25, 2017
- Showcase Apps at 2017 IPIN in Sapporo, Japan: September 18-21, 2017

Rules:

https://perfloc.nist.gov/perfloc-competition-rule.php
https://www.challenge.gov/challenge/perfloc-prize-competition/

Prizes

1st place - $20,000

2nd place - $10,000

3rd place - $5,000

- To be eligible for a cash prize, you (individual or team lead, in the case of a group project) must be age 18 or older and a U.S. citizen or permanent resident of the U.S. or its territories
- In the case of a private entity, the business shall be incorporated in and maintain a primary place of business in the U.S. or its territories
- See rules for complete eligibility

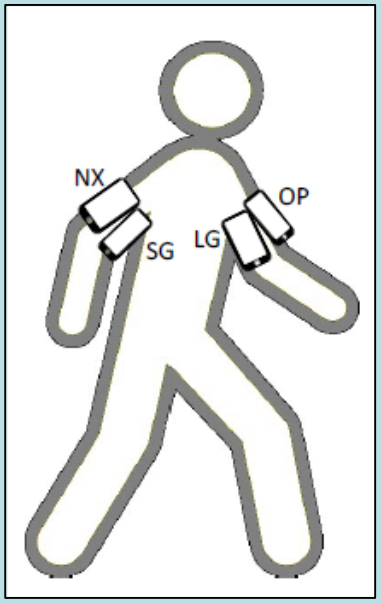
Additional Incentive: The participants with the top overall performance may receive travel funds from NIST to demo their apps in-person at IPIN in Sapporo, Japan*

**Regardless of eligibility for a cash prize*

How to Participate

1. Create a user account for yourself (or your team) at the PerfLoc website, https://perfloc.nist.gov (NOTE: one account per team).
2. Download the Perfloc Data collected by NIST from the PerfLoc website (https://perfloc.nist.gov/perfloc-data.php).
3. Built a smartphone indoor localization and tracking Android App that can generate location estimates for time instances in each scenario for Buildings 1-4. (See the PerLoc User Guide: https://perfloc.nist.gov/perfloc-user-guide.php)
4. Upload your Evaluation Location Estimates (up to 150 times) to the PerfLoc website at https://perfloc.nist.gov/perfloc-evaluation.php. Your successful upload will automatically return a score. Your best ever score will be posted to the Leaderboard (see https://perfloc.nist.gov/perfloc-ranking.php).

About the Data



- Four different Android smartphones used
- Four buildings with different characteristics
- Over 900 dots (~3 cm dia.) used to mark locations of interest
- Total of 34 T&E scenarios used for data collection (defined in the ISO/IEC 18305 standard)

The data is composed of:

1.RF signal strengths measured from Wi-Fi access points in range

2.RF signal strengths measured from cellular towers (base stations) in range

3.Built-in environmental, position and motion sensors

4.Detected geophysical position using the Global Positioning System (GPS)

5.Timestamps at certain test points (dots) in the buildings with known x,y,z coordinates

6.Metadata involving the features of the device that was used to collect a data set corresponding to a particular T&E Scenario and the air pressure value at the beginning of the scenario, whenever applicable.

7.Building-specific information - coordinates of the corners of each building, the coordinates of Wi-Fi access points (APs) deployed in the building, and the coordinates of the training dots in that building

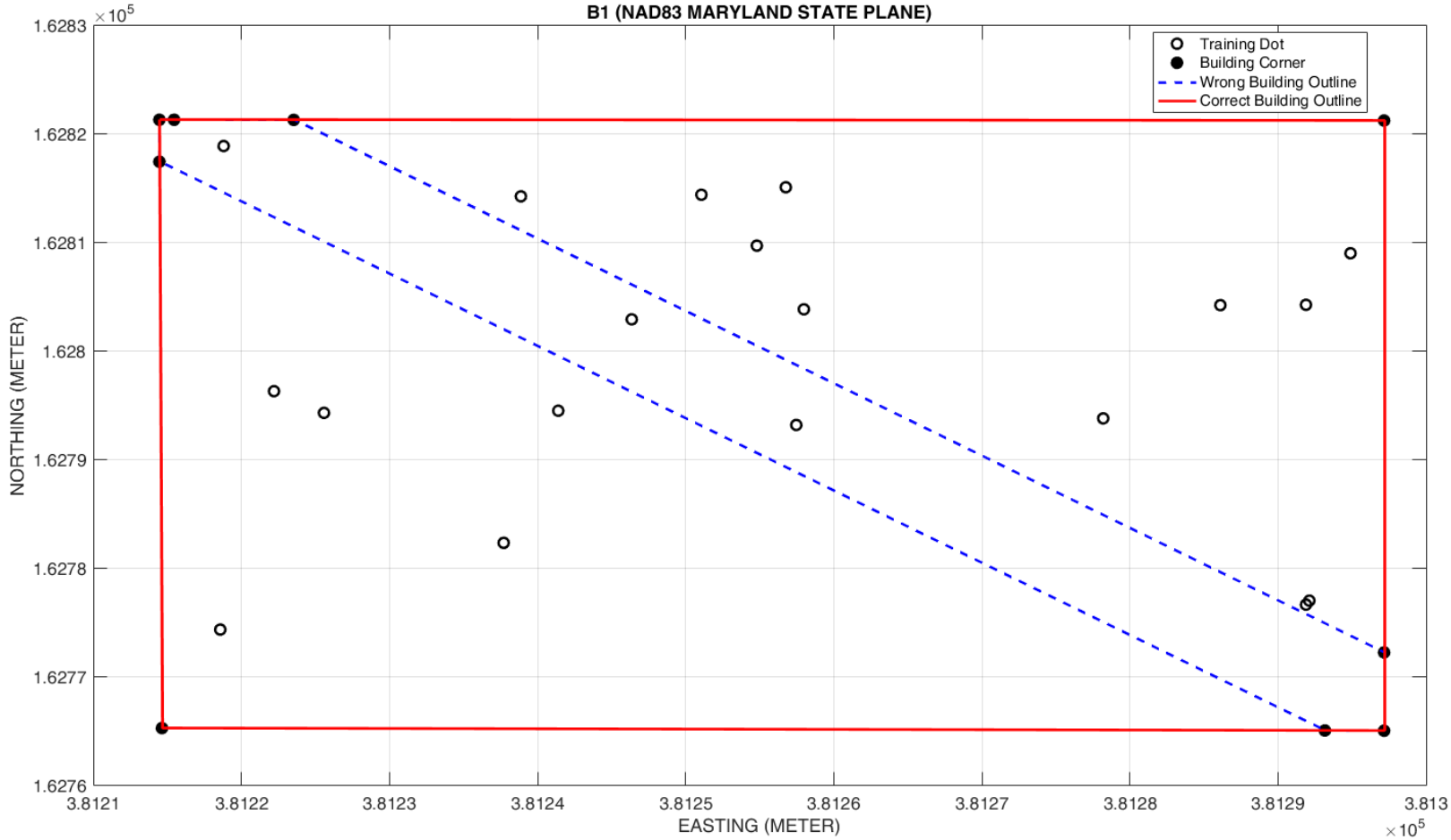
8.Definitions of protocol buffers

For details see the PerfLoc User Guide: https://perfloc.nist.gov/perfloc-user-guide.php

Correction to Building 1 Footprint

- Seven points were specified as the “corners” of Building 1. The coordinates provided on the PerfLoc website are correct, but those points are not the real corners of Building 1.

Building 1 Footprint



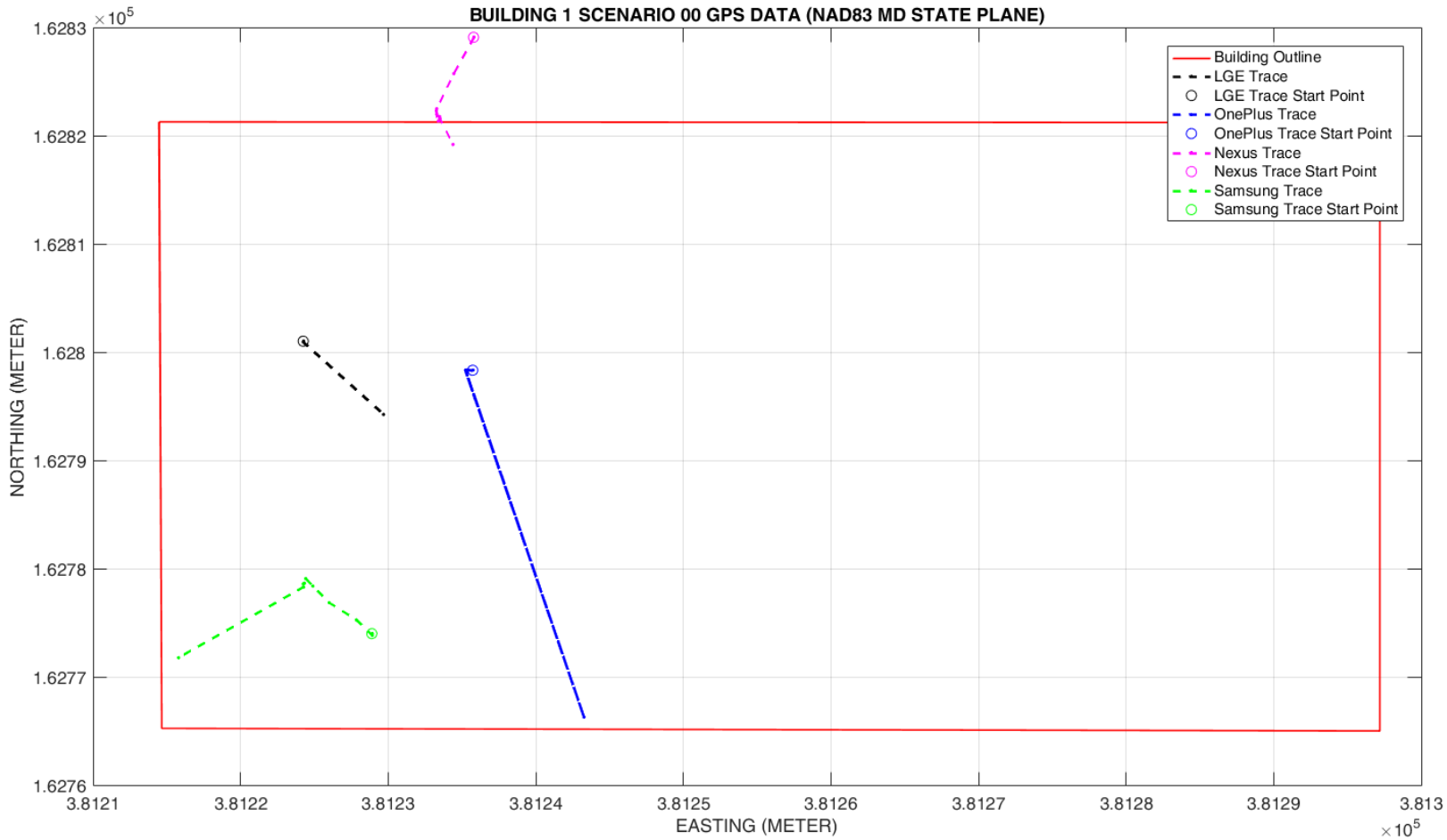
Correction Made

- The coordinates of the true four corners of Building 1 have been posted on the PerfLoc website and the “old” seven corners have been removed.
- Do not pay much attention to the elevation over sea level of the corners <u>for any of the buildings</u>. The differences in elevation may reflect the reality or may be due to the fact that the coordinates of the corners may have been measured at different floors of a building.

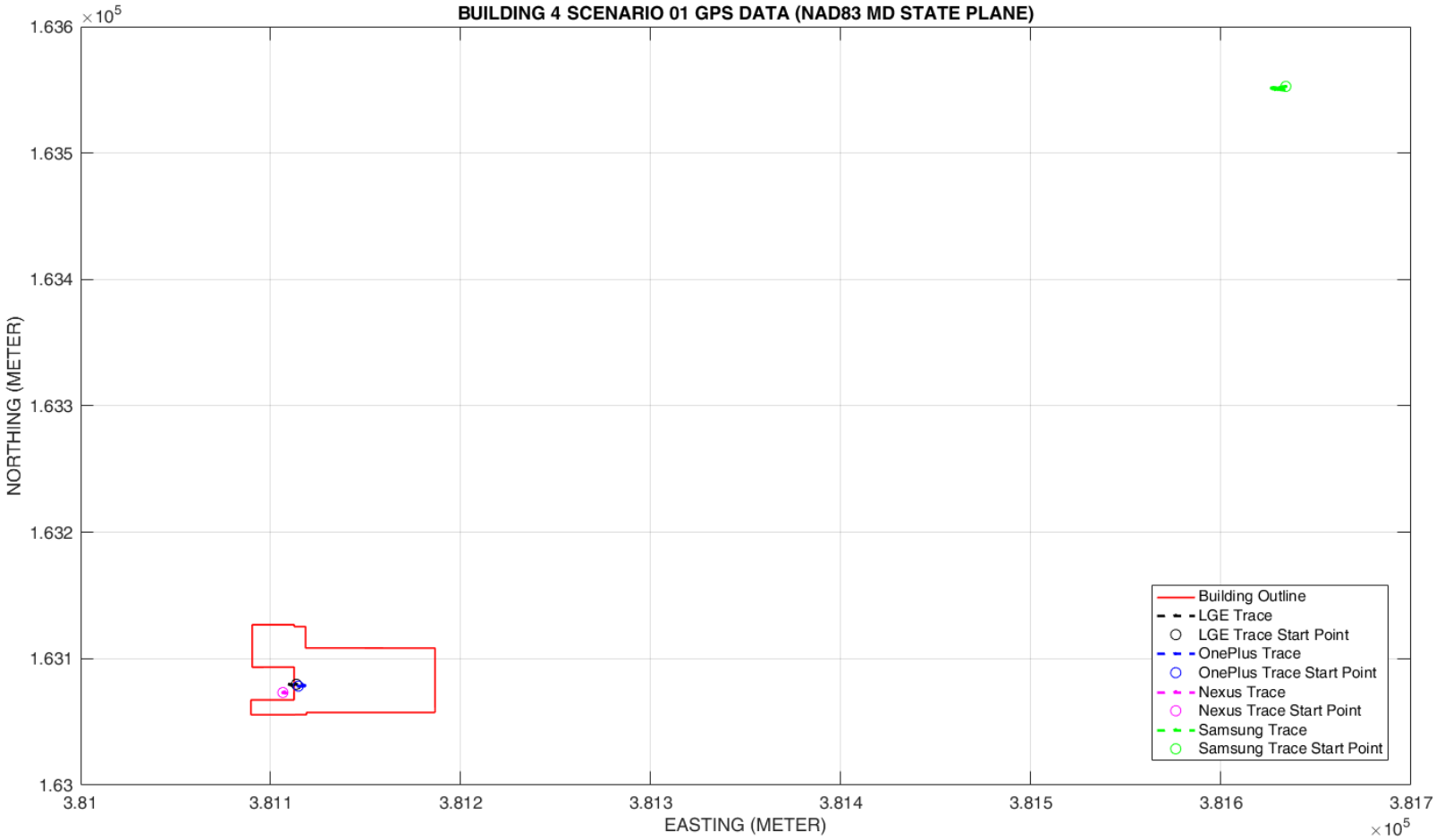
Starting Point of Each Scenario

- We considered two options for providing the coordinates of the starting points of training and test scenarios:
  1. Get a GPS fix at the starting point and provide its coordinates (latitude, longitude, and elevation over sea level).
  2. Manually measure the Cartesian coordinates of the starting point and provide northing, easting, and elevation over sea level.
- We picked the first option when we released the PerfLoc data, because it made more sense from an operational point of view when you are about to enter a building and you wish to navigate inside the building using the indoor localization app on your smartphone.
- However, we have noticed that the quality of the GPS fixes we obtained with our four smartphones are not that good.

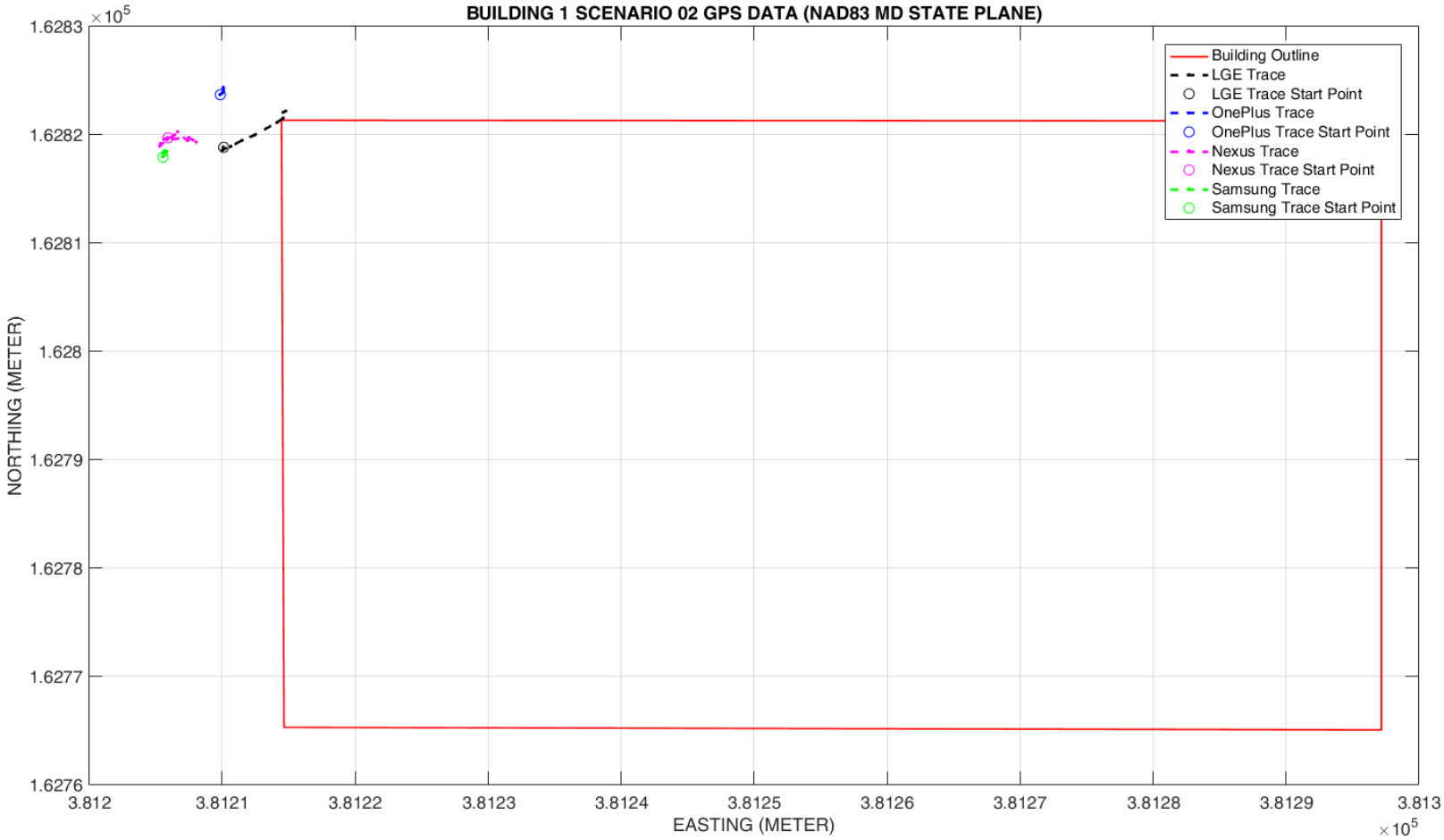
Examples of Bad Starting Coordinates (I)



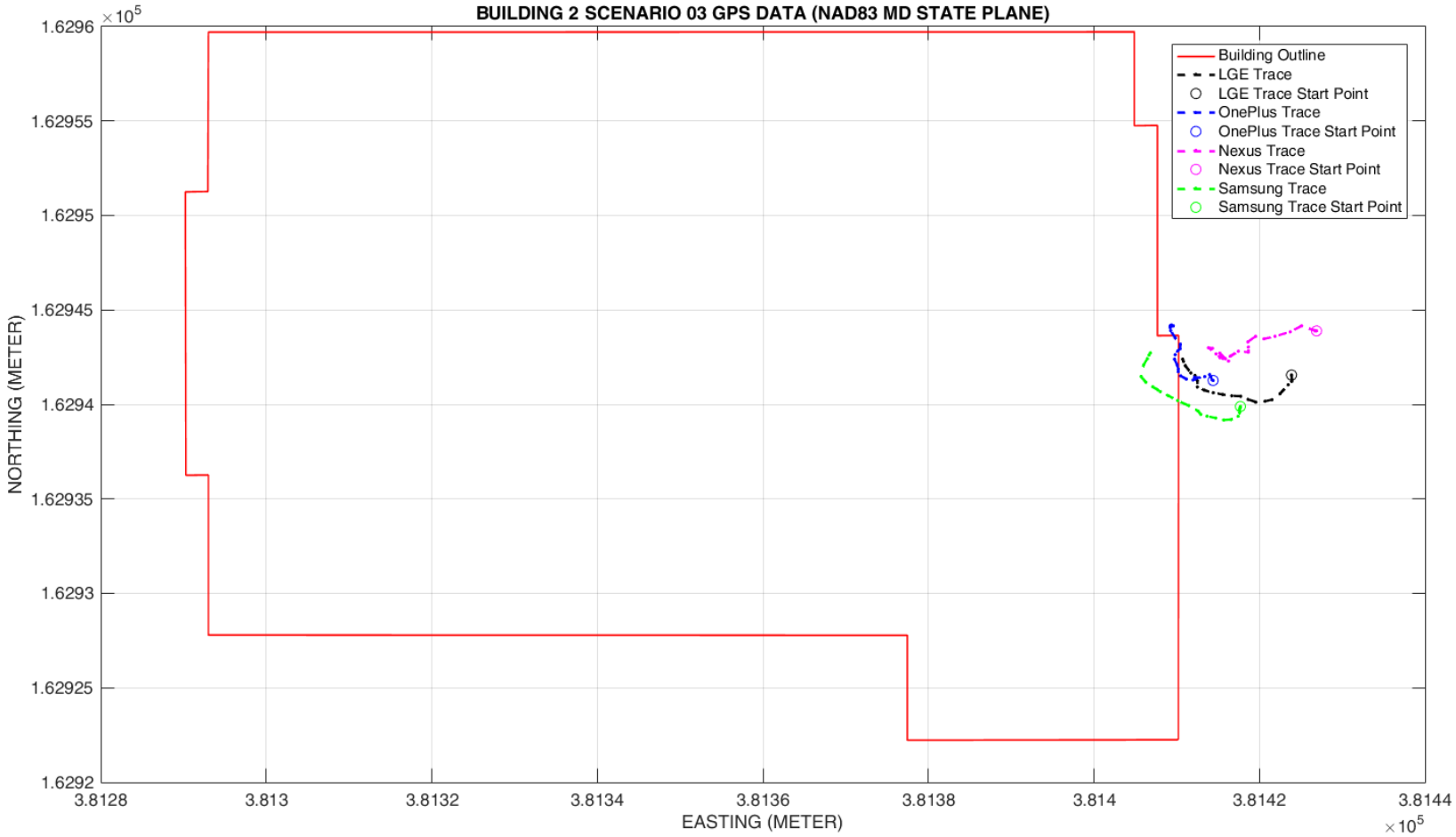
Examples of Bad Starting Coordinates (II)



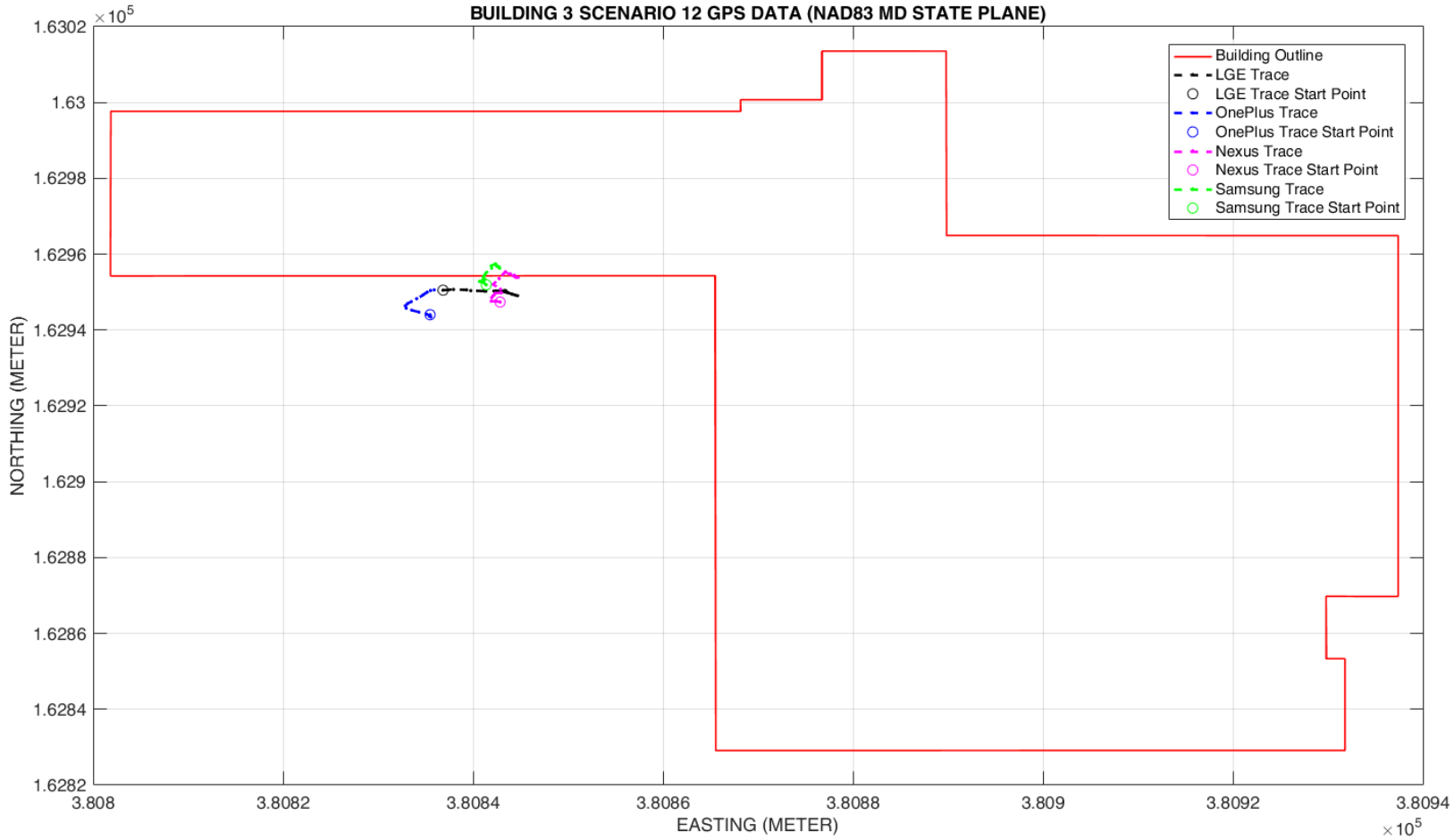
Examples of Good Starting Coordinates (I)



Examples of Good Starting Coordinates (II)

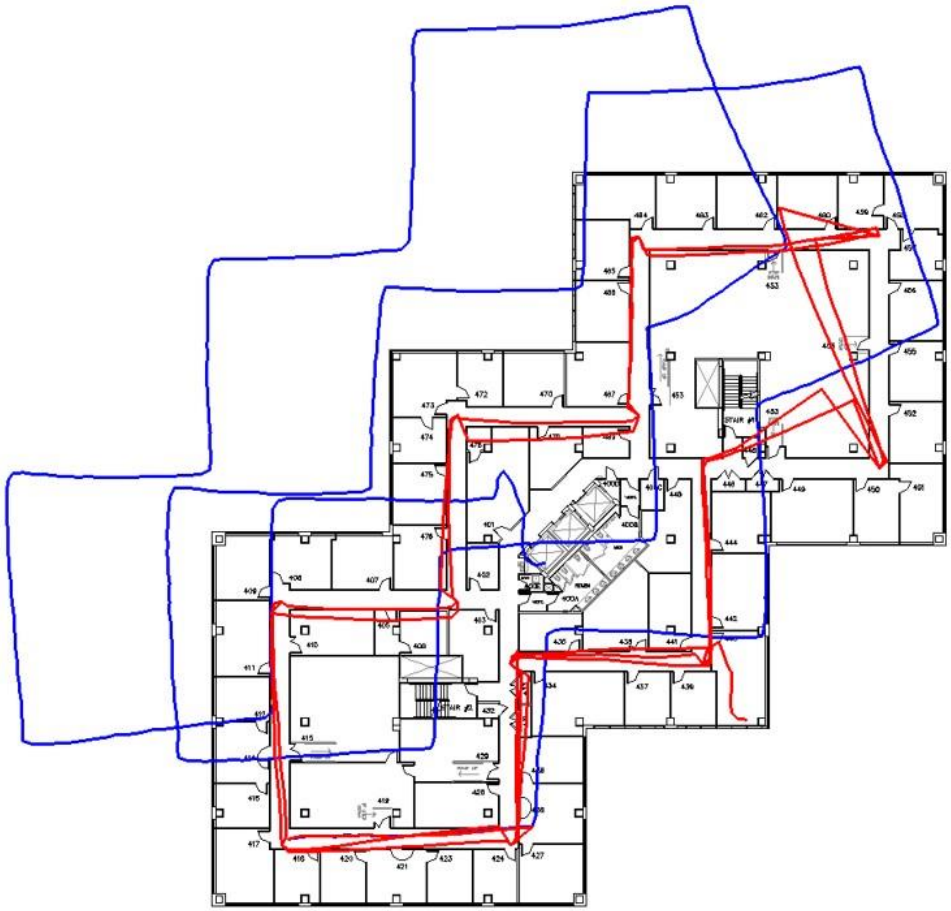


Examples of Good Starting Coordinates (III)



Errors in Dead-Reckoning

- There are two sources of error in dead-reckoning:
  - Errors in measuring linear displacement and angular motion
  - Errors in the starting point coordinates
- Even if you do a great job of controlling the first type of error, the use of inaccurate starting coordinates can overshadow all the gains obtained from controlling the first type of error.



Correction Made

- We measured the coordinates of the starting point of each scenario – <u>to the best of our recollection</u> – and we are making those coordinates available as an additional file to download from the “PerfLoc Data” page on the PerfLoc website. So, you need to download a total of 12 files.
- We are also making available the initial direction of motion as we entered the building, even though you may be able to deduce that from the magnetometer measurements and gravity. This information is in the same file described above.

Correction Made

Building #	Scenario #	NAD83 MARYLAND STATE PLANE NORTHING (METER)	NAD83 MARYLAND STATE PLANE EASTING (METER)	NAVD88 ELEVATION (METER)	Starting Direction
1	00, 01, 09, 11, 12, 13, 14	162774.5829	381221.5532	134.9313112	South
1	2	162819.4262	381208.8614	136.3225578	East
1	3	162774.5829	381221.5532	134.3813112	South
1	10	162819.4262	381203.8614	136.3125578	East
2	00, 01	162939.7817	381420.4284	139.2323353	West
2	02, 10	162963.754	381283.9927	139.1211908	South
2	3	162939.7817	381420.4284	138.6823353	West
2	12	162963.6962	381355.6282	139.1895926	South
2	13, 14	162915.7634	381342.2192	139.1000549	North
2	16	162952.5562	381338.9632	145.8090389	West

Correction Made

Building #	Scenario #	NAD83 MARYLAND STATE PLANE NORTHING (METER)	NAD83 MARYLAND STATE PLANE EASTING (METER)	NAVD88 ELEVATION (METER)	Starting Direction
3	0	162945.2488	380802.8397	133.4497137	North
3	1	163010.6468	380822.2546	132.8854239	South
3	2	162920.8798	380851.482	132.870763	East
3	3	162867.5134	380951.2537	133.3853117	West
3	10	162984.6423	380895.8341	133.915495	West
3	12	162947.2998	380840.582	132.8979116	North
3	13	163009.2468	380822.2546	132.8854239	South
3	14	162942.2998	380840.582	132.8979116	North

Correction Made

Building #	Scenario #	NAD83 MARYLAND STATE PLANE NORTHING (METER)	NAD83 MARYLAND STATE PLANE EASTING (METER)	NAVD88 ELEVATION (METER)	Starting Direction
4	0	163112.9723	381169.4195	138.9351684	East
4	1	163072.494	381106.3488	139.2748143	East
4	2	163117.5972	381128.4048	138.1589469	West
4	3	163049.4212	381170.9349	138.6447529	North
4	10	163049.4212	381170.9349	139.1947529	North
4	12	163119.3723	381163.4695	138.9351684	East
4	13	163089.2373	381107.3653	139.2237328	East

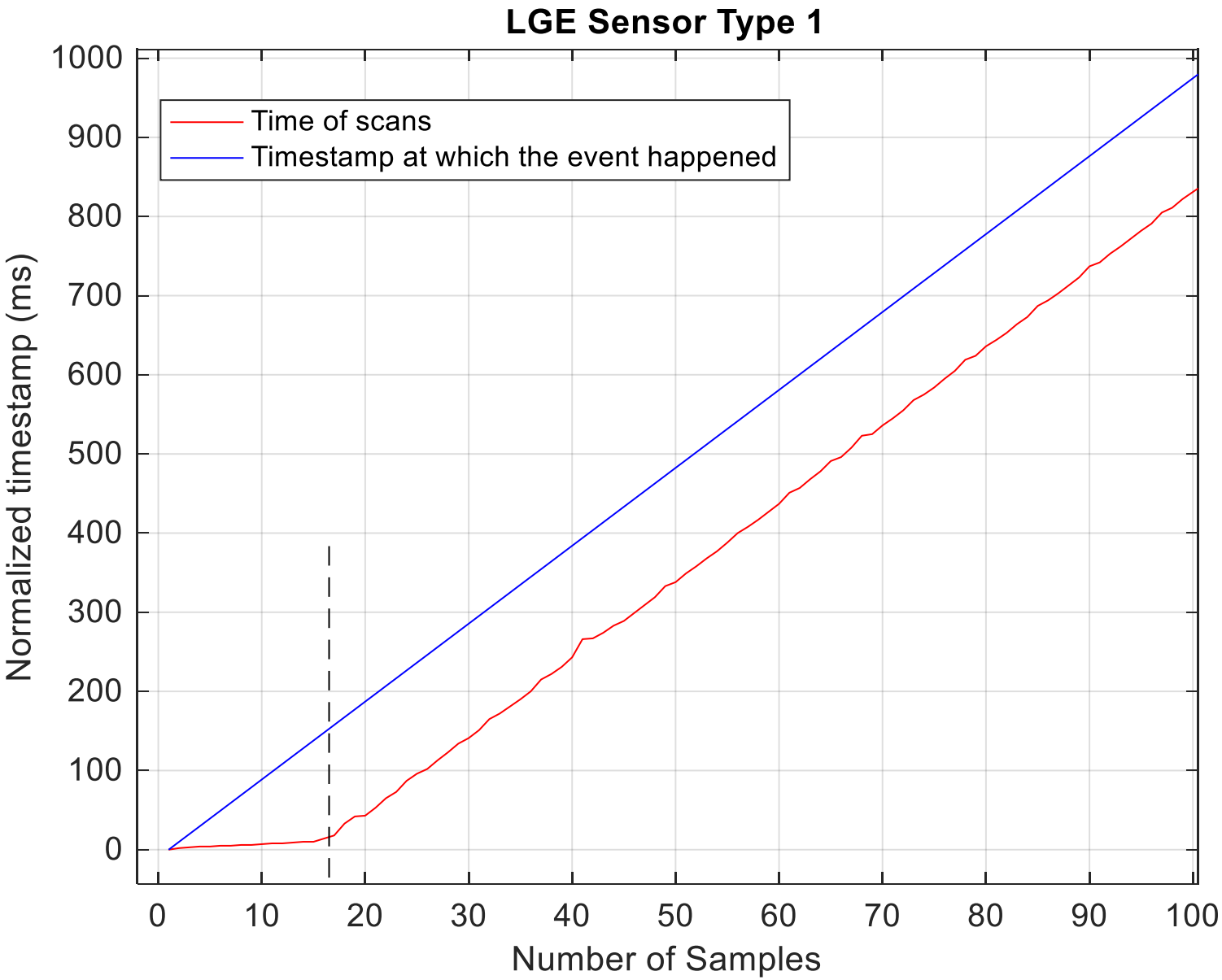
Different Types of Timestamps

- Two types of timestamps are found in certain PerfLoc data files:
  - UNIX time in milliseconds, which specifies the time elapsed since 00:00:00 UTC, January 1, 1970
  - Event time in nanoseconds, which specifies the time elapsed since the smartphone was last turned on
- This may cause some consternation, particularly in light of the information shown on the next two slides, <u>but this is really not a problem</u>.
- We wish to share the info with you just in case it has caused any confusion.

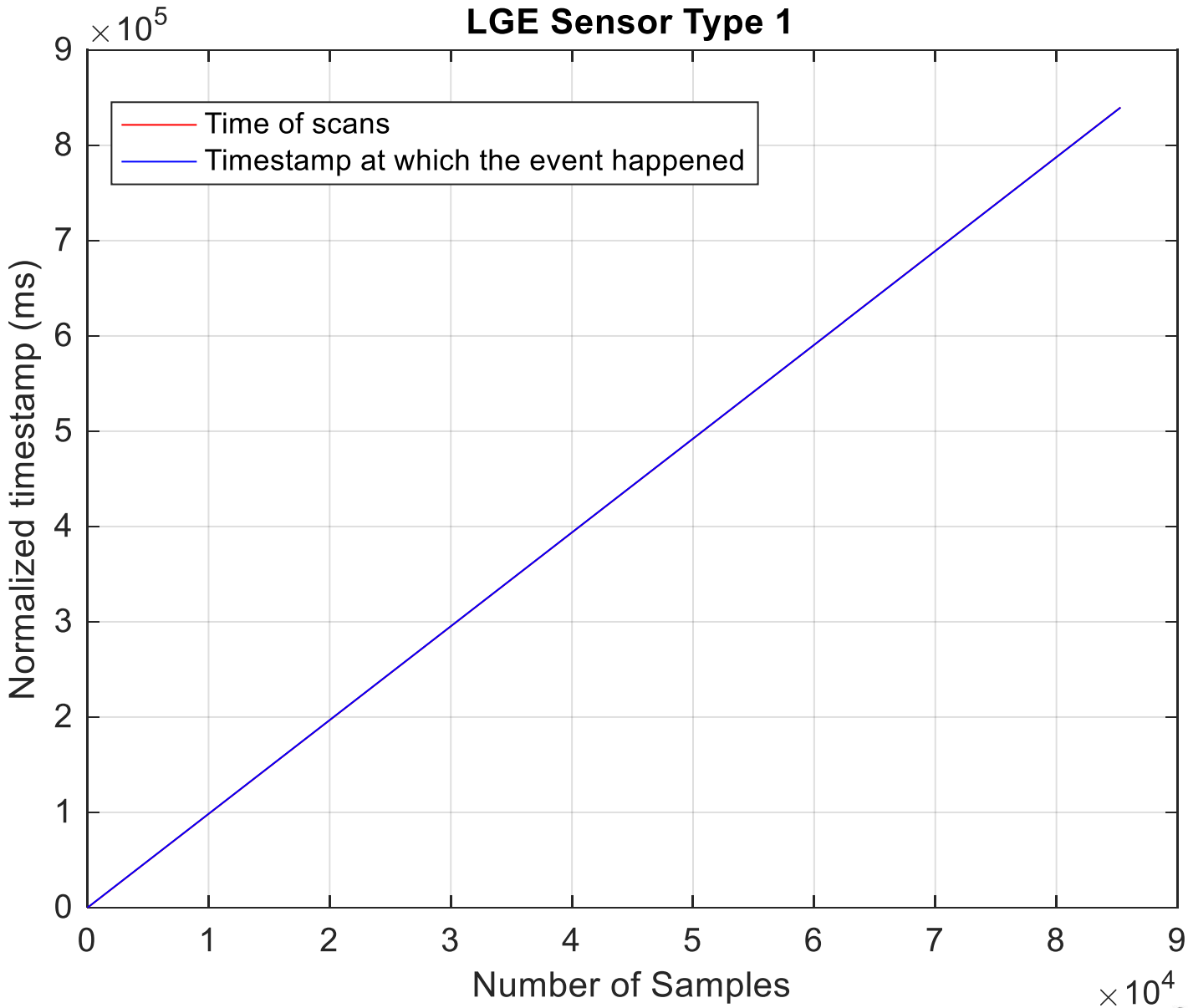
Discrepancies in Timestamps

```
Sequence number: 1
Time of this scan in milliseconds: 1453855915131
Location where the measurment was taken: 0
Type of the sensor: 1
Timestamp in nanosecond at which the event happened: 21354659602245
Accuracy : 3
value: -0.8308868408203125
value: 8.917617797851562
value: 2.8076019287109375
============================================================
Sequence number: 13
Time of this scan in milliseconds: 1453855915133 (+2ms)
Location where the measurment was taken: 0
Type of the sensor: 1
Timestamp in nanosecond at which the event happened: 21354669489940
Accuracy : 3                                        (+9.887695ms)
value: -1.059539794921875
value: 8.9188232421875
value: 2.75732421875
============================================================
Sequence number: 28
Time of this scan in milliseconds: 1453855915134 (+1ms)
Location where the measurment was taken: 0
Type of the sensor: 1
Timestamp in nanosecond at which the event happened: 21354679316601
Accuracy : 3                                        (+9.826661ms)
value: -1.11700439453125
value: 8.894866943359375
value: 2.7034454345703125
============================================================
Sequence number: 42
Time of this scan in milliseconds: 1453855915135 (+1ms)
Location where the measurment was taken: 0
Type of the sensor: 1
Timestamp in nanosecond at which the event happened: 21354689143261
Accuracy : 3                                        (+9.826660ms)
value: -1.0894622802734375
value: 8.908035278320312
value: 2.7812652587890625
```

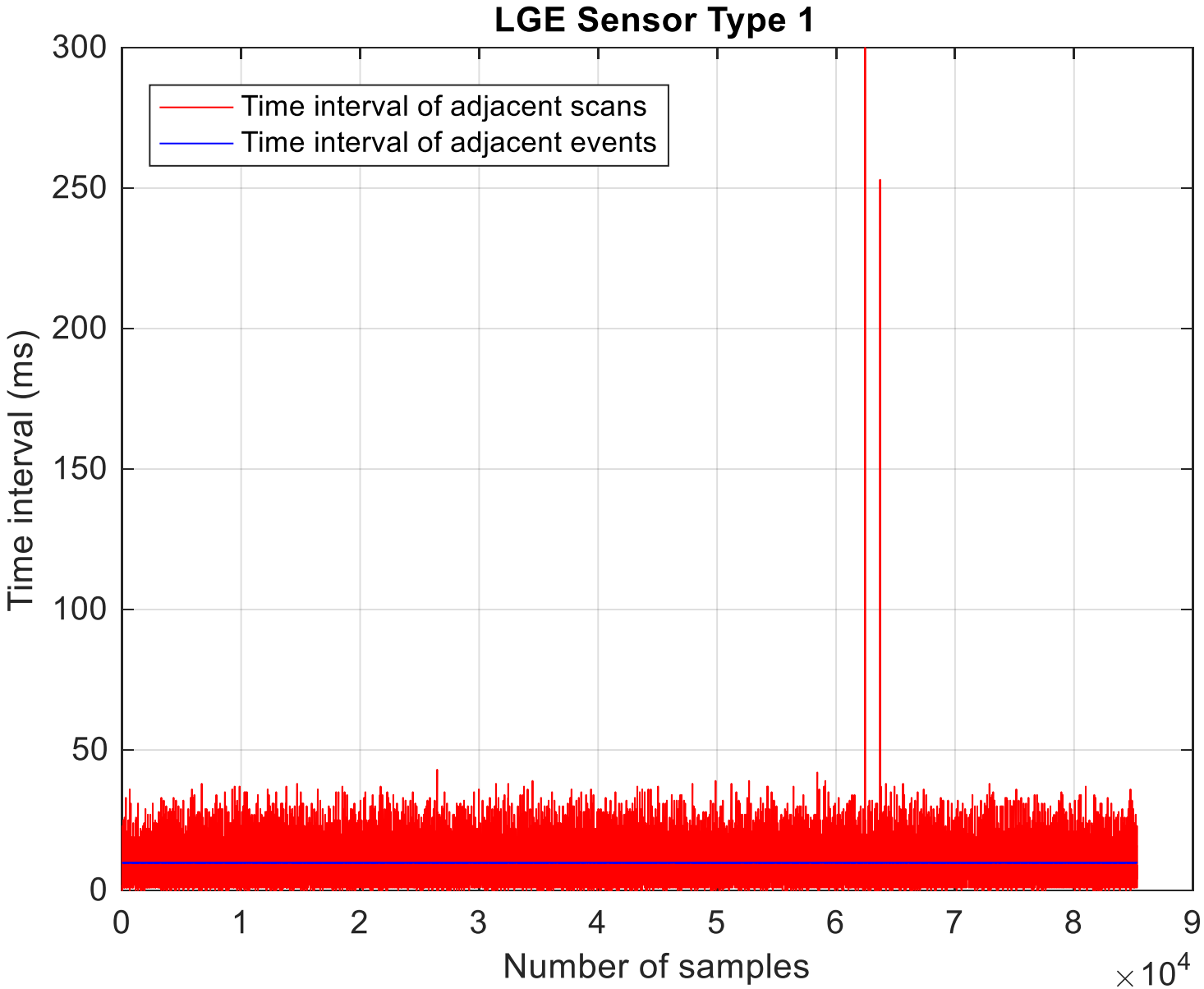
Elapsed Time by Timestamp (I)



Elapsed Time by Timestamp (II)



Inter-Sample Times



Statistics of Inter-Sample Times

	Total Duration of Scenario	Statistics of Inter-Sample Time	
		Mean	Std. Dev.
UNIX Time (ms)	839,885	9.8471	3.6794
Event Time (ms)	839,735	9.8453	0.017364

Guidance on Timestamps

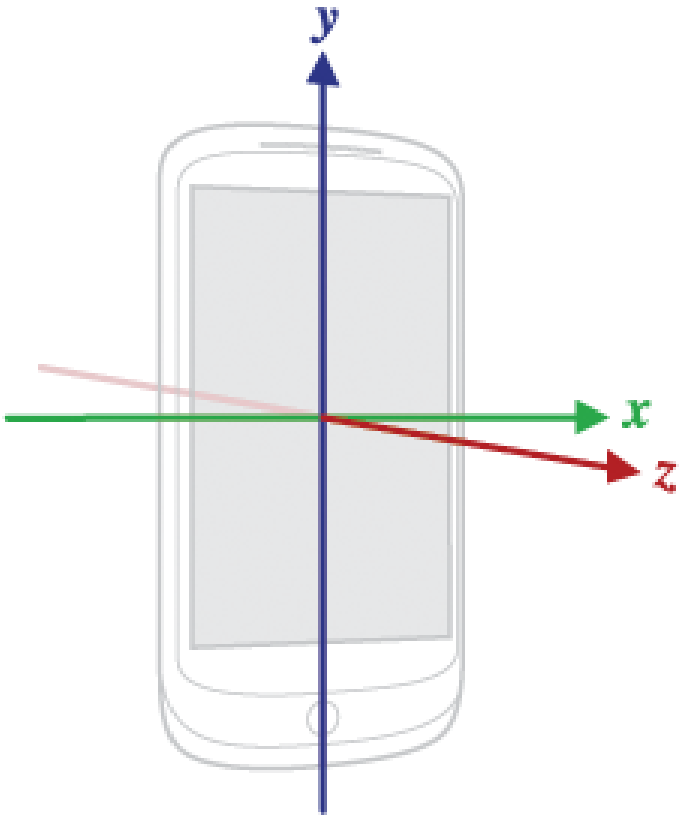
- It really doesn’t make a difference which of the two timestamps you use or even if you use both.
- However, the times when dots were visited and Wi-Fi scans were made have been specified in UNIX time only.
- Therefore, perhaps you should use the UNIX timestamps exclusively.

How to Compete Effectively

- PerfLoc is indeed challenging.
- Do not try to develop the ultimate algorithm and then do your first performance evaluation.
- Instead, start by developing a baseline algorithm using a subset of the sensor / RF data available and ignoring the building footprints initially, get it evaluated by using the PerfLoc website, and then make improvements gradually.
- Don’t expect to get accuracies in the 1-2 meter range that have been reported at other competitions. NIST will be happy if the best algorithm achieves 10 meter accuracy.
- Others use average accuracy. NIST uses SE95.
- Get on the Leaderboard early and do not leave your 150 opportunities for performance evaluation to the end, because you are limited to three usages per day.

Devil in the Details (I)

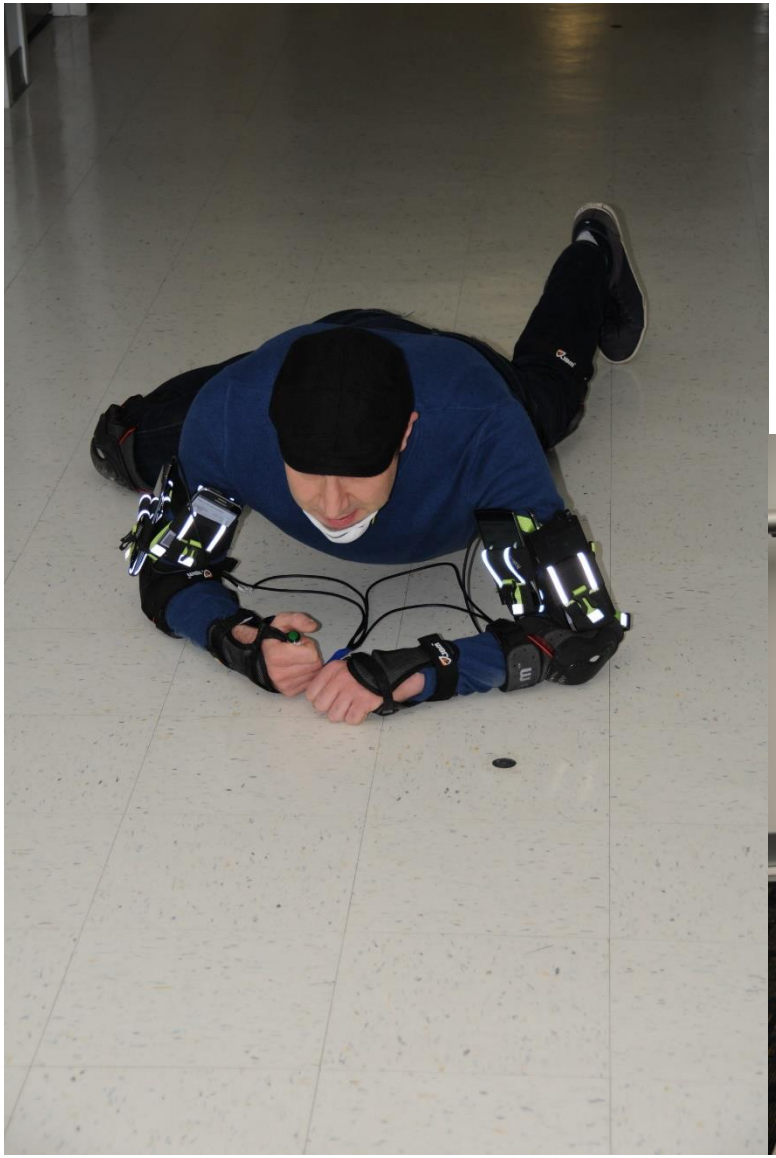
- The xyz coordinate system of the smartphone constantly varies with respect to the fixed xyz coordinate system of the building (northing, easting, elevation over sea level).
- Need to compute the displacements and turns of the phone with respect to the building coordinate system from the measurements made by the accelerometer, gyroscope, and other sensors (magnetometer, gravity, and air pressure) as well as the initial location of the phone and its poise.



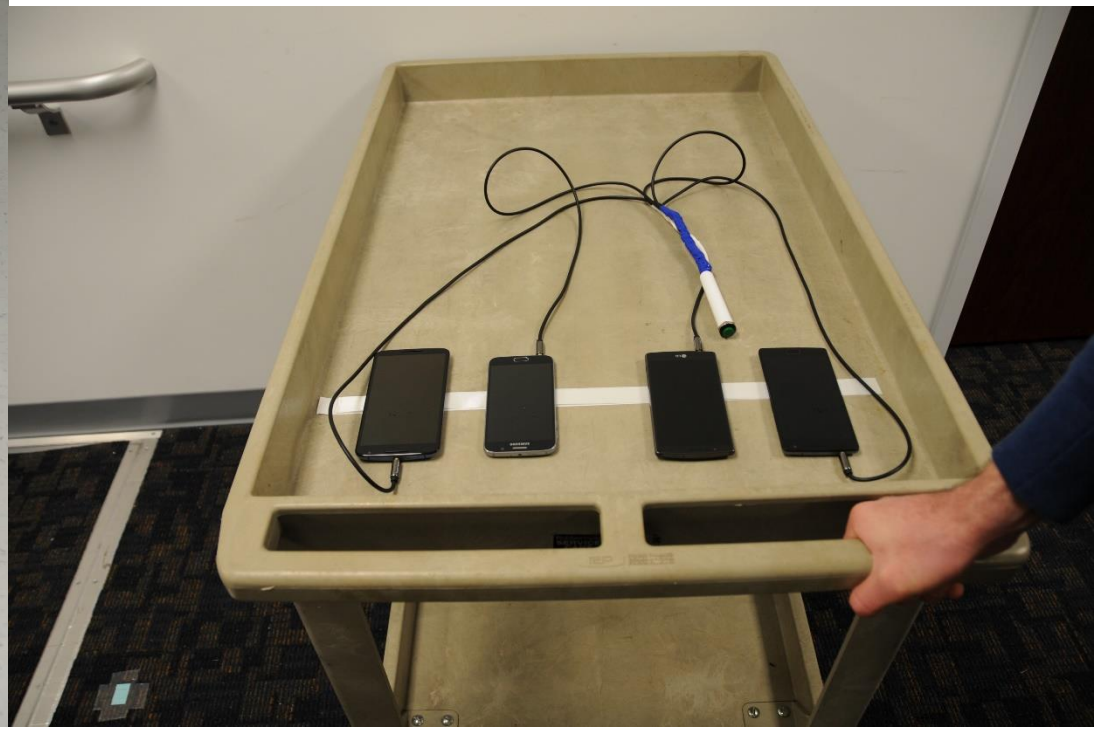
Devil in the Details (II)

- Need to be able to determine the mobility mode of the person who collected the data (walking normally / sideways / backward, running, crawling on the floor, going up and down the stairs).
- Need to be able to detect transitions from one mode to another.
- Need to be able to determine if the smartphone is being transported on a cart.
- Need to be able to detect if the smartphone is in an elevator.

Devil in the Details (III)



- Need to take into account how the phones were attached to the arms of the person collecting data and how they were laid on the bed of the cart.



Devil in the Details (IV)

- You need to upload your estimate of the location of the dot on the floor, as stated in "User Instructions for Uploading Location Estimates" in the PerfLoc User Guide, as opposed to your estimate of the location of the smartphone, as stated in the "Dots" section in the PerfLoc User Guide. The User Guide has been revised to mitigate the above discrepancy and to include the new pieces of information below and posted on the PerfLoc website.
- You need the following information in order to do this:
  - The height of the phones from the floor when the person collecting data was standing was on the average 130 cm.
  - The distance from one arm of the person collecting data to the other was 45 cm.
  - New Information: The height of the phones from the floor when the person collecting data was crawling on the floor was on the average 15 cm.
  - New Information: The height from the floor of the bed of the cart used for transporting the smartphones was 75 cm.

Devil in the Details (IV)

- Match the leftmost eleven hexadecimal digits of the BSSID for a received Wi-Fi signal to the eleven leftmost hexadecimal digits of the base radio MAC addresses of the Wi-Fi APs to determine from which AP the given Wi-Fi signal with the given RSSI is coming from. Basically, ignore the rightmost digits.
- Beware of the fact that the Wi-Fi APs use Transmit Power Control (TPC). This makes it more challenging to determine the path loss from an AP to a smartphone and to roughly estimate the range from the path loss.

In Conclusion

Questions? Ask today or email LocSprt@nist.gov

Answers will be posted on the FAQs page - https://perfloc.nist.gov/perfloc-faq.php

The PerfLoc Prize Competition is part of the NIST Public Safety Innovation Accelerator Program. To learn about more opportunities to win prizes in support of public safety, visit www.challenge.gov or send an email to Psprizes@nist.gov