Android GNSS Measurements under Spoofing and Interference

Andrea Botticella[*,†]
andrea.botticella@studenti.polito.it

Elia Innocenti[*,†]
elia.innocenti@studenti.polito.it

Renato Mignone[*,†]
renato.mignone@studenti.polito.it

Simone Romano[*,†]
simone.romano2@studenti.polito.it

ABSTRACT

This laboratory exercise examines how consumer smartphones process raw GNSS measurements under both stationary and motion conditions, and evaluates the impact of imposed spoofed location inputs and timing delays on computed navigation solutions. Leveraging open-source filtering and weighted least-squares estimation, we measure deviations in reported fixes and identify key factors—geometry shifts, signal strength fluctuations, and clock behavior—that influence accuracy. Our findings underscore strategies for detecting anomalous GNSS outputs on mobile devices.

1 INTRODUCTION

Global Navigation Satellite Systems (GNSS) provide critical positioning services for a wide range of consumer and industrial applications. However, GNSS signals are inherently vulnerable to spoofing attacks, in which counterfeit signal parameters are supplied to the receiver, potentially leading to incorrect location or time estimates. Understanding how smartphone GNSS observables respond under legitimate and spoofed inputs is essential for developing reliable detection mechanisms.

This laboratory exercise captures raw GNSS measurements from an Android handset in two scenarios: a static rooftop deployment and a tram-based kinematic test. Each dataset is processed twice with a weighted least-squares estimator—once to establish baseline performance and again with an overridden reference location and controlled timing delays. By comparing these runs, we isolate the effects of satellite geometry, signal quality, and receiver clock behavior on output integrity.

The remainder of this report is organized as follows. Section 2 describes the experimental setup, including device configuration, data collection procedures, and the processing pipeline. Section 3 presents results and discussion, contrasting static versus dynamic performance, examining spoofed-location impacts, and analyzing delay effects. Finally, Section **??** summarizes the key findings and outlines directions for future work.

2 METHODS

2.1 Devices and Software

We used a Samsung Galaxy A51 smartphone running Android 11 with GNSS Logger v3.1.0.4 to capture raw measurements. Data processing and analysis were performed in MATLAB R2024b using Google's open-source `gps-measurement-tools` library.

[*]The authors collaborated closely in developing this project.
[†]All the authors are students at Politecnico di Torino, Turin, Italy.

2.2 Data Collection

Two datasets were acquired on 3 May 2025 under cloudy conditions:

- **Static (Monte dei Cappuccini):** Device fixed by hand on a rooftop at latitude 45.059888°, longitude 7.697348°; logging ran from 10:35:20 for 5 minutes.
- **Dynamic (Tram Route):** Handheld during a tram ride between start point 45.0707622°, 7.6850644° and end point 45.063912°, 7.696680°; logging ran from 10:00:21 for 5 minutes.

2.3 Processing Pipeline

Raw GNSS logs were first filtered to exclude observations below a carrier-to-noise ratio of 25 dB-Hz and satellite elevation below 15°. We extracted pseudorange and Doppler measurements per epoch, then computed a weighted least-squares (WLS) position solution. For spoof-input evaluation, the same static dataset was reprocessed by specifying a false reference location (`spoof.position`) and an artificial timing delay (`spoof.delay`), allowing comparison of the shifted navigation output against the baseline.

3 RESULTS AND DISCUSSIONS

"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum."

"Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo. Nemo enim ipsam voluptatem quia voluptas sit aspernatur aut odit aut fugit, sed quia consequuntur magni dolores eos qui ratione voluptatem sequi nesciunt. Neque porro quisquam est, qui dolorem ipsum quia dolor sit amet, consectetur, adipisci velit, sed quia non numquam eius modi tempora incidunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur?"

3.1 Baseline Performance: Static vs. Dynamic

3.2 Impact of Spoofed Position

3.3 Effects of Timing Delays

3.4 (Optional) Interference Effects

4 CONCLUSIONS

"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum."

"Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo. Nemo enim ipsam voluptatem quia voluptas sit aspernatur aut odit aut fugit, sed quia consequuntur magni dolores eos qui ratione voluptatem sequi nesciunt. Neque porro quisquam est, qui dolorem ipsum quia dolor sit amet, consectetur, adipisci velit, sed quia non numquam eius modi tempora incidunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur?"

A APPENDIX

"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum."