A Comprehensive analysis of Android Smartphones GNSS Positioning and Signal Strength in Indoor and Outdoor Environments

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INTRODUCTION

- **Various global and regional satellite-based navigation systems (GPS, GLONASS, Galileo, BeiDou, QZSS and NavIC) are currently operational.**
- **The GNSS smartphone positioning system has gained significant attention due to its cost-effectiveness.**
- **However, achieving high-accuracy smartphone positioning faces challenges such as noisy GNSS data, environmental effects, and GNSS sensor configurations.**
- **An effort has been made for a comprehensive analysis of low-cost smartphones namely ‘Poco M3’, ‘Moto G52’, and ‘Huawei Nova 3e’ in indoor and outdoor contexts.**
- **The present investigation evaluates the C/No along with position solutions using WLS and KF methods with code measurements.**

METHODOLOGY

Figure 1. Concurrent GNSS data collection carried out using smartphones at a) outdoor and b) indoor environment conditions.

- ✓ Used ‘GnssLogger’ Android application to collect raw GNSS data in NMEA 0183 format at a 1 Hz rate.
- ✓ Wi-Fi, Bluetooth, and cellular data were turned off to avoid interference.
- ✓ Data was collected on August 23, 2023, in both indoor (Advanced GNSS Research Laboratory) and outdoor (roof of the ECE building, Osmania University) environments.
- ✓ Monitored continuous variations of signal strength and mean C/No for the strongest signal strength satellites in each constellation.

- ✓ **Compared mean C/No values with ICAO signal strength requirements.**
- ✓ **Post-processed the acquired single-frequency and dual-frequency raw data using MATLAB® software. Used the WLS based PVT algorithm with raw measurements and WLS with KF estimated positions for Single Point Positioning (SPP) performance assessment.**
- ✓ **Weighted Least Squares (WLS): A method for optimal position estimation from a set of observations at a given time. It doesn't consider past observations or predict future states.**
- ✓ **Kalman Filter (KF): An algorithm that uses a series of measurements over time to produce more accurate estimates of unknown variables. It's used in GNSS for estimating positions over time.**
- ✓ **Used the mean of position solutions estimated with raw PR as a reference point. Evaluated horizontal and vertical positioning errors with a probability of both 50% and 95%.**

Table 1 GNSS chipsets in employed smartphones with supporting frequency bands and constellations [note: constellations are denoted as GPS (G), GLONASS (R), Galileo (E), BeiDou (C), QZSS (Q), IRNSS/NavIC (I)]

Model Name (Android Version/ API Level)	GNSS chip model No	Manufacturer	Frequency	GNSS Constellation
Huawei Nova3E (9/28)	HI6250 Honor Kirin 710 (12 nm)	HiSilicon (Shenzhen, China)	Single (L1)	G,R,C,E,Q
Poco M3 (11/30)	SM6115 Snapdragon 662 (11 nm)	Qualcomm (San Diego, USA)	Dual (L1-L5)	G,R,C,E,Q
Motorola G52 (12/31)	SM6225 Snapdragon 680 4G (6 nm)	Qualcomm (San Diego, USA)	Dual (L1-L5)	G,R,C,E,Q,I

Signal Strength Variations

❑ Single-frequency Measurements

❖ Indoor Environment

- Failed to acquire signals due to highly multipath conditions.
- Insufficient satellite availability hindered position analysis.

❖ Outdoor Environment

- Successfully acquired signals from available satellites.
- Enabled position analysis and signal strength assessment.

➢ Outdoor Environment: SF Signal Strength Variations

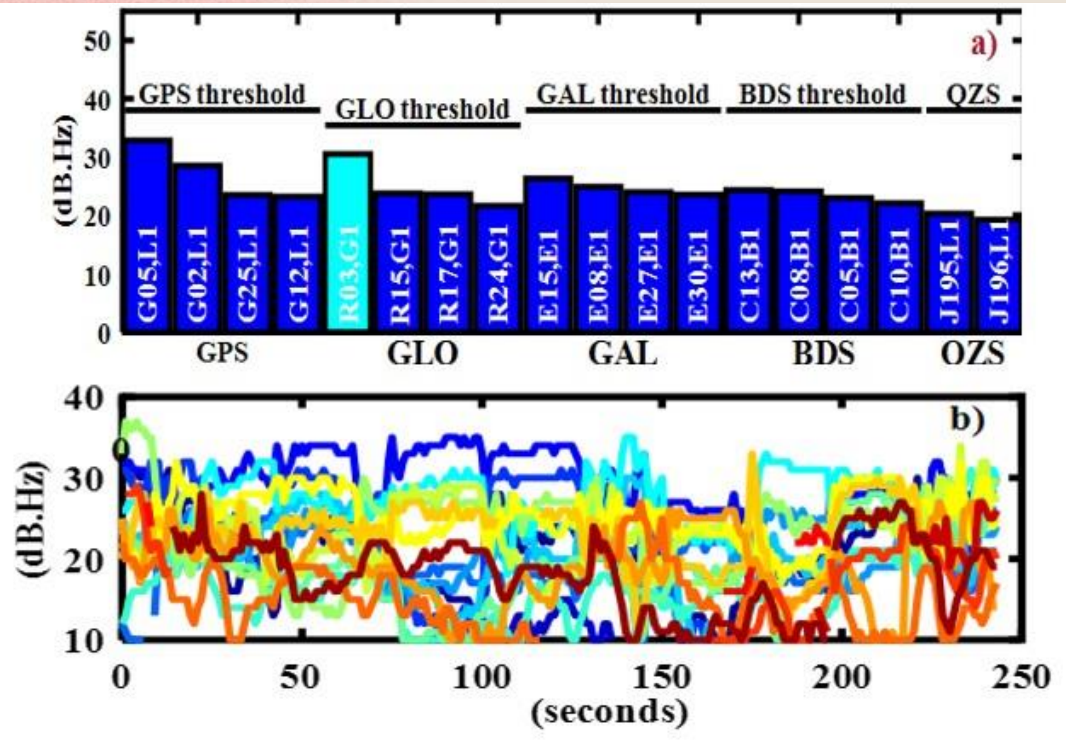

Figure 2 Mean Signal Strength and b) Signal Strength Variation of GPS L1, Galileo E1, BDS B1, GLONASS G1, and QZSS L1 Signals Collected by the 'Huawei Nova 3e' Smartphone in outdoor environment.

➤ Indoor Environment- DF Signal Strength Variations

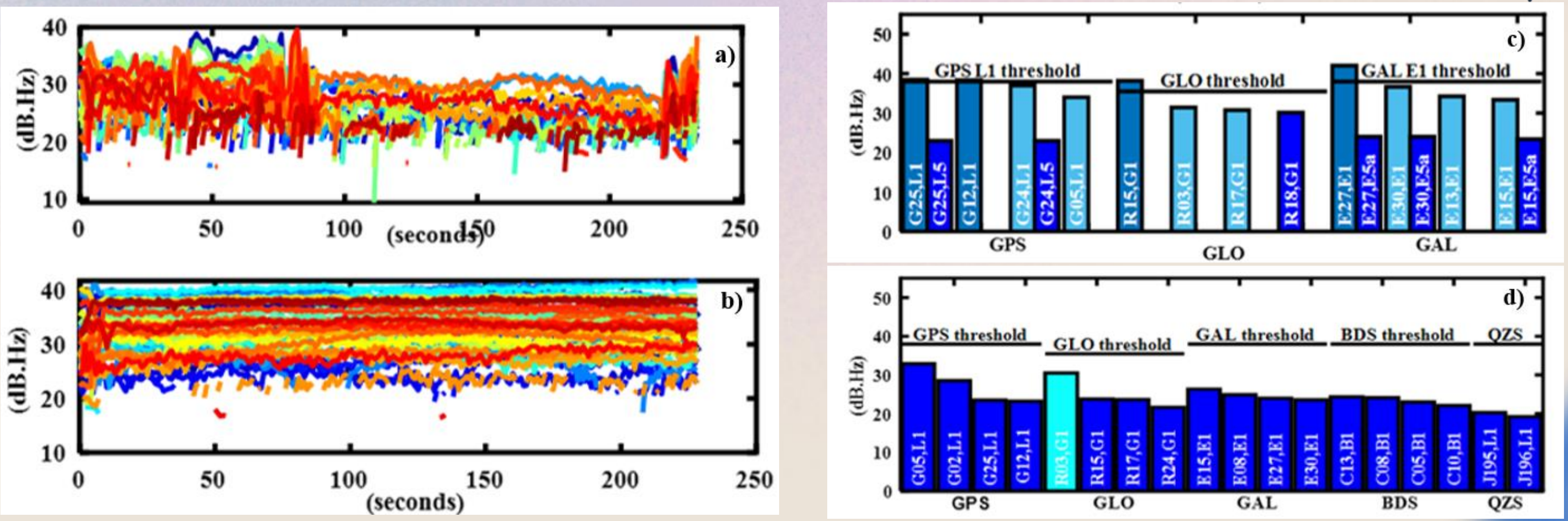

Figure 3 Signal strength variations of a) Poco M3, b) Moto G52, and Mean signal strength of c) Poco M3, and d) Moto G52 smartphones in an indoor environment.

➢ Outdoor Environment- DF Signal Strength Variations

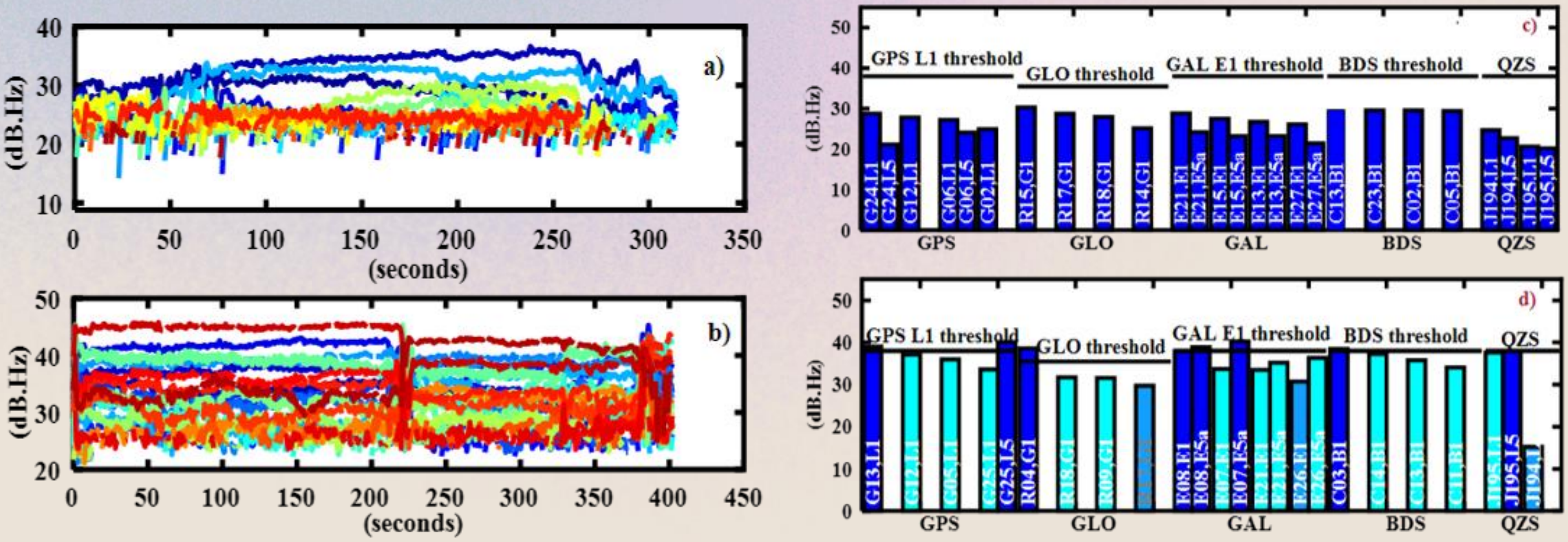

Figure 4 Mean signal strength of a) Poco M3, b) Moto G52, and signal strength variations of c) Poco M3, and d) Moto G52 smartphones in an outdoor environment.

Signal Strength Variations of SF/ DF devices:

Table 2 Mean C/No (dB-Hz) between corresponding GNSS signals in Indoor and Outdoor environments acquired by smartphones.

Constellations	Huawei Nova 3e (Single Frequency)		Poco M3 (Dual Frequency)		Motorola G52 (Dual Frequency)	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
GPS	27.2	25.7	26.9	37	26.7	36.4
GLONASS	22.6	24.9	24.9	32.6	28.0	32.9
Galileo	-	36.6	-	24.7	27.3	34.0
BeiDou	19.3	23.4	-	23.4	29.6	36.4
QZSS	-	19.8	-	19.8	22.7	26.4

POSITION ACCURACY IN DUAL-FREQUENCY ANDROID MEASUREMENTS

➤ Outdoor Environment: SF Variation of Horizontal and Vertical Positioning

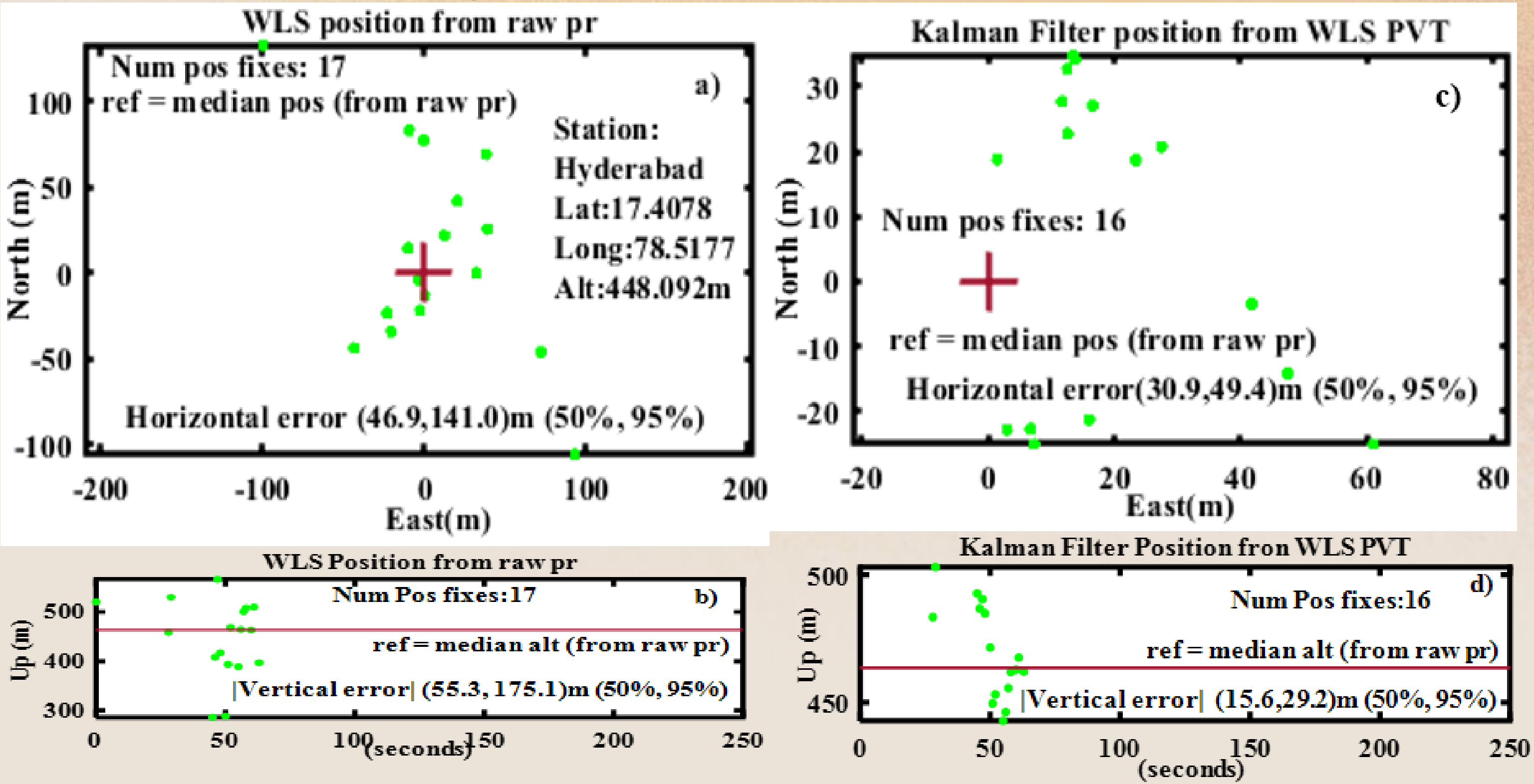

Figure 3. Comparison of Positioning Errors: a) Raw PR Horizontal Error, b) Kalman Filtered PR Horizontal Error, c) Raw PR Vertical Error and d) Kalman Filtered PR Vertical of single-frequency Huawei (3e).

➤ Indoor Environment- DF Variation of Horizontal Positioning

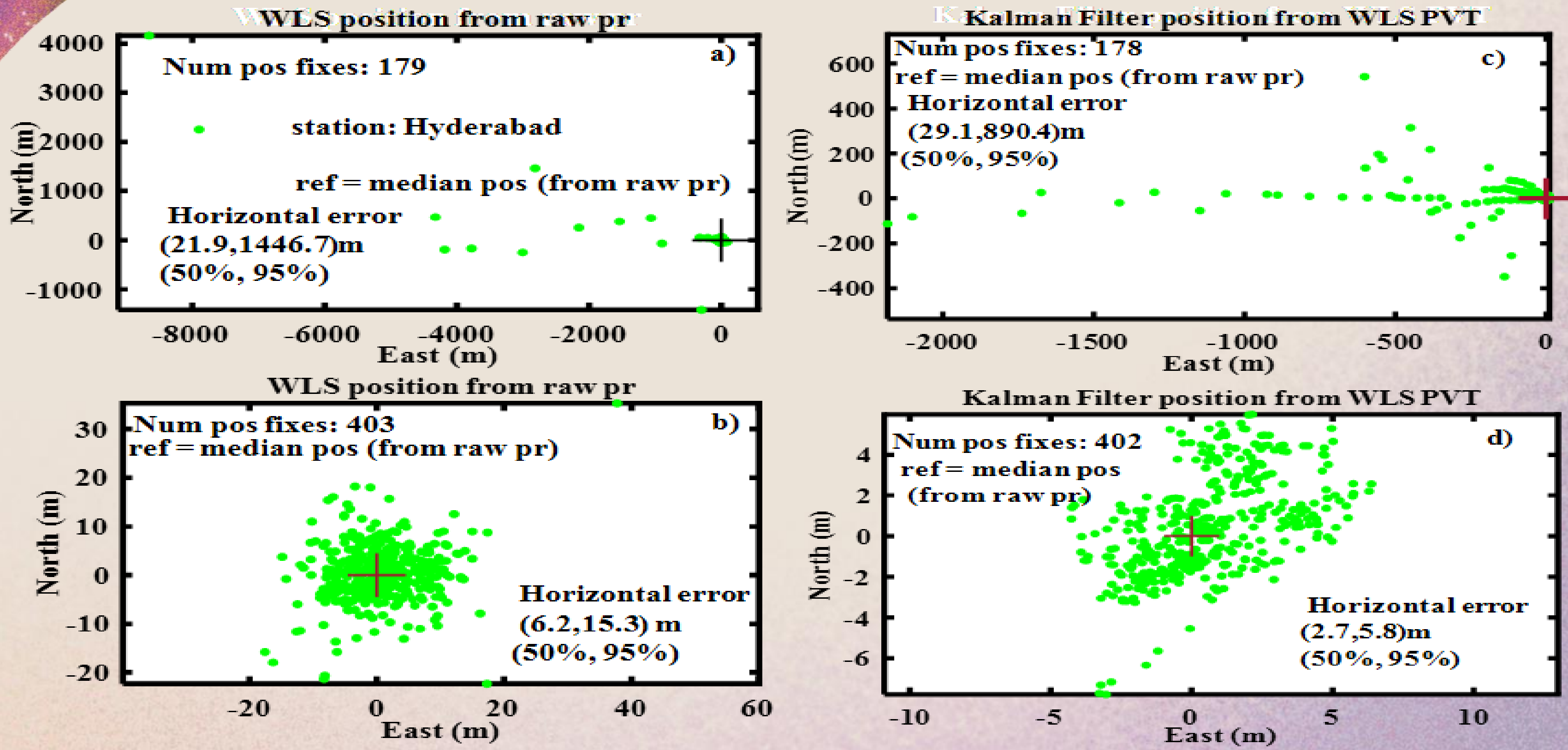

Figure 5. Variation in horizontal positioning for the observed smartphones a) M3 raw PR; b) G52 raw PR; c) M3 Kalman computed PR; and d) G52 Kalman computed PR.

➢ Indoor Environment- DF Variation of Vertical Positioning

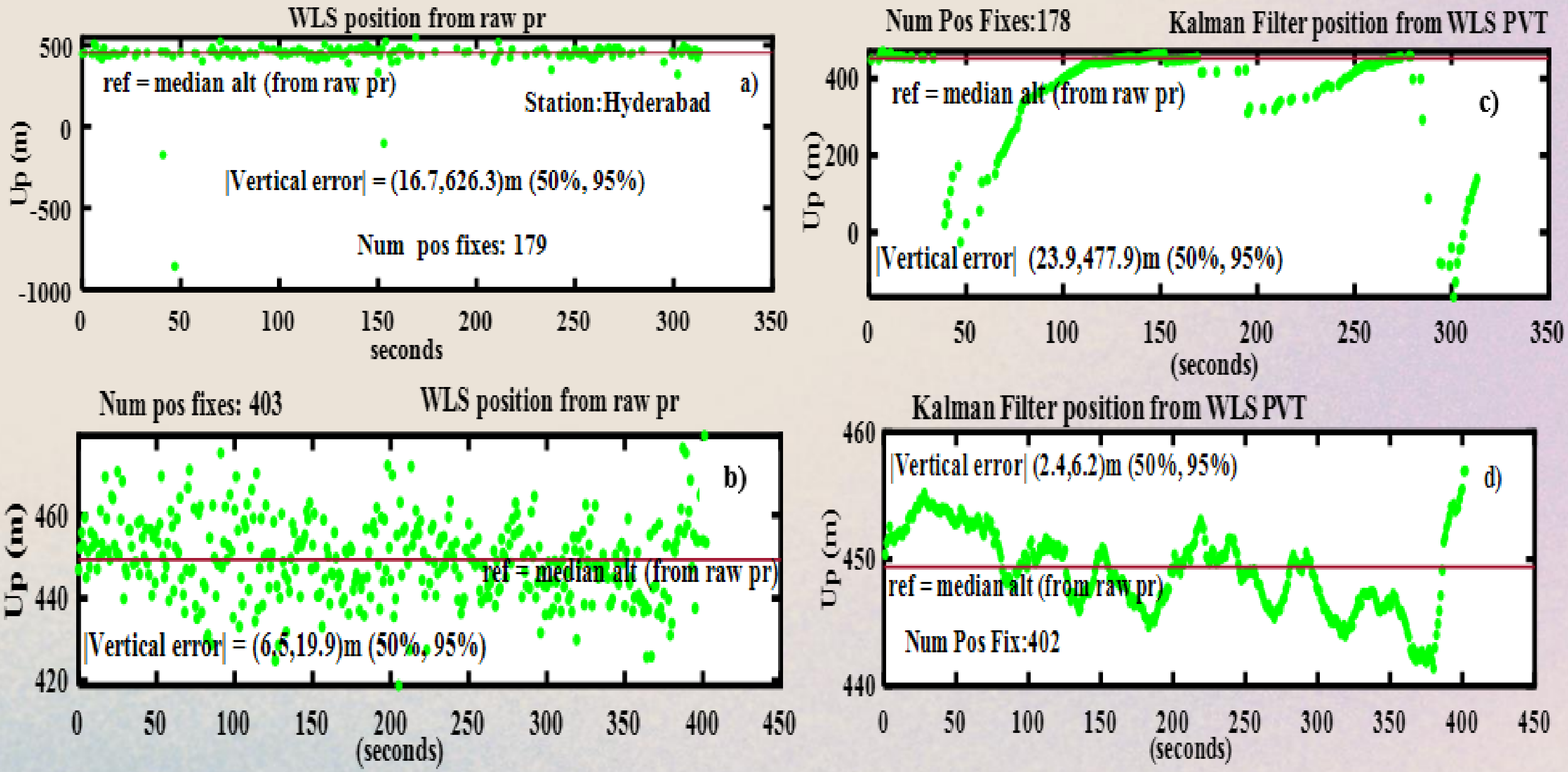

Figure 6. Vertical positioning error for the observed smartphones: a) M3 raw PR; b) G52 raw PR; c) M3 Kalman computed PR; and d) G52 Kalman computed PR.

➢ Outdoor Environment-Variation of Horizontal Positioning

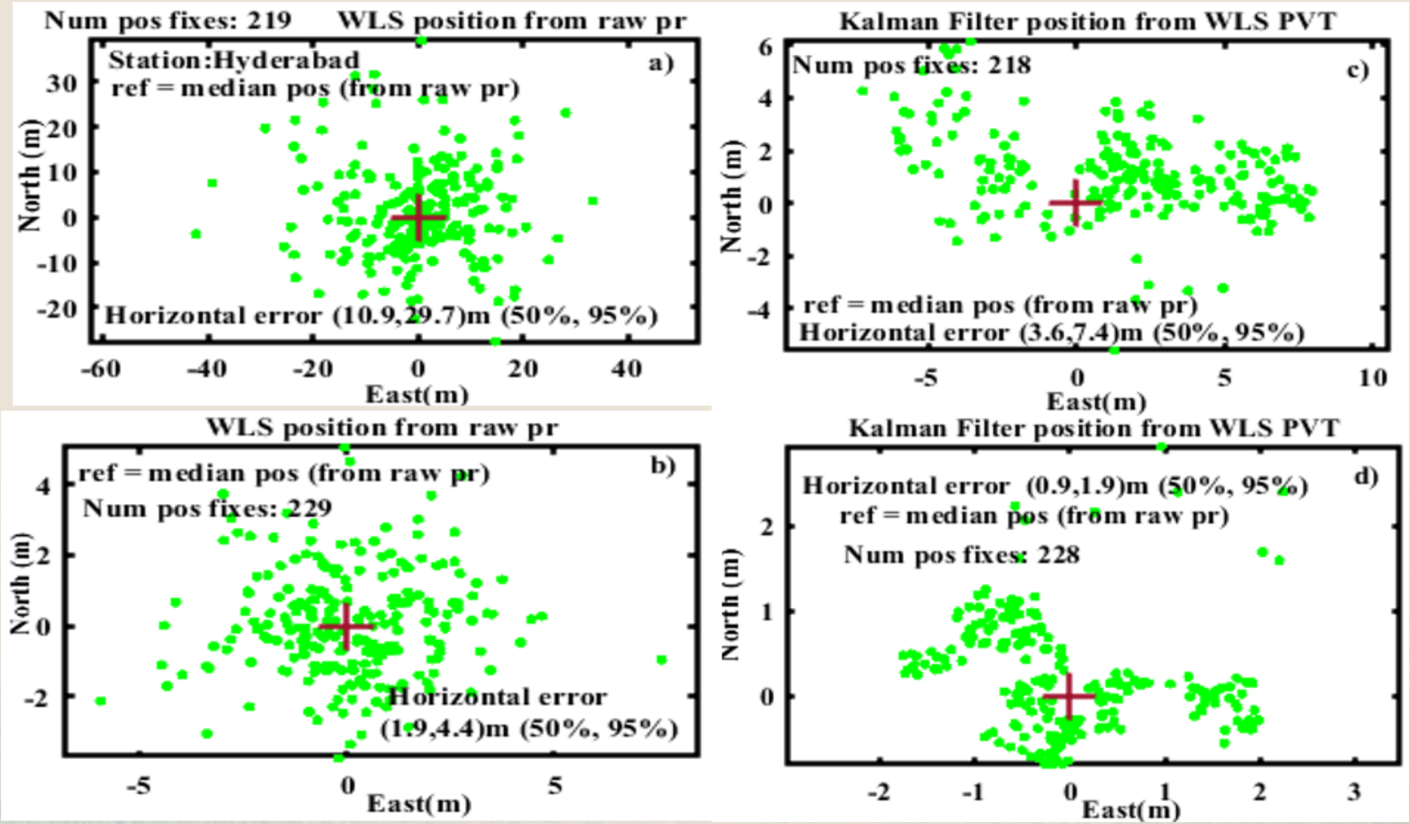

Figure 8. Horizontal Positioning error variation for the observed smartphones a) M3 raw PR; b) G52 raw PR; c) M3 Kalman computed PR; and d) G52 Kalman computed PR.

➢ Outdoor Environment-Variation of Vertical Positioning

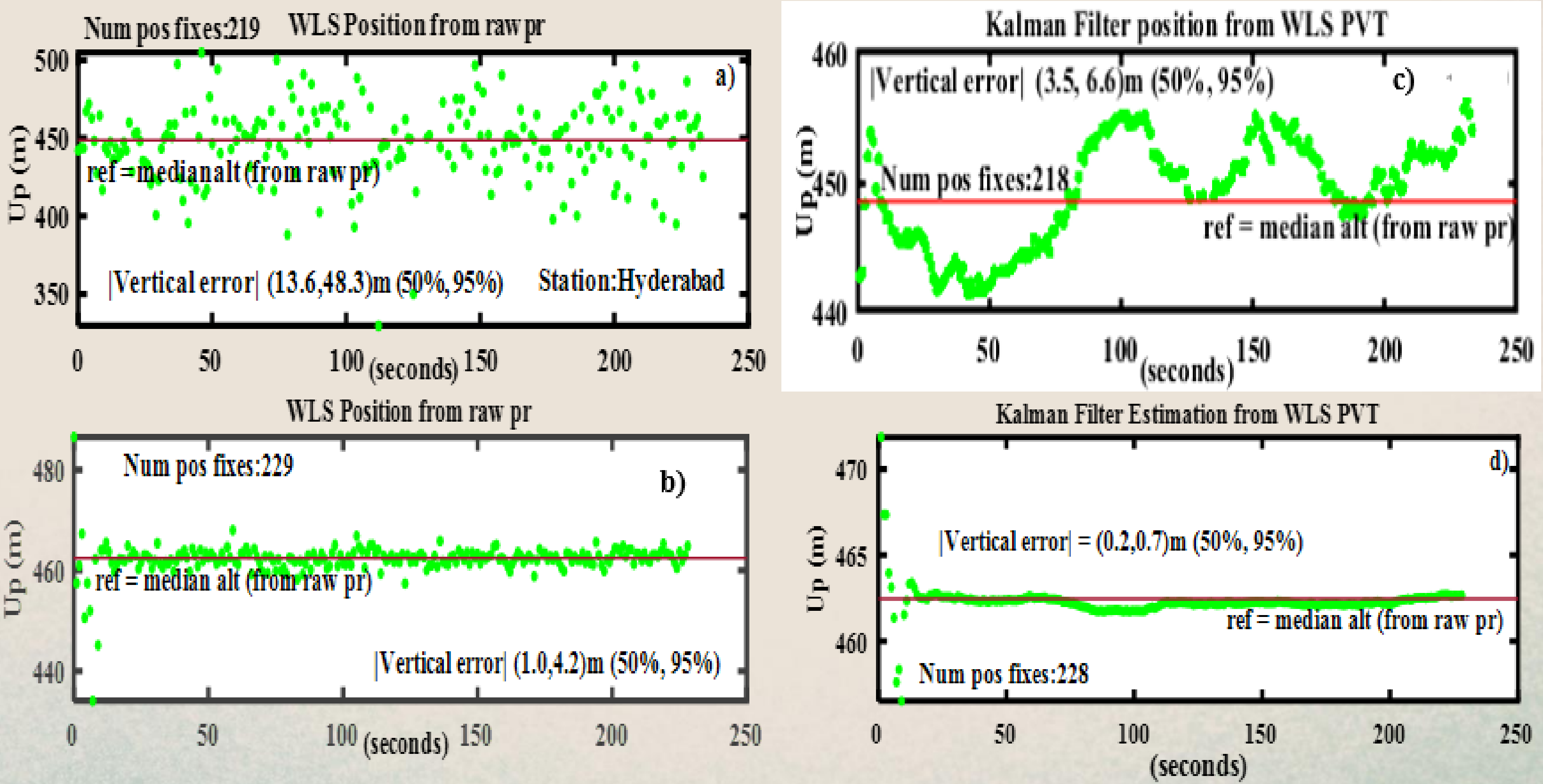

Figure 9. Variation in vertical direction positioning for the observed smartphones a) M3 raw PR; b) G52 raw PR; c) M3 Kalman computed PR; and d) G52 Kalman computed PR.

Table 3 The horizontal (H) and vertical (V) position accuracy with 50% and 95% probability were obtained using the Huawei Nova 3e (3e), Poco M3 (M3), and Motorola G52 (G52) smartphones with two different estimators (KF and WLS).

PVT Algorithm/ Environment	Smartphone	50% probability		95% probability	
		H	V	H	V
SPP WLS/ Indoor	3e	-	-	-	-
	M3	21.9	16.7	1446.7	626.3
	G52	6.2	6.5	15.3	19.9
SPP KF/ Indoor	3e	-	-	-	-
	M3	29.1	23.9	890.4	477.9
	G52	2.7	2.4	5.8	6.2
SPP WLS/ Outdoor	3e	30.9	15.6	49.4	29.2
	M3	10.9	13.6	29.7	48.3
	G52	1.9	1.0	4.4	4.2
SPP KF/ Outdoor	3e	46.9	55.3	141.0	175.1
	M3	3.6	3.5	7.4	6.6
	G52	0.9	0.2	1.9	0.7

CONCLUSIONS

- ✓ Dual-frequency multi-GNSS signals provided better strength and reliability than single-frequency GNSS signals.
- ✓ At irregular intervals, smartphone measurements have a lower C/N0 ratio, highlighting the sensitivity of smartphone signal acquisition.
- ✓ WLS Kalman Filter approach leads to improved positioning accuracy for both the dual-frequency Poco M3 and the Motorola G52 in both horizontal and vertical directions.
- ✓ The Motorola G52 shows better positioning performance compared to the Poco M3.
- ✓ This analysis will be helpful of using Android smartphones as low-cost multi-GNSS receivers for various applications

RECOMMENDATIONS

- ✓ **Diversity in Data: Collect geospatial data from different environments (urban, rural, coastal, mountainous).**
- ✓ **Use a range of Android devices to ensure robustness and generalizability across different hardware specifications.**
- ✓ **Equip Android devices to receive RTK data from network services or local base stations.**
- ✓ **Use ML to process and analyze location data for patterns, anomalies, or predictive features.**

REFERENCES

1. Gabryszuk, J. The Potential to Use Smartphone-based GNSS Receivers for Surveying. Geomat. Environ. Eng. 2020, 14, 49–57. https://doi.org/10.7494/geom.2020.14.2.49.
2. Specht, C.; Dabrowski, P.S.; Pawelski, J.; Specht, M.; Szot, T. Comparative analysis of positioning accuracy of GNSS receivers of Samsung Galaxy smartphones in marine dynamic measurements. Adv. Space Res. 2019, 63, 3018–3028. https://doi.org/10.1016/j.asr.2018.05.019.
3. Zangenehnejad, F.; Gao, Y. GNSS smartphones positioning: Advances, challenges, opportunities, and future perspectives. Satell.Navig. 2021, 2, 24. https://doi.org/10.1186/s43020-021-00054-y.
4. Skorupa, B. The problem of GNSS positioning with measurements recorded using Android mobile devices. Bud. i Archit. 2019,18, 51–62. https://doi.org/10.35784/bud-arch.738.
5. Elmezayen, A.; El-Rabbany, A. Precise point positioning using world's first dual-frequency GPS/galileo smartphone. Sensors 2019, 19, 2593. https://doi.org/10.3390/s19112593.
6. Kuna, D. & Perumalla, N. (2023). Assessment of android smartphones positioning in multi-GNSS/NavIC environment. Journal of Applied Geodesy, 17(4), 325-331. https://doi.org/10.1515/jag-2022-0062
7. Kuna, D., & Perumalla, N. K. (2023, April). An Analysis of Multi-GNSS Observations From Android Smartphones. In 2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT) (pp. 961-965). IEEE.

IT'S SO LOVELY TO MEET ALL OF YOU!

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Thank you for listening.