Using Wi-Fi HaLow Technology for IoT GNSS Monitoring Systems

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Key words: Internet of Things, GNSS, Wi-Fi HaLow, Kurloo, Landslide, Post-processed Kinematic

SUMMARY

This study pioneers the integration of Wi-Fi HaLow technology into IoT-based Global Navigation Satellite System (GNSS) monitoring systems, with a focus on landslip monitoring applications. Wi-Fi HaLow offers an advantageous mix of low power consumption, extended communication range, and robust data throughput, making it highly suitable for remote and challenging environments. While the limited connection range of Wi-Fi HaLow may appear restrictive, this limitation aligns well with the short baseline requirements of high-precision, low-cost GNSS monitoring.

The research compares Wi-Fi HaLow with traditional communication technologies, highlighting its advantages in scenarios where LTE is unavailable. Field experiments were conducted at two sites in New South Wales, Australia: one utilizing LTE-M communication and the other Wi-Fi HaLow. Results demonstrate the capability of Wi-Fi HaLow to support reliable data transmission over significant distances while maintaining system autonomy with solar-powered devices. Despite observed delays, the system's store-and-forward mechanism ensured no data loss during network outages. The findings underscore Wi-Fi HaLow's potential as a viable solution for high-precision GNSS applications, providing critical insights for advancing IoT-GNSS monitoring in remote or harsh environments.

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1. INTRODUCTION

The advantage of low-cost Global Navigation Satellite System (GNSS) techniques ensures its growing across various domains, including UAV-based geo-location, landslide monitoring, and Geographic Information System (GIS) applications [1-6]. Affordable GNSS devices now enable centimeter-level accuracy through Real-Time Kinematic (RTK) and Post-Processing Kinematic (PPK) methods [7,8]. Weston and Schwieger (2014) and Jackson et al. (2018) both explore the potential of low-cost GNSS receivers for high-accuracy positioning. Together, these studies underscore the growing feasibility of affordable GNSS solutions for high-precision applications without compromising performance or cost-efficiency [4, 5]. Applications range from environmental monitoring to construction and disaster response, often using lightweight, power-efficient systems to reduce operational complexity and costs [9-11].

On the other hand, the rapid expansion of Internet of Things (IoT) technologies has reshaped industries and everyday life. By utilizing an array of IoT sensors, the characteristics of a critical infrastructure or hazardous environment can be m,onitoring at regular time intervals continuously. IoT sensors and devices are increasingly used in monitoring solutions, leveraging communication protocols like Long-Term Evolution (LTE)/4G, Wi-Fi, and Long Range (LoRa) [12-17]. However, each protocol has unique limitations, particularly for precision GNSS applications. For instance, traditional wireless solutions like LTE/4G, Wi-Fi rely on network operators, introducing higher power consumption and additional operational costs, making them unsuitable for many battery-operated, low-power IoT devices [18-21]. LoRa enables long-distance, low-power communication without relying on network operators, making it highly suitable for specific IoT applications [22]. However, its limited bandwidth and duty-cycle constraints can impede consistent and efficient data transmission for applications requiring frequent updates. On the other hand, Bluetooth excels in energy efficiency and maintaining reliable connections over short distances, but its range is insufficient for medium to long-distance outdoor applications, restricting its suitability in such scenarios. Wi-Fi HaLow, operating on the Institute of Electrical and Electronics Engineers (IEEE) 802.11ah standard, offers a compelling alternative [15,16]. Designed for IoT, it supports extended range, low power consumption, and robust data throughput, making it suitable for high dense network, e.g., Smart Grid [12]. A comparison between them is provide in Table 1 [12-17].

Table 1 Comparison of typical wireless communication techniques

	LTE/4G	**Bluetooth**	**LoRa**	**Wi-Fi**	**Wi-Fi HaLow**
Frequency	600-2600 MHz	2.4 GHz	868/900 MHz	5-60 GHz	Sub-1 GHz
Data rate	1 Mb/s	1-24 Mb/s	0.3-50 Kb/s	1-6.75 Gb/s	150k – 86.7Mb/s
Range	1 – 10 km	8-10 m	<30 km	20 -100 m	<1500m
Energy consumption	Medium	Medium	Very low	High	Low
OTA firmware updates	Supports	Supports	-	-	Supports
Pros	Coverage area, flexible, network density	Most popular peer-to-peer wireless technology	low-power wide area	Data transfer speed	Scalable, longer range, low power
Cons	Cost, rural area network	Short range	low data rates	Power consumption	Few suppliers

In past years, the category of IoT devices consisted predominantly of internet-connected sensors, which in order to transmit their telemetry, required very small amounts of data and few packets (e.g. 10's to 100's of bytes). Now we see the IoT category including devices which stream audio and video, with vastly larger data transmission volume and rate demands. GNSS sensors collecting post-processed data lean more towards the larger end of the data demand spectrum, which requires a transmission technology that can handle greater file sizes and transmit them quickly to return to a low-power state to conserve energy. Wi-Fi HaLow is a technology which enables the transmission of raw GNSS data and other applications which have an even greater demand for bandwidth, i.e. HaLow cameras [23].

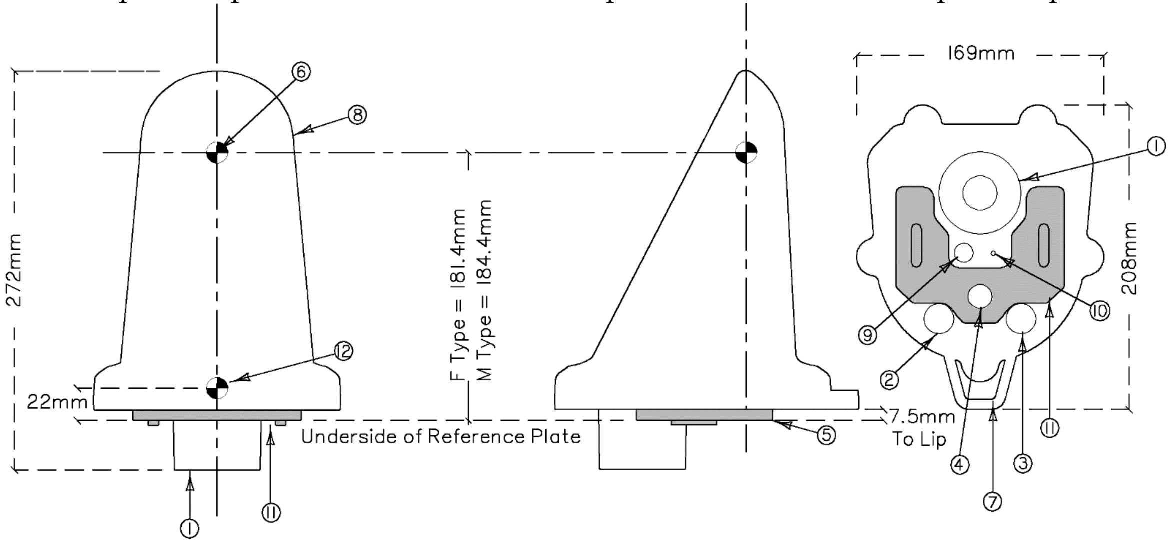
Despite advancements, the use of Wi-Fi HaLow for GNSS applications remains largely unexplored in literature. This research seeks to fill this gap by exploring the integration of Wi-Fi HaLow technology into an automatic high-precision GNSS monitoring system, targeting applications like landslide monitoring. The rest of this paper is organized as follows: We briefly introduce the general system architecture of Kurloo in Section 2 including the device components, data communication options and GNSS data processing method. Section 3 describes an experiment of landslip monitoring in Queensland. Section 4 presents the results and discussions. Finally, we conclude the main contribution of the present study and future work.

2. SYSTEM ARCHITECTURE

2.1 Device Components

Kurloo is an end-to-end, automated surface displacement monitoring device, which mainly consists of GNSS, IoT sensor, battery, outer radome and mounting parts shown in Figure 1

[24]. The device has dimensions of 207.7 mm (Length) x 168.8 mm (Width) x 272.2mm (Height) and weighs 1325g, including the internal battery and supplied antennas. It is a plug-and-play compact device that can operate in ambient environmental temperatures of -10°C to +65°C. Each device is equipped with LTE CAT-M1 modem that has further reach than LTE / 4G / 5G network that allows bi-directional communication of data: GNSS data, regular status update, remote command, and configuration and firmware-Over-the Air (FOTA) update. The internal 46 WH rechargeable Lithium Ion Phosphate (LiFePO4) battery is designed for 2-4 weeks of operation, without recharging. Coupled with a 1.5W integrated solar panel, the device is capable of permanent autonomous site operation without external power inputs.



1. Ultrasonic Distance Sensor
2. LTE-M Connector
3. Wi-Fi HaLow/LTE Connector
4. 5/8" Adapter Thread
5. Antenna Reference Point
6. Antenna Phase Centre
7. Locking Feature
8. Device Housing
9. External Interface Connector
10. On/Off/Status Button
11. Kurloo Reference Plate Accessory
12. Ultrasonic Phase Centre

Figure 1 Kurloo hardware components.

2.2 Data Communication Network

2.2.1 Communication Hub

In many regions where remote monitoring is required, an LTE network connection is not available, or, LTE is available, but either requires a large (high-gain) antenna for connection or is CAT-1 only and therefore incompatible with the Kurloo Monitoring Station. In this case, a Wi-Fi HaLow module can be installed inside the Kurloo. The HaLow module then connects to a HaLow gateway device to send data to the cloud. This approach enables the deployment of a long-range, low-power wireless network which is independent of the LTE coverage available, and a network solution can be tailored to the customer's needs and availability of internet connections. To provide cloud connectivity to the sensor devices, a range of communication hub solutions ("Commubs") are available shown in Figure 2:

- **CommHub 01**: consists of a HaLow Wireless Access Point (WAP). This device is a bridge to an existing wired network and requires supporting infrastructure to operate (power and established internet connection).
- **CommHub 02**: consists of a HaLow WAP and LTE modem. The LTE modem can be customised to suit the local LTE network, and fitted with a larger antenna if reception is poor. The hub can be situated in a location optimal for LTE performance (where on-site power is available), whereas monitoring stations are placed based on monitoring needs, hence the hub can provide a better/more stable LTE connection than that available to the monitoring stations.
- **CommHub 03**: consists of the same functionality as CommHub 02, but adds a battery and solar panel. This solution offers the greater flexibility in terms of hub placement as it does not require on-site power.
- **CommHub 04**: consists of the same functionality as CommHub 03 but uses an internet service provided by low Earth orbit satellites. This hub offers the greatest flexibility in terms of placement, as it does not require on-site power, or LTE coverage – only a clear view of the sky without obstruction from trees or buildings.

CommHub 01:
- WiFi HaLow
- Requires:
  - Onsite power
  - Onsite internet access via passive Power over Ethernet (PoE)

CommHub 02:
- WiFi HaLow
- 4G modem
- Requires:
  - Onsite power
  - 4G coverage

CommHub 03:
- WiFi HaLow
- 4G modem
- Solar & Battery
- Requires:
  - 4G coverage

CommHub 04:
- WiFi HaLow
- Starlink internet (mini dish 1/3 of power usage)
- Wireless router
- Solar & Battery

Figure 2 Different data communication hub options.

2.2.2 Communication Framework

The Kurloo is an IoT device, which means it transmits data to the cloud, where a server processes and stores the data, then end users access the data via a website or application programming interface (API) endpoint. Figure 3 shows the major network segments in the Kurloo communication framework. The first segment, the Low Power Wide Area Network

(LPWAN), consists of one or more sensing devices connecting to a shared gateway. HaLow is used for this network segment, due to its combination of energy efficiency, transmission range, data rate and seamless integration with downstream IP networking protocols.

The next segment is the backhaul domain, which is the part of the communications framework which connects the network edge to core functions, e.g. a remote area to a datacenter. For this monitoring application, the collected GNSS data is sent to an AWS-hosted server for processing. The data traverses the public internet via an undetermined route and combination of technologies, such as LTE, asymmetric digital subscriber line (ADSL), fibre-optic networks, and satellite links. With modern protocols and encryption techniques this is a trivial and reliable task.

Lastly, the processed data is made available to several end-user applications. One of these is a web-based front end, providing data access and analytical functions. Another is an API for integration into another monitoring platform.

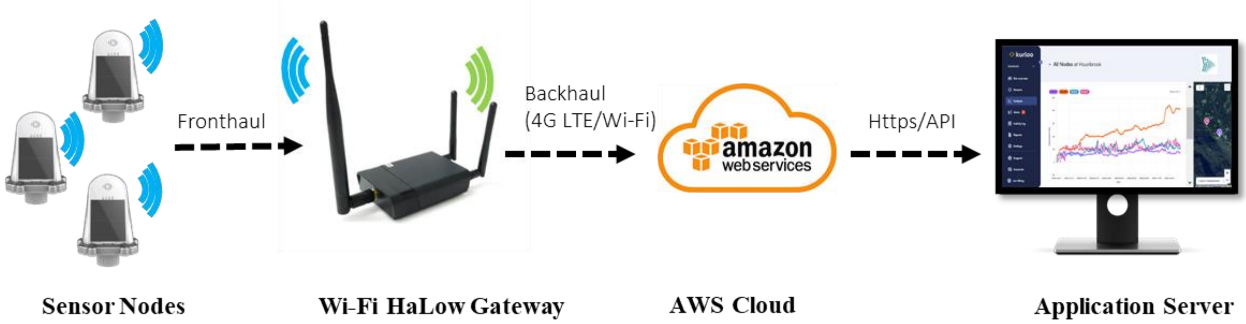


Figure 3 Diagram of data Wi-Fi Halow communication network.

2.3 GNSS Data Processing

Kurloo high-precision positioning system has integrated cost-effective but top-quality GNSS receiver and antenna and implemented PPK methods to obtain accurate antenna reference point (ARP) coordinates shown in Figure 1. The processing engine runs on AWS lambda that provide serverless computing resources anytime and anywhere. The GNSS data processing software utilizes RTKLIB, an open-source GNSS data processing toolkit for both RTK and PPK solutions [7,8]. The advantage of the PPK mode in RTKLIB is its ability to apply corrections both forwards and backwards in time, which helps to detect and correct anomalies such as cycle slips, thereby improving overall accuracy. The main RTKLIB parameter settings are listed in below:

- Positioning mode: Static
- Interval: 15 seconds
- Filter type: Combined
- Elevation mask: 20 degrees

- Satellite Ephemeris: Broadcast
- Ambigutity Resolution: GPS Fixed and hold
- Ambiguity Ratio: 3
- Constellations: GPS, Galileo and QZSS

The overall positioning performance of Kurloo is presented in Figure 4[25]. The monitoring projects with baseline lengths of less than 1.08 km are well-suited for the application of Wi-Fi HaLow technology, which supports reliable communication over such distances.

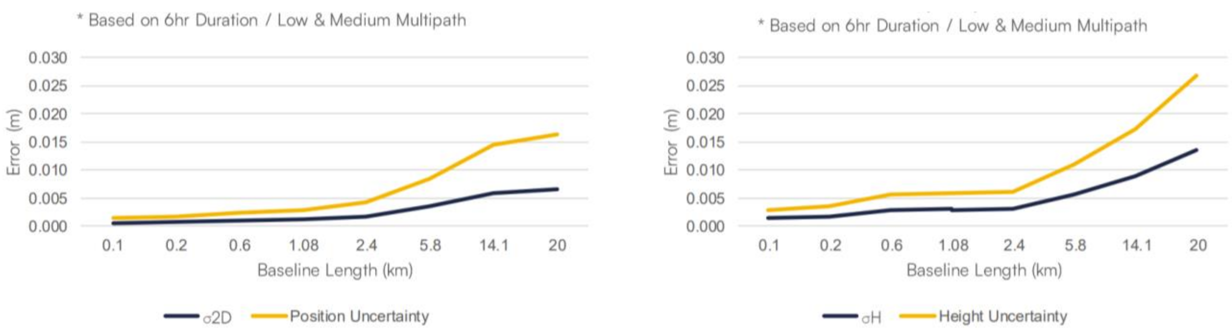


Figure 4 Kurloo typical positioning result performance.

3. EXPERIMENT

3.1 Field Installation

The experiment was conducted in the Northern Rivers region of New South Wales. According to the local government, evidence of landslips was identified at two distinct locations along a road (see Figure 5). Site 1, being close to the town, has access to LTE signal coverage. In contrast, Site 2 is located 7.59 km away, and a site inspection confirmed the absence of cellular network signals at this location. Consequently, a Wi-Fi HaLow solution was implemented at Site 1 to enable reliable communication.

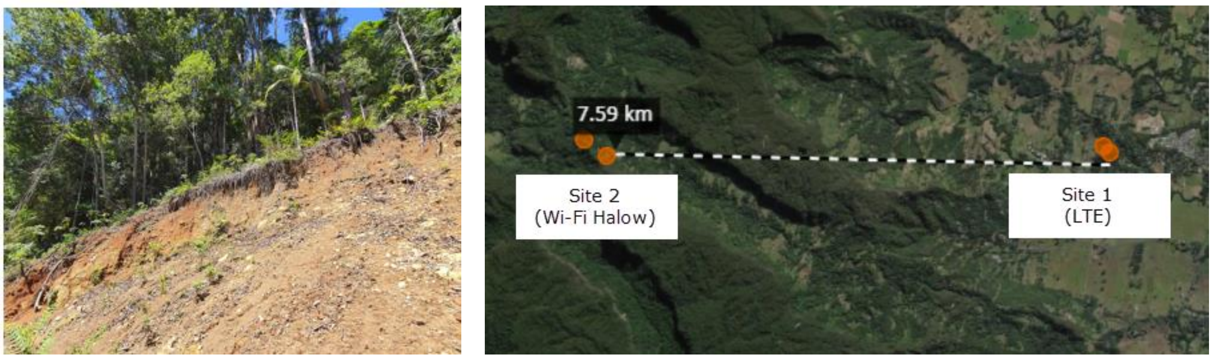


Figure 5 Experiment location. Left panel: Site landslips evidence. Right panel: Sites location.

3.1.1 Site 1 (LTE-M)

Three Kurloo devices are installed in Site 1. The base station is installed in existing pole on bracket located on top of water tank fitted with high gain anteena as shown in Figure 6. The other two monitoring units were attached 70mm diameter, 2.1 metres high galvanised poles with a 450mm long ground spike. The ground spikes were installed with a jackhammer and the soil condition and depth of installation is noted for each individual location where exhibits landslip movement.

Figure 6 Site 1 photos. Left panel: base station on the top of water tank; Center panel: base station; Right panel: monitoring node.

3.1.2 Site 2 (Wi-Fi HaLow)

Figure 7 shows the installation devices in Site 2. The base station is installed on the roof or nearby coffee shop. 4 monitoring stations are installed on the embankment which measure daily 3D displacement. The Wi-Fi Halow gateway is setup behind the coffee shop. With the local council and coffee shop owners assistance and permission, the gateway is configured to connect with the coffee shop Wi-Fi network.

Figure 7 Site 2 photos. Left panel: base station on the roof of coffee shop; Center panel: monitoring node; Right panel: Kurloo CommHub 03 gateway.

4. RESULTS AND DISCUSSION

4.1 Power Consumption

One of the key considerations in this project is the power consumption of the devices. Figure 8 illustrates the battery level variations for the two base stations at Site 1 (LTE) and Site 2 (Wi-Fi Halow) during the period from July 2024 to October 2024. Overall, the LTE communication method demonstrates better power consumption efficiency compared to Wi-Fi HaLow. However, during the period from 15 July 2024 to 5 August 2024, the battery level variations for both methods exhibit similar trends. It is important to note that these variations are also influenced by the performance of the solar panel charging system, which is closely tied to environmental factors.

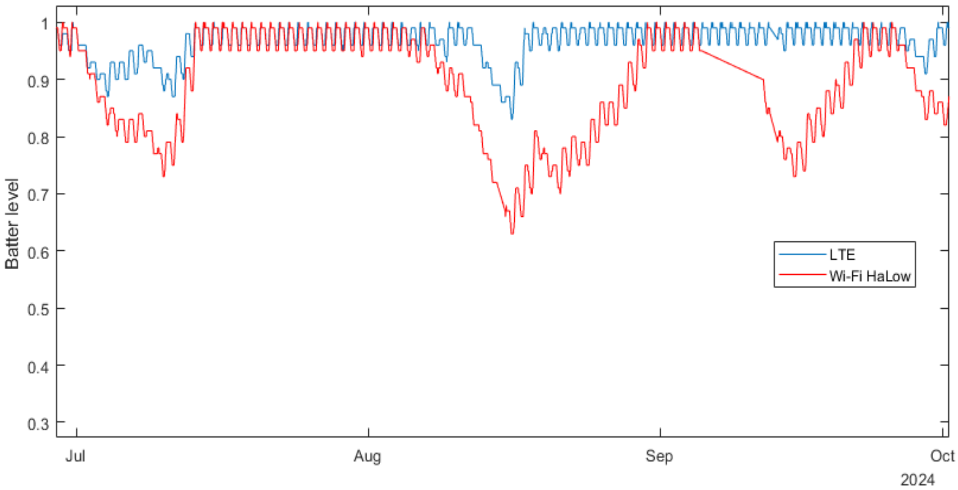


Figure 8 The devices batter level varition with different communication methods.

4.2 Time Latency

Data connection reliability is a critical factor for IoT applications. To assess the performance of data transmission, a Grafana panel was configured to display the Message Queuing Telemetry Transport (MQTT) interval, set by default to 30 minutes. Figure 9 presents the message update latency for Site 1 (LTE connection) and Site 2 (Wi-Fi HaLow connection). Two significant Wi-Fi HaLow connection time-lag events were observed at Site 2 on 15 August 2024 and 11 September 2024 as shown in the left panel of Figure 9. These extreme delays obscure other details. To provide a clearer analysis, the right panel of Figure 9 presents the MQTT message update latency after excluding these two days. This refined view reveals that the LTE connection maintained a consistent update interval of approximately 30 minutes from July to October 2024, except for a single one-hour latency event on August 5, 2024.

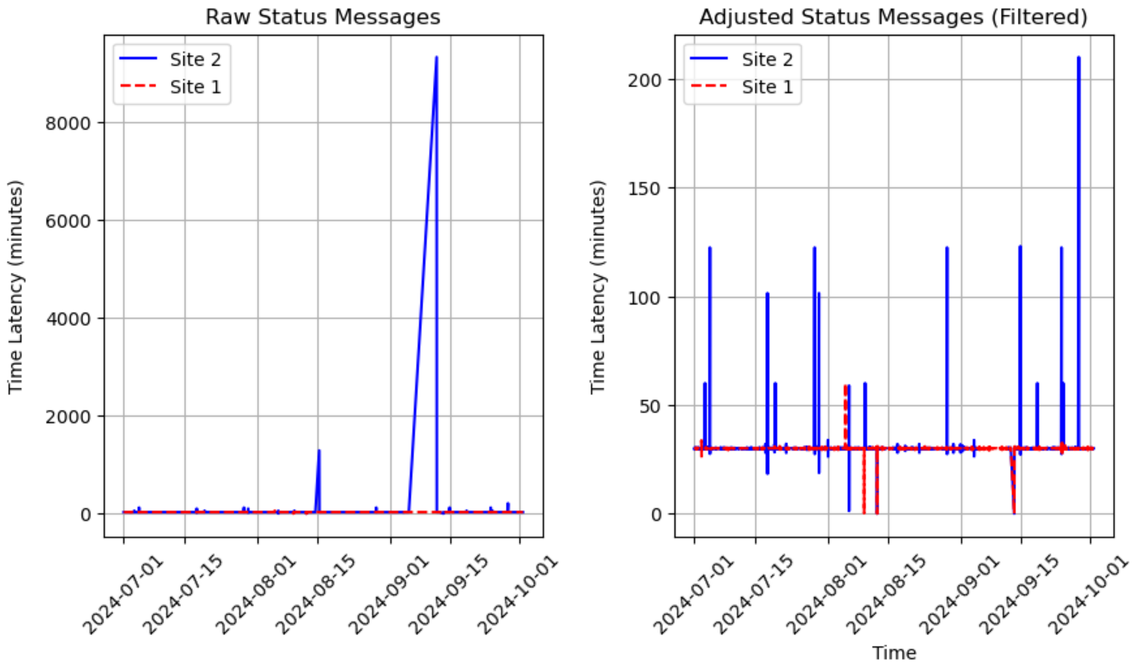


Figure 9 Time latency of MQTT status messages from base stations at Site 1 (using LTE) and Site 2 (using Wi-Fi HaLow). The left panel shows raw status messages time latency, while the right panel presents filtered status messages data.

4.3 Monitoring Solution

This section presents the displacement results of the monitoring nodes from the platform at the two experimental sites since the project's commencement in October 2023, as part of the end-user application. The platform provides displacement visualization in North/East/Up (NEU), 2D horizontal, 3D XYZ, or a customer-aligned axis direction [10, 24]. Figure 10 displays a screenshot of the 3D displacement trends of two monitoring nodes at Site 1. Initially, both nodes exhibit similar 3D displacement trends. However, after December 26, 2023, their displacement variations begin to diverge.

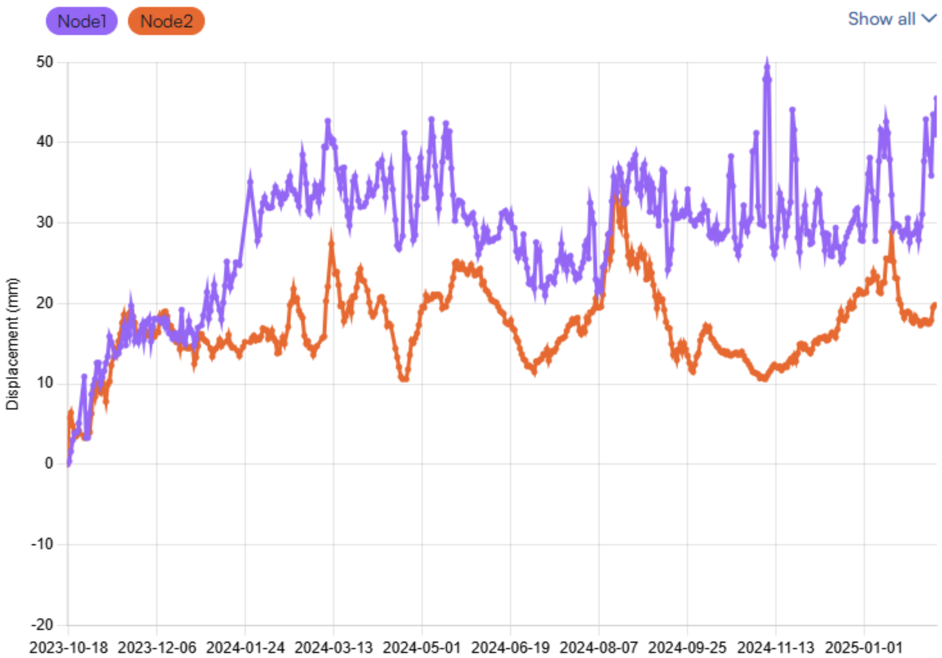


Figure 10 3D displacement of 2 monitoring nodes in Site 1.

Figure 11 depicts the 3D displacements of the monitoring nodes at Site 2, where it is evident that Node 2 demonstrates a distinct displacement trend in contrast to the other three monitoring nodes at the same site. Despite the communication delays discussed section 4.2, the proposed IoT GNSS monitoring system, equipped with a store-and-forward mechanism, effectively addresses these challenges. This mechanism enables the device to locally buffer data during network outages and subsequently synchronize and upload the delayed data to the cloud once connectivity is restored. This functionality ensures no data loss, enhancing data reliability and enabling seamless operation. It is particularly advantageous for GNSS monitoring applications involving the transmission of Mb-sized data files in remote or harsh environments where connectivity may be intermittent.

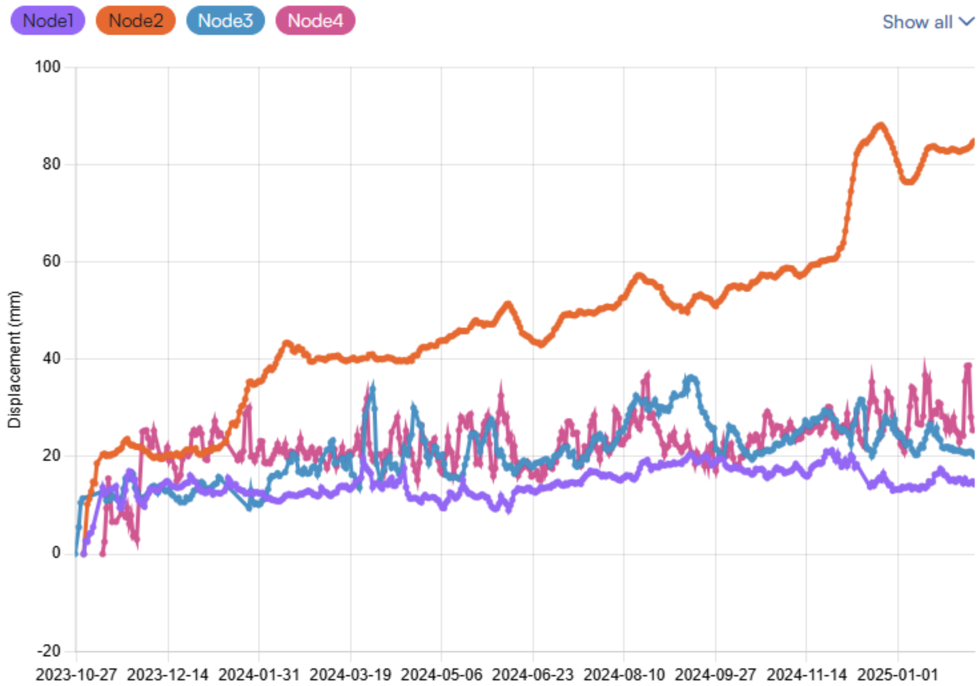


Figure 11 3D displacement of 4 monitoring nodes in Site 2.

5. CONCLUSION

This research demonstrates the successful integration of Wi-Fi HaLow technology into an IoT-GNSS monitoring system for landslip applications. The experimental results indicate that Wi-Fi HaLow offers several advantages over traditional communication technologies, including extended range, low power consumption, and cost-effectiveness. These features are critical for deploying monitoring systems in remote locations with limited or no cellular network coverage.

The field trials conducted at two sites highlight Wi-Fi HaLow's ability to support real-time data transmission while maintaining system autonomy through solar-powered operation. Despite occasional communication delays, the store-and-forward mechanism effectively buffered and transmitted delayed data once connectivity was restored, ensuring uninterrupted data collection and reliability. The system's performance validates the feasibility of Wi-Fi HaLow for transmitting large GNSS datasets, making it a promising alternative for precision monitoring applications in harsh or remote environments.

Future work will explore scaling the system to larger deployments, optimizing power management, and further investigating Wi-Fi HaLow GNSS monitoring performance with diverse baseline length. This study provides a foundation for adopting Wi-Fi HaLow in GNSS-based monitoring, addressing the challenges of connectivity, power efficiency, and data integrity.

REFERENCES

1. Radočaj, D., Plaščak, I., Heffer, G., & Jurišić, M. (2022). A Low-Cost Global Navigation Satellite System Positioning Accuracy Assessment Method for Agricultural Machinery. Applied Sciences, 12(2), 693. https://www.mdpi.com/2076-3417/12/2/693
2. Hill, A. C., Limp, F., Casana, J., Laugier, E. J., & Williamson, M. (2019). A New Era in Spatial Data Recording: Low-Cost GNSS. Advances in Archaeological Practice, 7(2), 169-177. https://doi.org/10.1017/aap.2018.50
3. Zhang, L., Stange, M., & Schwieger, V. (2012). Automatic low-cost GPS monitoring system using WLAN communication. In: FIG working week 2012. Rome, Italy; 2012. 6-10 May 2012.
4. Weston, N. D., & Schwieger, V. (2014). Cost effective GNSS positioning techniques, 2nd ed.; FIG Commission 5 Publication: Copenhagen, Denmark, 2014.
5. Jackson, J., Saborio, R., Ghazanfar, S. A., Gebre-Egziabher, D., & Davis, B. (2018). Evaluation of Low-Cost, Centimeter-Level Accuracy OEM GNSS Receivers; Department of Aerospace Engineering and Mechanics, University of Minnesota: Minneapolis, Minnesota, 2018; Report No. MN/RC 2018-10
6. Wang, J., Hellen, L., Morschel, T., & Cronin, S.(2019). A Low-cost High-Precision Geo-Location Solution for UAVs. Proceedings of the 15th South East Asian Survey Congress (SEASC2019) Darwin, Australia, 15-18 August 2019
7. Takasu, T.; Yasuda, A (2009). Development of the low-cost RTK-GPS receiver with an open source program package RTKLIB. In Proceedings of the International Symposium on GPS/GNSS, International Convention Center, Jeju, Republic of Korea, 22–25 September 2009; Volume 1, pp. 1–6.
8. Everett, T. RTKLib Demo5. Available online: https://rtkexplorer.com/downloads/rtklib-code/ (accessed on 10 November 2024).
9. Biagi, L., Grec, F. C., & Negretti, M. (2016). Low-Cost GNSS Receivers for Local Monitoring: Experimental Simulation, and Analysis of Displacements. Sensors (Basel, Switzerland), 16(12), 2140. https://doi.org/10.3390/s16122140
10. Wang, J. etc. (2023) Kurloo: the GNSS-IoT solutions for continuous monitoring of embankment instabilities applied to Froggy Beach (Gold Coast, Queensland, Australia). Proceedings of the 14th Australia and New Zealand Conference on Geomechanics, Cairns 2023 (ANZ2023)
11. Koo, G., Kim, K., Chung, J. Y., Choi, J., Kwon, N.-Y., Kang, D.-Y., & Sohn, H. (2017). Development of a High Precision Displacement Measurement System by Fusing a Low Cost RTK-GPS Sensor and a Force Feedback Accelerometer for Infrastructure Monitoring. Sensors, 17(12), 2745.
12. Kane, L., Liu, V., McKague, M., & Walker, G. (2023). An Experimental Field Comparison of Wi-Fi HaLow and LoRa for the Smart Grid. Sensors, 23(17), 7409. https://www.mdpi.com/1424-8220/23/17/7409
13. Lee, I.-G., Kim, D. B., Choi, J., Park, H., Lee, S.-K., Cho, J., & Yu, H. (2021). WiFi HaLow for long-range and low-power Internet of Things: System on chip development and performance evaluation. IEEE Communications Magazine, 59(7), 101-107.

14. Liang, R., Zhao, L., & Wang, P. (2020). Performance Evaluations of LoRa Wireless Communication in Building Environments. Sensors, 20(14), 3828.
15. Wi-Fi Alliance.(2023) Wi-Fi Alliance Introduces Low Power, Long Range Wi-Fi HaLow. Available online: https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-introduces-low-power-long-range-wi-fi-halow (accessed on 1 July 2024).
16. Wi-Fi Alliance (2021). Wi-Fi Certified HaLow Technology Overview. Avaliable online: https://20524844.fs1.hubspotusercontent-na1.net/hubfs/20524844/Wi-Fi_CERTIFIED_HaLow_Technology_Overview_20211102.pdf (accessed on 1 July 2024).
17. Gift, M., Gololo, D., Nyathi, C., Boateng, L., Nkadimeng, E., McKenzie, R., Atif, I., Kong, J., Mahboob, M., Cheng, L., & Mellado, B. (2024). Review of IoT Systems for Air Quality Measurements Based on LTE/4G and LoRa Communications. IoT 2024, 5, 711–729.
18. Ghazali, M. H. M., Teoh, K., & Rahiman, W. (2021). A Systematic Review of Real-Time Deployments of UAV-Based LoRa Communication Network. IEEE Access, 9, 124817-124830.
19. Mayer, P., Magno, M., Berger, A., & Benini, L. (2021). RTK-LoRa: High-Precision, Long-Range, and Energy-Efficient Localization for Mobile IoT Devices. IEEE Transactions on Instrumentation and Measurement, 70, 1-11. https://doi.org/10.1109/TIM.2020.3042296
20. Bouras, C.; Gkamas, A.; Kokkinos, V.; Papachristos, N(2019). Using LoRa technology for IoT monitoring systems. In Proceedings of the 2019 10th International Conference on Networks of the Future (NoF), Rome, Italy, 1–3 October 2019; IEEE: Piscataway, NJ, USA; pp. 134–13
21. Nahar, R. S., Ng, K. M., Johari, J., Kamal, M. M., & Razak, N. A. (2021, 7-7 Aug. 2021). Evaluation of Dynamic Measurements from RTK-GNSS Operating in Sub-urban Environment. 2021 IEEE 12th Control and System Graduate Research Colloquium (ICSGRC)
22. T. Karunathilake, A. Udugama and A. Förster, "LoRa-DuCy: Duty Cycling for LoRa-Enabled Internet of Things Devices," 2021 Twelfth International Conference on Ubiquitous and Future Networks (ICUFN), Jeju Island, Korea, Republic of, 2021, pp. 283-288
23. Enriko, I. Ketut Agung, and Fikri Nizar Gustiyana. "Wi-Fi HaLow: Literature Review About Potential Use Of Technology In Agriculture And Smart Cities in Indonesia." 2024 International Conference on Green Energy, Computing and Sustainable Technology (GECOST). IEEE, 2024.
24. Hellen, L. W., Jun; Wang, Charles;Feng, Yanming; Keenan, Ryan. (2023, 28 May - 1 June). Development of Australian automated Internet of Things monitoring sensor (AAIMS) - Kurloo FIG Working Week 2023, Orlando, Florida, USA.
25. Kurloo Brochure(2024). https://globalsurvey.co.nz/wp-content/uploads/2024/02/Introducing-Kurloo-Brilliantly-Simple-NZ.pdf (accessed on 1 December 2024)

BIOGRAPHICAL NOTES

Dr. **Jun Wang** is Head of Research of Kurloo Technology. Currently leading efforts in integrating IoT and GNSS systems as well as developing UAV processing platform, Jun Wang focuses on enabling high-precision, low-cost solutions for industries such as construction, and transportation. Their work spans both academic research and industry projects, with a notable emphasis on deploying advanced GNSS monitoring systems for critical infrastructure and environmental applications. Jun Wang graduates from Queensland University of Technology with a Doctor Degree in Computer Science and was awarded the Siganto Foundation Medal in 2013. Jun Wang and his team have won twice Asia-Pacific Spatial Excellence Awards (APSEA) for Innovation-Small business in 2021 and 2022. Jun is also awarded National APSEA for Future Leader of the Year in 2022.

Dr. **Charles Wang** is Head of Product of Kurloo Technology. His expertise areas include GNSS, precise positioning technologies, wireless networking and communication and cloud computing and services. Charles Wang has been involved in a few major CRC funded projects (CRCSI-1 & 2, iMove, IMCRC), ARC linkage project and several industry leaded projects (TMR, FrontierSI SBAS and FrontierSI PA1004). Dr. Wang has shown strong motivation and abilities in working with partners to delivering industry focused demonstrator projects and operational systems. Whilst working with CRCSI project, he has established, maintained and enhanced a complex software suite for GNSS satellite orbit determination with performances matching international benchmarks. His involvement in several technology showcase demonstrator projects (TMR-CAVI, SBAS) has shown the ability to design, build, test various cutting-edge technologies with detailed evaluation to showcase the benefits to the industry applications.

Mr. **David Cooper** is is the Senior Firmware Engineer at Kurloo Technology, where he plays a pivotal role in overseeing the quality control and maintenance of IoT GNSS monitoring sensors. David leads a team of in-house electrical engineers, driving innovation and ensuring the reliability of Kurloo's cutting-edge technologies. With exceptional technical problem-solving skills, David has made significant contributions to the development of the Kurloo Wings. David's expertise and dedication are integral to Kurloo's mission to deliver high-precision GNSS monitoring solutions for diverse industries and applications..

Mr. **Lee Hellen** is a geospatial entrepreneur and consultant specialising in geospatial and surveying technology. He is the founder of Land Solution Australia, Monitum and most recently the CEO of Kurloo Technology in Australia. Though his commercial enterprise, Lee has supported greater levels of geospatial technology adoption to many major infrastructure and building construction projects over the past 25 years across Australia and Europe. His passion for geospatial innovation and technology has delivered efficiency in process, risk management and stakeholder engagement across a variety of industries. Lee has been consistently recognised by his peers for advancing private sector capability and knowledge of the Surveying and Spatial sciences professions in Australia and Asia.

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