MyRTKnet - Past, Present and Future

Saad, L. S.,[1] Che Amat, S. D. M. A.,[2] Ruslan, M. R.[3*] and Aziz, S. N. H.[4]
Geodetic Survey Division, Department of Survey and Mapping Malaysia (JUPEM), Malaysia
E-mail: shabudin@jupem.gov.my,[1] asyran@jupem.gov.my,[2] ridhwan@jupem.gov.my[3]* nurulhusna@jupem.gov.my[4]
**Corresponding Author*

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Abstract

Malaysia Real-Time Kinematic GNSS Network (MyRTKnet) has played a pivotal role in transforming the country's geospatial landscape since its inception in 2002. This paper traces the evolution of MyRTKnet from its early establishment with just 27 stations in Phase I to its current configuration of 109 continuously operating reference stations (CORS) under Phase V. The network has undergone significant technological upgrades in both hardware and software to support high-accuracy real-time and post-processed positioning services for a wide range of applications, including land surveying, engineering, navigation, precision agriculture, and disaster response. The paper reviews key milestones, including the adoption of new GNSS constellations, coordinate system revisions following major seismic events, and the integration of semi-kinematic models to support time-dependent reference frames. It also highlights JUPEM's proactive efforts to enhance network reliability, including the deployment of a secondary processing centre and the automation of station integrity monitoring. Looking ahead, MyRTKnet is being further developed to support multipurpose geospatial applications, mobile deployment for disaster resilience, web services for coordinate transformation, and its role as the national geodetic benchmark. The paper concludes by outlining JUPEM's vision to align MyRTKnet with international geodetic standards and user demands, ensuring it remains a vital pillar of Malaysia's geospatial infrastructure in the decades to come.

Keywords: Coordinate System, CORS, MyRTKnet, Network RTK

1. Introduction

Since the 19th century, national mapping authorities around the world have established coordinate reference systems using conventional surveying techniques. Most of these systems were based on local datums, designed to meet the mapping needs of specific countries or regions. Malaysia followed a similar path, initially implementing two classical triangulation networks: the Malayan Revised Triangulation 1948 (MRT48) for Peninsular Malaysia, and the Borneo Triangulation 1948 (BT48) for Sabah and Sarawak. As additional data became available and network adjustments were made, these systems were subsequently updated. The Malayan Revised Triangulation 1968 (MRT68) and the Borneo Triangulation 1968 (BT68) were introduced to replace MRT48 and BT48, providing improved accuracy for national mapping in Peninsular Malaysia and Borneo, respectively.

In the early 1990s, JUPEM adopted Global Positioning System (GPS) technology, marking a major shift in geodetic surveying practices. This led to the establishment of two large-scale GPS networks: the Peninsular Malaysia GPS Scientific Network 1994 (PMGSN94) with 238 stations, and the East Malaysia GPS Scientific Network 1997 (EMGSN97) with 171 stations. By the end of 1998, JUPEM further strengthened its geodetic infrastructure by setting up 18 permanent GPS tracking stations, known as the Malaysia Active GPS System (MASS).

Using GPS data collected from these MASS stations, along with supplementary data from International GNSS Service (IGS) stations, JUPEM derived highly precise coordinates based on four years of continuous GPS observations (1999 - 2002). These coordinates formed the foundation of Malaysia's first geocentric reference frame, the Geocentric Datum of Malaysia (GDM2000), which was officially launched on 26 August 2003. The GDM2000 coordinates are aligned with the International Terrestrial Reference Frame (ITRF2000), referenced to epoch 1 January 2000 (i.e. 2000.0) [1]. Starting in 2002, JUPEM advanced its GNSS infrastructure by establishing a modern active GNSS network equipped with state-of-the-art technology, known as the Malaysia Real-Time Kinematic GNSS Network (MyRTKnet) [2] and [3].

This system delivers real-time positioning services with centimetre-level accuracy, providing high-precision data to users across various industries and applications [4][5] and [6].

2. MyRTKnet Operational Phases

2.1 Phase I: 2002 – 2007

MyRTKnet Phase I (2002 - 2007) comprised 27 GNSS stations, including 25 in Peninsular Malaysia and one each in Sabah and Sarawak (Figure 1(a)). All stations were equipped with Trimble 5700 GPS receivers paired with Zephyr Geodetic antennas. During this phase, users in Penang, the Klang Valley, and Johor Bahru were able to access network-based real-time positioning services, while users in other regions could obtain single-base corrections.

2.2 Phase II: 2007 – 2013

MyRTKnet Phase II (2007 - 2013) expanded the network to 78 stations, comprising 50 in Peninsular Malaysia, 13 in Sabah, 14 in Sarawak, and 1 in the Federal Territory of Labuan (Figure 1(b)). The stations were equipped with either Trimble 5700 or NetR5 GPS / GNSS receivers, paired with Zephyr Geodetic II antennas. This phase marked a significant milestone as Network RTK coverage was extended across the entire Peninsular Malaysia as well as to key urban centres in East Malaysia, such as Kota Kinabalu, Miri, and Kuching. Users in other areas continued to access positioning services via single-base corrections.

2.3 Phase III: 2013 - 2019

MyRTKnet Phase III (2013 - 2019) expanded the network to 96 stations, comprising 65 in Peninsular Malaysia, 15 in Sabah, 15 in Sarawak, and 1 in the Federal Territory of Labuan (Figure 1(c)). This phase featured an upgrade in hardware, with stations equipped with either Trimble NetR5 receivers and Zephyr Geodetic II antennas, or Leica GR25 receivers paired with Leica AR10 antennas. In tandem, the central processing software was upgraded from the Trimble Pivot Platform (TPP) to Leica SpiderNet [7] and [8] for improved services. Network RTK coverage was extended to the entire Peninsular Malaysia, as well as major population centres in East Malaysia, such as Kuching, Sibu, and Miri in Sarawak, and Tawau and the West Coast of Sabah. In areas beyond the network RTK coverage, users continued to benefit from single-base correction services [9].

2.4 Phase IV: 2019 – 2023

MyRTKnet Phase IV (2019 - 2023) maintained a similar network configuration to that of Phase III (Figure 1(d)), while incorporating several key upgrades. Each station is equipped with either a Trimble NetR5 GNSS receiver paired with a Zephyr Geodetic II antenna or a Leica GR25 / GR50 GNSS receiver paired with a Leica AR10 antenna. The inter-station spacing ranges from 30 to 100 kilometres, ensuring optimal signal coverage and positioning accuracy. At the central facility, the processing software was upgraded from Leica GNSS SpiderNet to the more advanced Leica Spider Business Center (SBC), enhancing overall system functionality and user support. Network RTK coverage continues to span the entirety of Peninsular Malaysia as well as major urban and coastal regions in Sabah and Sarawak. For users operating beyond these zones, single-base correction services remain available [9] and [10]. To bolster service reliability and continuity, a disaster recovery centre was established at the Public Sector Data Centre in Putrajaya, ensuring uninterrupted MyRTKnet operations in the event of disruptions to the primary system.

2.5 Phase V: 2023 – Present

MyRTKnet Phase V (2023 - present) comprises 109 stations across Malaysia: 79 in Peninsular Malaysia, 15 in Sabah, 14 in Sarawak, and 1 in the Federal Territory of Labuan (Figure 1(e)). This phase marks a significant upgrade in hardware with 62 stations across Peninsular and East Malaysia being modernised with Trimble Alloy GNSS receivers paired with Trimble Choke Ring antennas. This upgrade enhances overall signal quality, tracking capabilities, and system resilience. In addition, the central processing software was migrated from Leica Spider Business Center (SBC) to the latest Trimble Pivot Platform (TPP), aligning the backend system with the upgraded hardware to support improved performance, scalability, and future service enhancements.

3. Revision of MyRTKnet Coordinates

3.1 GDM2000 in 2006

At the time of its launch in 2003, the GDM2000 included coordinates for only 18 MASS stations. This was later expanded to incorporate 27 MyRTKnet stations under the MyRTKnet Phase I project. Between 2007 and 2008, JUPEM further expanded the network to 78 stations as part of Phase II of the MyRTKnet implementation [11].

Additionally, two major earthquakes that struck Indonesia in 2004 and 2005 caused significant tectonic displacements that also affected the coordinates within the GDM2000 reference frame. In response, JUPEM updated the GDM2000 coordinates in 2006 to reflect both the inclusion of the new 51 stations and the displacements resulting

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from these seismic events [12]. This updated coordinate set is referred to as GDM2000 (2006). The derivation of GDM2000 (2006) coordinates was based on GNSS data collected from 1 January 2006 to 28 February 2007. Data was processed daily using Bernese GPS Software to generate daily solutions, which were then consolidated into weekly solutions. The final coordinate estimates were derived from 61 weekly solutions. During the adjustment process, the coordinates of MyRTKnet stations in Sabah and Sarawak were held fixed, as displacement in these regions was found to be negligible [13][14] and [15]. Importantly, GDM2000 (2006) retained the same reference frame and epoch as the original GDM2000, namely ITRF2000 at epoch 2000.0, ensuring consistency with the original realisation [16].

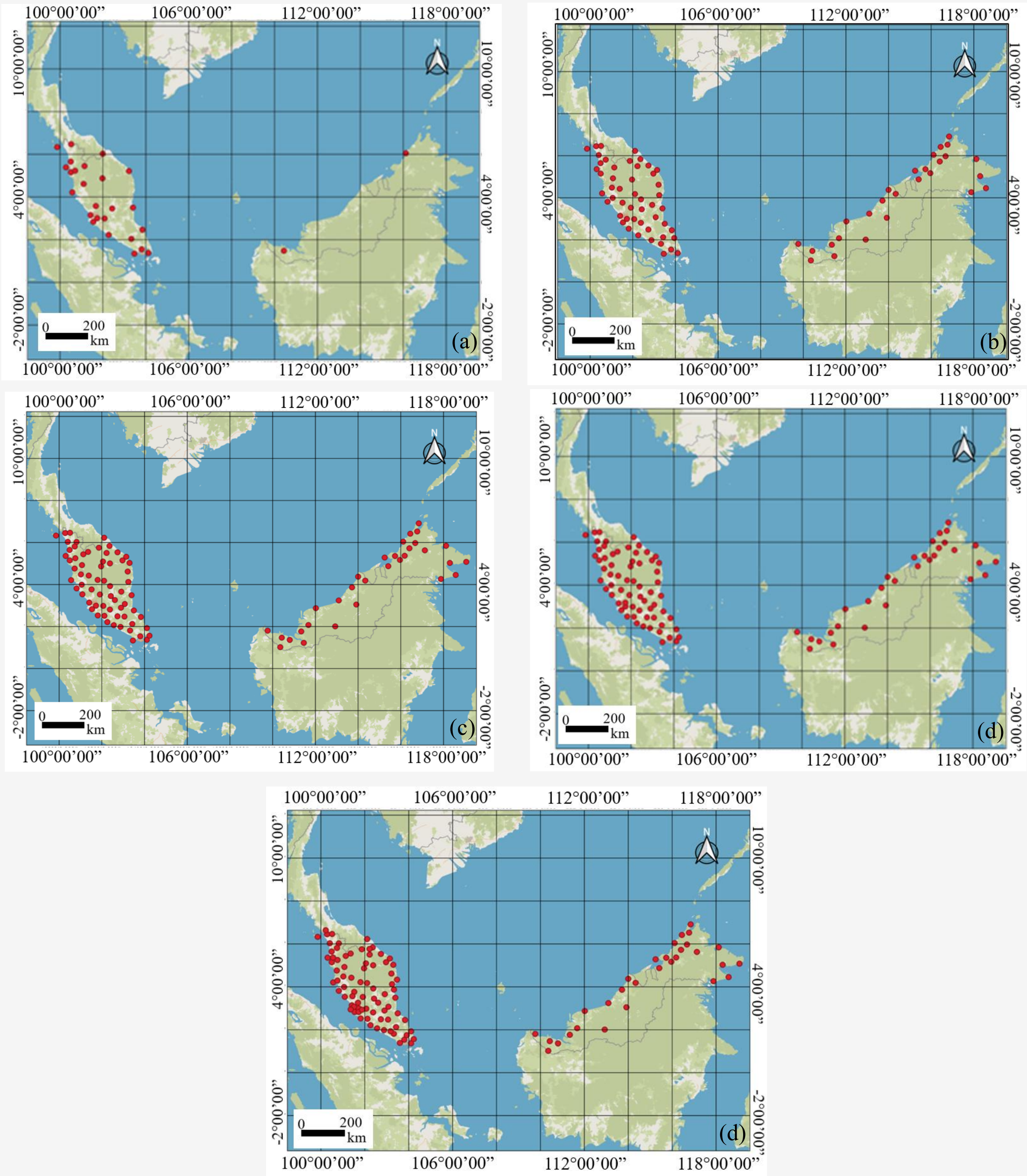

Figure 1: Distribution of MyRTKnet stations in: (a) Phase I, (b) Phase II, (c) Phase III, (d) Phase IV and (e) Phase V of its implementation. Blue points show the new 15 MyRTKnet stations established in Phase V

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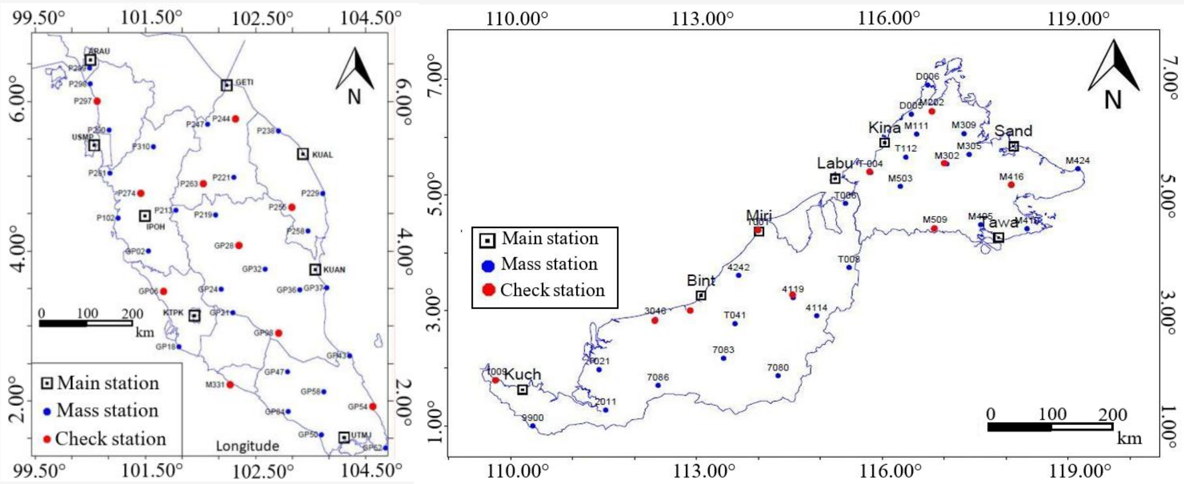
In addition to updating MyRTKnet stations to GDM2000 (2006) coordinates, similar efforts were undertaken for the Malaysia Primary Geodetic Network 2000 (MPGN2000) stations, comprising 238 PMGSN94 and 171 EMGSN97 stations. To ensure seamless integration between MPGN2000 and GDM2000 (2006), it was first necessary to determine the 36 link stations that connect the PMGSN94 and MASS networks within the GDM2000 (2006) reference frame. This integration process began by performing a network adjustment using GPS vector data collected from October to November 2000 for the 36 link stations and 10 MASS stations, with the MASS stations held fixed at their GDM2000 (2006) coordinates. Once the coordinates of the link stations were aligned to GDM2000 (2006), the adjustment was extended to include the remaining PMGSN94 stations using their respective GPS vectors [17]. A similar methodology was applied to the EMGSN97 network using 30 link stations to connect it with the MASS stations (refer to Figure 2).

3.2 GDM2000 in 2009

Another major earthquake struck Indonesia on 12 September 2007, causing significant displacement to the MyRTKnet station coordinates. In response, JUPEM conducted a second revision of GDM2000 in 2009 to account for these displacements and ensure continued positional accuracy. For this revision, GNSS data from 78 MyRTKnet stations and 56 IGS stations, covering the period from 1 January 2006 to 30 April 2009, were processed to re-establish the zero-order geodetic network in the ITRF2005 reference frame. Additionally, data from a January 2009 GPS observation campaign on three MASS stations (KUCH, BINT, and KINA) were included. In the case of Sabah and Sarawak, 33 IGS stations served as fiducial points. These stations, originally referenced to ITRF2005 at epoch 2007.67, were transformed to ITRF2000 at epoch 2000.0 using published velocity models.

A combined network adjustment was then performed, fixing the solution at epoch 2000.0. The resulting coordinate set was designated GDM2000 (2009) [18] and [19]. To evaluate the impact of the revision, a three-parameter Helmert transformation was applied to compare GDM2000 (2006) and GDM2000 (2009) coordinates. The root mean square (RMS) fitting for the four reference stations (KUCH, BINT, KINA, and MIRI) was found to be less than 1 cm in the northing, easting, and height components. However, larger displacements were observed at other stations, likely due to seismic activity or seasonal environmental effects. The final adjustment, which involved only the MyRTKnet and MASS stations, was based on the 2009 data, with the coordinates of the four reference stations held fixed to preserve alignment with the original GDM2000 reference frame. The adjusted coordinates obtained for the MyRTKnet stations were officially designated as GDM2000 (2009). Despite the availability of the GDM2000 (2009) coordinates, they were not adopted for operational use in Malaysia's active and passive GNSS networks, primarily because the National Digital Cadastral Database (NDCDB) had already been established based on GDM2000 (2006) [20][21] and [22]

Nevertheless, users who require GDM2000 (2009) coordinates can obtain them via coordinate conversion or specific computation services offered by the Geodetic Survey Division, JUPEM [23].



(a) (b)

Figure 2: Link stations distribution in: (a) Peninsular and (b) East Malaysia

3.3 GDM2000 in 2016

The GDM2000 (2006) coordinate system remained in use for over a decade. During that period, JUPEM expanded the MyRTKnet network from 78 to 96 stations with the completion of MyRTKnet Phase III. In addition, the network management software at JUPEM's central facility transitioned from Trimble Pivot Platform (TPP) to Leica SpiderNet. Over time, several issues were reported regarding the stability of the GDM2000 (2006) coordinates. Most notably, users experienced difficulty in achieving fixed ambiguity resolution when using MyRTKnet services. The situation was further complicated by two major earthquakes that struck Indonesia on 11 April 2012, which caused additional displacement of station coordinates. In response, JUPEM initiated a review of the GDM2000 (2006) coordinates. As a short-term measure, JUPEM processed GNSS data from March to September 2016, involving 62 IGS and 90 MyRTKnet stations, to derive a new set of coordinates in International Terrestrial Reference Frame 2014 (ITRF2014), i.e. the latest realisation of the International Terrestrial Reference Frame at the time [24]. As part of the review, the stability of MyRTKnet stations was assessed, revealing that some stations, such as AMAN (Sri Aman, Sarawak) and KRAI (Kuala Krai, Kelantan), exhibited instability. Further investigation identified that the AMAN station was affected by a movable monument, while the KRAI station had been reconstructed following the 2014 flood, which contributed to its instability.

To ensure accuracy, daily GNSS solutions were meticulously screened to eliminate data influenced by external disturbances. After careful evaluation, GNSS data collected from 29 May to 4 June 2016 were selected for deriving the MyRTKnet coordinates in ITRF2014. The resulting coordinate set achieved RMS values of 2.63 mm (north), 3.19 mm (east), and 5.98 mm (height). These coordinates were then transformed to ITRF2000 at epoch 2000.0 using a Helmert 3-translation transformation, and the result was officially designated as GDM2000 (2016).

3.4 GDM2020

JUPEM has developed a new time-dependent national reference frame that is fully aligned with ITRF2014 [25]. This initiative aims to maintain the accuracy of MyRTKnet coordinates over time by leveraging continuous GNSS / GPS data collected from Malaysia's CORS infrastructure, namely the MASS and MyRTKnet networks. Two conceptual models were assessed to develop the new reference frame, i.e. kinematic and semi-kinematic.

1. In a kinematic reference frame, time-dependent elements such as crustal motion are inherently modelled within the coordinates of CORS stations. ITRF2014 itself is a kinematic global reference frame, defined by station coordinates, velocities, and post-seismic deformation models within a stable terrestrial framework. Applying this concept at the national level, a kinematic datum includes a deformation model that estimates plate motion at any location in the country and accounts for localised displacements due to events like earthquakes.
2. However, continuously changing coordinates as in a kinematic datum pose major challenges for many spatial data users. This is especially true for cadastral databases, where spatial data collected at different times must align precisely to satisfy legal and regulatory requirements. To address this, JUPEM incorporates the semi-kinematic model, which allows time-dependent coordinates to be consistently transformed to a fixed reference epoch. This approach offers a more practical and user-friendly solution for maintaining spatial databases, enabling seamless integration of geospatial data across different time periods.

The cumulative solution obtained from the stacking of the Malaysian CORS station positions time series formed the basis of the new datum realisation. It consists of station positions at epoch 1 January 2020, station velocities and PSD parametric models for stations subject to major earthquakes. The resultant coordinates obtained through this endeavour are known as GDM2020. Despite the decision to adopt the semi-kinematic concept, it still presents challenges for many geospatial users in Malaysia who are accustomed to static coordinate systems. As a result, GDM2020 has not yet been implemented for MyRTKnet stations, despite being technically available [26]. Following feedback gathered during stakeholder engagement sessions, JUPEM made the strategic decision to delay the rollout of GDM2020. One key recommendation was for JUPEM to develop a web-based service that enables users to easily transform coordinates between the existing and new systems. In tandem with this, JUPEM has also expanded the MyRTKnet network by adding 15 new stations. With these enhancements underway, JUPEM aims to officially launch the GDM2020 coordinate system in 2026.

4. MyRTKnet Users and Applications

As of the latest records, MyRTKnet supports a diverse user base totalling 1,596 registered users across various sectors (refer to Figure 3). Internal users from JUPEM account for 483 users, representing 30% of the total. Government-related agencies and local authorities account for 10% with 160 users, reflecting MyRTKnet's importance in supporting public infrastructure, planning, and land management initiatives. The majority of users, i.e. 899 or 56%, are from private entities, including survey firms, engineering consultancies, and geospatial service providers, highlighting the network's critical role in commercial applications requiring high-precision positioning. Meanwhile, 54 users (3%) are from universities and research institutes, indicating MyRTKnet's contribution to education, research, and innovation in geospatial sciences.

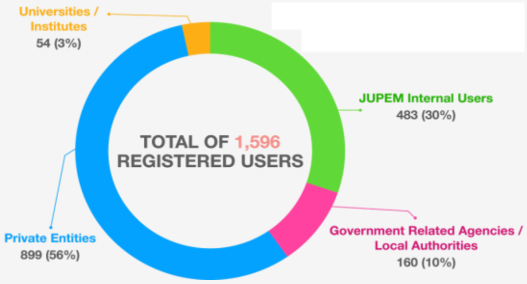


Figure 3: MyRTKnet registered users

MyRTKnet supports a wide range of applications across multiple sectors that rely on high-precision, real-time positioning. In land surveying and cadastral work, it enables accurate boundary demarcation and title surveys with centimetre-level precision. In engineering and construction, MyRTKnet is essential for tasks such as alignment, setting out, deformation monitoring, and infrastructure development [20] and [27]. The agriculture sector leverages MyRTKnet for precision farming, enhancing productivity through GNSS-guided planting, fertilising, and harvesting. In transportation and logistics, it improves fleet tracking, route optimisation, and autonomous vehicle navigation. MyRTKnet also supports geohazard monitoring and disaster management, offering reliable positioning in early warning systems, emergency response, and post-disaster assessments. In research and education, universities and scientific institutions use MyRTKnet for GNSS studies, atmospheric science, and tectonic motion analysis [28] and [29]. Furthermore, urban planning, utility mapping, and marine navigation also benefit from MyRTKnet's reliable and accurate positioning capabilities, underscoring its importance as a national geospatial infrastructure.

5. MyRTKnet Upgrades

MyRTKnet is undergoing significant upgrades to better serve the evolving needs of professionals, industries, and communities. These enhancements are designed not only to improve accuracy and reliability but also to future-proof the system for a broader range of applications, from precision mapping to disaster response.

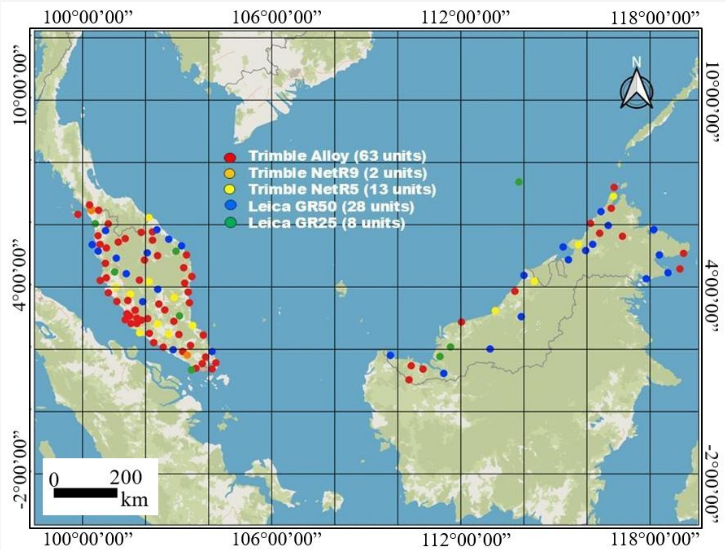


Figure 4: Current sensors deployed at MyRTKnet station

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5.1 Full Multi-GNSS Tracking for All Stations

The current MyRTKnet network comprises a variety of GNSS sensors, as illustrated in Figure 4. At present, only stations equipped with Trimble Alloy GNSS receivers are capable of tracking all major constellations, namely GPS, GLONASS, BeiDou, and Galileo, while the remaining stations are limited to GPS and GLONASS. To enhance performance and service reliability, JUPEM is progressively upgrading all MyRTKnet stations to support full multi-constellation tracking. This enhancement will significantly improve satellite availability and positioning accuracy, particularly in challenging environments such as urban canyons, dense vegetation, and remote regions.

5.2 Stronger System to Serve a Diverse User Base

MyRTKnet is being expanded to support a broader range of applications, including the development of a mobile MyRTKnet platform that can be rapidly deployed in emergency situations. This mobile capability ensures the continuity of accurate positioning services during natural disasters such as floods, earthquakes, and landslides, thereby supporting critical rescue, recovery, and reconstruction operations [30] and [31]. The upgraded MyRTKnet infrastructure is being designed with greater versatility and resilience, enabling it to serve an increasingly diverse user base that includes surveyors, engineers, farmers, researchers, and public sector agencies. MyRTKnet will be better equipped to meet the evolving demands of emerging applications, ranging from precision farming and environmental monitoring to smart city development and autonomous navigation.

5.3 Automated Integrity Assessment and Process Efficiency

To ensure the highest level of trust in its data, MyRTKnet will be integrated with automated integrity monitoring of station coordinates and network operations. This includes automated checks and alerts for anomalies, as well as streamlining internal processes such as offline data requests, making support for customers faster and more efficient.

5.4 Integrated Web Services for Coordinate Access

A new web-based service platform will provide easy access to horizontal and vertical geodetic control information, making it easier for users to integrate their field data with national geospatial frameworks. This empowers users with faster access to verified control data without the need for manual requests.

5.5 Unifying Horizontal and Vertical Infrastructures

In addition to supporting horizontal positioning, MyRTKnet is also being enhanced to serve as part of the national vertical control infrastructure. Traditionally, vertical control relied on spirit levelling and physical benchmarks, which are time-consuming to maintain and susceptible to damage or displacement due to environmental factors. With the integration of the Malaysian Geoid Model (MyGEOID) [32], MyRTKnet allows users to determine orthometric heights accurately and efficiently with a single GNSS receiver. This development marks a major shift toward modernising the national height reference system, enabling faster and more cost-effective height determination for surveying, construction, flood mapping, and other engineering applications. As MyRTKnet continues to evolve, its role in vertical control will reduce dependence on conventional benchmarks and support a seamless, GNSS-driven height reference framework across Malaysia [19][33] and [34].

6. Conclusions

MyRTKnet has emerged as a cornerstone of Malaysia's geospatial infrastructure, evolving from a modest network of GPS stations into a robust, nationwide GNSS CORS network supporting high-precision applications across various sectors. From its early foundations in response to the limitations of traditional coordinate systems to its current role in enabling real-time and post-processed positioning services, MyRTKnet has consistently adapted to technological advancements and national needs. With each development phase, JUPEM has demonstrated a strong commitment to enhancing positioning accuracy, system resilience, and user accessibility. The introduction of time-dependent reference frames, integration of multiple GNSS constellations, automation of data processing, and deployment of backup systems have ensured MyRTKnet remains relevant and future-ready. As the network continues to expand and diversify its services, including mobile applications, web-based tools, and disaster support capabilities, MyRTKnet is well-positioned to meet the demands of an increasingly digital and spatially aware society. Looking ahead, its role will not only be as a positioning infrastructure but also as a national benchmark for precision, innovation, and geodetic excellence.

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The authors would like to express their sincere gratitude to JUPEM's Top Management for their unwavering trust, strategic guidance, and continuous support in the management and operation of MyRTKnet services. Their commitment has been instrumental in driving the development, expansion, and innovation of the network over the years. Appreciation is also extended to the dedicated officers and technical teams across JUPEM who have contributed tirelessly to the planning, maintenance, and enhancement of MyRTKnet, ensuring it remains a reliable and accurate geospatial infrastructure for the nation.

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