Land Governance in an Interconnected World

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The Benefits and Challenges of implementing a Continuously Operating Reference Stations (CORS) GNSS Network in Emerging Countries

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Abstract

A Continuously Operating Reference Stations (CORS) GNSS Network is essential to provide a regional positioning service that can provide fit-for-purpose positioning. For many GNSS applications only meter or sub-meter level positioning is required, but more and more often, centimeter accuracy positioning is required and an efficient measurement processes is increasingly demanded. CORS plays a major role in achieving these goals in many applications, for example, urban land parcel mapping, machine control, precision agriculture, and utility mapping. To achieve this at a regional level, a CORS network needs to cover the complete region. In developing countries this represents significant challenges, yet offers significant benefits.

In this paper, new technologies that can benefit from a CORS GNSS Network will be presented, and the various challenges of establishing a CORS network in emerging countries will be highlighted, and importantly, recommendations will be given on how best to overcome the many challenges based on experiences gained with the establishment of many Networks.

Key Words:

BYOD, Benefits, Challenges, CORS, GNSS

Introduction

The motivation behind establishing a Continuously Operating Reference Station (CORS) network is to model and correct for distance-dependent errors that reduce the accuracy of conventional GNSS (GPS, GLONASS, Galileo, BeiDou, etc.). The corrections calculated by the CORS network are provided in real-time to any number of GNSS users via the internet within the network to correct their positioning accuracy from meters to centimeters, and is commonly referred to as Real Time Kinematic (RTK) positioning or Network RTK (NRTK).

The Benefits of CORS Networks – Time and cost savings

Prior to the availability of the hardware and software to operate a CORS network, GNSS users were forced to set-up local base stations that provided corrections via a radio wave. This set-up limited their centimeter positioning to (near) line-of-sight operation that received the terrestrial radio corrections. Such a configuration also increased the cost of utilizing high accuracy GNSS by requiring the user to have two survey grade GNSS receivers, the local base station and the RTK rover. A significant benefit of a CORS networks is that a single survey grade GNSS receiver with access to the internet can receive CORS correction data and compute centimeter accuracy positions. Furthermore, additional time and costs are saved by not requiring the set-up of the local base station (including the coordination of the base station position), and the time required to move the base station to ensure line-of-sight of the radio wave correction data is avoided. The benefit of reducing the costs for individual users to take advantage of CORS correction data, and hence centimeter positioning, is particularly interesting in emerging countries where users don't have the ability to finance multiple survey grade GNSS receivers.

The Benefits of CORS Networks – Ease-of-use

Accurate positioning with a CORS network is also very easy to achieve. With minimal training and the correct equipment, professionals and non-professionals, can easily use GNSS to derive centimeter coordinates. In emerging countries where it's often difficult to find educated personnel, a team of non-professionals can be managed by a professional to conduct wide-spread data collection, for example land parcel coordination.

The Benefits of CORS Networks – Coordinate accuracy and homogeneity

A CORS GNSS Network provides the significant benefit that coordinate accuracy is maintained throughout the network, even over large distances between the reference stations and NRTK rover. With

all NRTK rovers using the same CORS network which utilize the same coordinate system, then all coordinates derived will be more homogeneous and consistent, and the source of many possible mistakes made by rover operators are minimized.

The Benefits of CORS Networks – International Terrestrial Reference Frame (ITRF)

A further benefit of CORS GNSS Networks is that they are essential to provide the framework for a unified geodetic reference network that provides a consistent and homogenous 3D coordinate system that can be traced to the International Terrestrial Reference Frame (ITRF). Many emerging countries miss a modern coordinate system, and hence are restricted in the wide-spread use of accurate geospatial information, and are hence missing a fundamental foundation for sustainable economic growth. The establishment of a CORS network can significantly assist emerging countries to establish a modern coordinate system and hence benefit from the economic advantages. The widespread adoption of CORS networks in Africa would make a significant contribution to the realization of a unified reference frame, AFREF.

A Benefit and Challenge of CORS Networks – Traceability of coordinates

With a bi-directional communication channel between the CORS network and the NRTK rovers, it is possible for the network to store the positions and accuracy of the rovers. This would provide the benefit of controlling that positioning is performed within the regulations, but equally, it represents a challenge that regulations would need to be adapted to include such quality/traceability checks.

The Challenges of CORS Networks – Cable/Mobile Internet Coverage

For a CORS network to operate in real-time, the data collected at the CORS stations needs to be transferred in real-time to a central location for processing. These corrections are then made available on the internet for processing to correct the position of NRTK rovers to centimeter accuracy. This requirement means that all CORS stations have an internet connection, either by a fixed cable, or by a mobile phone network. When the CORS station is in a built-up area, then this is generally not a problem, but when the CORS station is located at a remote location, then this can be challenging. The same applies for the NRTK rovers conducting their centimeter positioning tasks, they require at least a 2.5G mobile internet connection to receive the corrections which is not guaranteed in all locations, especially in emerging countries.

The Challenges of CORS Networks – CORS power supply

Operating 24/7, CORS stations need to be continuously supplied with power. Again, in built-up areas, then this is generally not a problem. But when CORS stations need to be in remote locations to provide complete network coverage, then providing a continuous power supply is problematic. Often photovoltaic panels and batteries are needed to accompany the CORS station and associated communication devices (modem/router) to ensure continuous operation, either as a primary source of power, or as a back-up of unstable power networks. Finally, the complete system needs to be protected from a poor quality or fluctuating power supply that can often cause power surges, spikes and voltage fluctuations.

The Challenges of CORS Networks – Security

The costs of establishing a CORS station are not insignificant, and hence the investment needs to be protected against vandalism, theft and exposure to environmental elements. In the case of a stable ground set-up, the GNSS antenna, receiver, modem/router and the photovoltaic panels and batteries should be located behind a security fence, and be mounted high enough to be free from floods, and mounted secure enough to withstand severe winds. In the more likely scenario of a roof set-up, the security is often easier to guarantee, and importantly in emerging countries the set-up costs are significantly lower, and hence fit-for-purpose. Furthermore, in both set-up scenarios, the complete system needs to include a grounding system to protect it from power or lightening strike.

Figure 1. CORS ground station with security fence – Ngong Ping Station – Hong Kong

Figure 2. CORS roof station – Peng Chau Station – Hong Kong

The Challenges of CORS Networks – Maintenance

Although a CORS network brings many benefits over many years, the continuous maintenance of the network needs to be ensured. The CORS stations need to be routinely visited to check for damage and replace and clean components to ensure their continued performance. In addition, the computer network that hosts the software that runs the CORS network, needs to be continually maintained to implement operating system and application software updates to benefit from the latest security and performance enhancements.

The Challenges of CORS Networks – Future proof

Mostly, a CORS network is never static and is continually being expanded and enhanced to adopt to changes and growth in the user base and their locations. This requires that the number of CORS stations in the network is continually expanding. Care should be taken when selecting the software for a CORS network that any receiver type can be added to the network irrespective of the brand of the receiver and without any additional charges being incurred for a brand that is not the same as the software. Failure to ensure this at the outset of the CORS network can significantly increase the total costs of owning and operating a network. Leica GNSS Spider software does not discriminate on brands of GNSS receivers added to the network, all are treated equally (Leica GNSS Spider, 2018).

Precise Point Positioning (PPP) and CORS networks

Alternative solutions to CORS do exist, for example Precise Point Positioning (PPP), that provide global meter to a few centimeter accuracy within 20-30 minutes. Without densification of Reference Stations

then centimeter accuracy within seconds can never be obtained. An optimal solution is to complement PPP with a Reference Station Network that can provide centimeter accuracy positioning in areas where greater accuracy is required, for example around highly populated areas, transport corridors and agriculture zones that can benefit from precision agriculture. The benefit of PPP is that no bi-directional communication channel (e.g. the internet) is required, the correction data is broadcast via L-band signals from satellites and received directly by GNSS receivers. This is particularly useful in areas where corrections from CORS networks via terrestrial mobile internet cannot be guaranteed, which can occur, particularly in emerging countries. Unlike positioning within a CORS network where centimeter level positioning is obtained in seconds, tens of minutes of data needs to be collected for positioning accuracies to converge to decimeter accuracy. Products like the Leica Zeno GG04 plus can seamlessly switch between PPP positioning and NRTK positioning. PPP corrections are mostly available on a subscription basis from different commercial service providers that have made a significant investment in the infrastructure required to make a global service available.

New technologies – Bring Your Own Device (BYOD)

Bring Your Own Device (BYOD) utilizing smartphones and tablets is becoming increasingly popular in professional/semi-professional environments. This is also the case in GNSS applications, a BYOD smartphone can be used for positioning below 10 meters but can also be used together with an external scalable fit-for-purpose GNSS sensor to provide sub-meter PPP accuracies, and centimeter accuracies together with a CORS GNSS Network. As an example, the Leica Zeno GG04 plus GNSS smart antenna can connect to Android, Windows® and iOS devices to provide positioning accuracies ranging from sub-meter to decimeter and further to centimeter if required (Leica Zeno GG04 plus, 2018).

Conclusion

This paper has highlighted the many benefits and challenges associated with CORS GNSS networks. In most mature markets, CORS networks are common place and make a significant contribution to the economy. In emerging countries, CORS networks have not yet reached widespread adoption, although the benefits are widely unquestioned. To minimize the impacts of the challenges associated with establishing a CORS network, and to avoid any surprises once implementing, this paper recommends that a thorough feasibility study is conducted prior to beginning a CORS project. The feasibility study should include:

- Analysis of the cable/mobile internet coverage within the network and at proposed CORS stations;

- Careful design and examination of the location of each CORS station to ensure that sufficient coverage, accessibility and security can be ensured;
- Esurance that the system is completely future proof, and that the CORS network can be expanded without discrimination of GNSS receiver brands;

With proper planning, the implementation of a CORS GNSS Network can deliver the many benefits to emerging countries both on-budget, and on-time.

References

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Figures

Figure 1. CORS station with security fence – Ngong Ping Station – Hong Kong. Retrieved from https://www.geodetic.gov.hk/smo/gsi/programs/en/GSS/satref/18cors.htm

Figure 2. CORS roof station – Peng Chau Station – Hong Kong. Retrieved from https://www.geodetic.gov.hk/smo/gsi/programs/en/GSS/satref/18cors.htm