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LEVERAGING ON GNSS CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS) INFRASTRUCTURE FOR NETWORK REAL TIME KINEMATIC SERVICES IN NIGERIA

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Abstract
Nigeria, in the past five years has established about fifteen (15) Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) across the country. The CORS network is primarily meant for the implementation of African Geodetic Reference Frame (AFREF) and Zero-order Geodetic Controls for Nigeria. This GNSS CORS infrastructure provides a viable and highly scalable platform for the implementation of wide range Real Time Kinematic (RTK) services for relevant user communities in Nigeria. However, the current network architecture and post processing system of the CORS infrastructure does not meet the multi-level application needs in the country. In order to scale down the GNSS application opportunity, there is need for the implementation of this RTK Network with Central Processing Facility (CPF), where the pre-processing, detection and repair of cycle slips, and double difference ambiguities between the reference stations are determined. Thereafter, local error modeling algorithms are derived and transmitted to the users epoch by epoch or at predefined time intervals in the fields. This paper therefore aims at developing this RTK Network Service implementation model for Nigeria, leveraging on the existing Zero-order GNSS CORS Network. The developments of GNSS Infrastructure in Nigeria and existing capacity for viable Network RTK implementation were examined. The requirements and feasibility of RTK services in Nigeria were identified, and a Network RTK Service Model was developed. The benefits and potential challenges in this RTK Network Services in Nigeria were identified, and recommendations on network densification architecture and implementation strategies for service sustainability and returns on investment were made.

Keywords: GNSS, CORS, Real Time Kinematic Services, Investment, Sustainability

1.0 INTRODUCTION

Global Navigation Satellite System data from hundreds of designated International GNSS Service (IGS) Reference Stations across the globe have been used in past two decades or more in the progressive realizations of the geocentric International Terrestrial Reference Frame (ITRF). Today, several countries, including Nigeria have established GNSS Continuously Operating Reference Stations (CORS) to help redefine their national datums compatible with the ITRF.

The first motivation to implement Nigeria GNSS Reference Network (NigNet) was to contribute to the African Reference Frame (AFREF) project in line with the recommendation of the United Nation Economic commission of Africa (UNECA) through its Committee on Development, Information Science and Technology (CODIST). The current status of the

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established reference stations is almost adequate for the AFREF vision and Zero-order user communities in Nigeria. The vision for AFREF at full implementation is to have a network of continuously operating permanent GNSS stations such that, a user anywhere in Africa would have access to GNSS data and products within 1000 km of such stations.

With the introduction of GPS-Real Time Kinematic (RTK) techniques in the early 1990s, carrier phase-based GPS technology became a powerful "surveying tool", and the number of points that could be coordinated in a day, with minimum constraints on operations increased to such a degree that private survey companies could invest in the receiver equipment (Lachapelle and Alves 2002*;* Lachapelle et al, 2002; Rizos, 2002). The widespread use of GNSS RTK and Differential GNSS (DGPS) techniques have encouraged geodetic government agencies to look for ways to use GNSS CORS or reference receivers to support ever expanding non-geodetic, real-time applications of high accuracy positioning for surveying, engineering, machine guidance, precision agriculture, etc (Rizos and van Cranenbroeck, 2006).

Network RTK requires a recommended minimum of five reference stations with an inter-station spacing of between 10km to 70 km, depending on the size of the network. The reference stations are usually permanent installations and form *the RTK Network*, which is the backbone of *the Network RTK* principle (Leica GeoSystem). In the case of RTK data transfer to the user, wireless communications are being used since rovers work in mobile mode. However, the main aspects that have to be considered when selecting a communication infrastructure are technical, economical and administrative factors (Wegener and Wanninger, 2005; Wanninger, 2008; Zinas, 2011). Rizos et al (1999, 2000) identified some advantages of network-RTK over single-base RTK:

i. *Rapid static and kinematic GPS techniques can be used over baselines many tens of kilometres in length.*
ii. *Single-epoch on-the-fly ambiguity resolution (OTF-AR) algorithms can be used for GPS positioning, at the same time ensuring high accuracy, availability and reliability for critical applications.*
iii. *Rapid static positioning is possible using low-cost, single-frequency GPS receivers, even over tens of kilometres.*

The benefits of GPS RTK Networks are numerous and cost savings are the most important of the adoption drivers. The widespread and easy access of high-speed Internet and various forms of wireless connection are now cutting significantly the fixed costs associated with running such infrastructures, and for accessing the GPS real-time data products in the field (van Cranenbroek et al, 2006).

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1.1 The Developments of GNSS Infrastructure in Nigeria

The development of satellite technology, especially its application in navigation through the use of GPS has opened a robust horizon for the observation, adjustment and strengthening of geodetic control network in Nigeria. The first motivation to implement NigNet was to contribute to AFREF project in line with the recommendation of the UNECA through its CODIST. The NigNet project was initiated in 2008 by the Office of the Surveyor General of the Federation (OSGoF), which is the National Mapping Agency of Nigeria. The network is established using state-of-the-art GNSS CORS equipment (figure 1.2), to serve as a new fiducial geodetic network for Nigeria.

Figure 1.2: State-of-the-art GNSS CORS Equipments

1.2 The Justification for Network RTK in Nigeria

The CORS infrastructure and services in its present form present some shortfalls in terms of real time kinematic applications to very many relevant user communities in Nigeria. The current architecture and post processing system of the CORS in Nigeria does not meet the multi-level application needs in the areas of cadastral and large scale mapping, mobile Geographic Information System (GIS), rapid mapping and positioning in oil and gas, precision agriculture, mineral prospecting, marine/oceanography and marine safety administration, flood and drainage control, engineering and construction surveys, civil aviation and navigation, road and rail transport, asset tracking, structural deformation and subsidence, infrastructure and location based systems, etc.
These applications which require rapid approaches in information gathering would require some sort of augmentation and broadcast of corrections or client server-based services for enhanced the ***accuracy, integrity, continuity*** and ***availability*** of GNSS RTK services. The following technical reasons support the developments and implementation of Network RTK (NRTK) for Nigeria.

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i. The current wide area GNSS network in Nigeria, and as envisioned by AFREF are generally sparse (station spacing of 500-1000 km); hence would not be good enough for cadastral, large scale and engineering applications.
ii. One of the implications of ionospheric effects on GNSS Network is that, ionospheric models can suffer degraded performance in regions where large spatial gradients in total electron content (TEC) exist (Skone et al, 2004).
iii. However, ionospheric delay is removable using correction data set that is generated and transmitted from a *Network Data Processing Centre* based on integrated solutions from reference stations within the network around the domain of the user.
iv. The need to invest on buying two geodetic GNSS receivers and the relatively short distance that has to be maintained between the two receivers to accurately determine users' position common with the single baseline RTK positioning will be minimized.

1.3 Objectives of the study

The objectives of this paper therefore are to:

i. Examine the developments of GNSS Infrastructure for Network RTK implementation in Nigeria;
ii. Identify the requirements and feasibility of Real Time Kinematics services, and develop a Network RTK Service Model for Nigeria;
iii. Identify the benefits and potential challenges in Network RTK Services in Nigeria;
iv. Propose network densification architecture and strategies for the implementation of sustainable Network RTK services in Nigeria.

1.4 Brief Background about Nigeria

Nigeria is made up 36 states and the Federal Capital Territory (FCT), and located approximately between latitudes 4°N and 14°N, and longitudes 3°E and 15°E (Fig.1.3). It lies wholly within the tropics along the Gulf of Guinea, on the west coast of Africa.

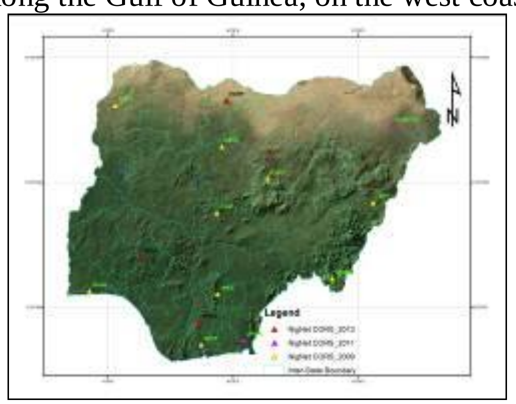

Figure 1.3: The Spatial Administrative View of Nigeria

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It is bounded on the west by the Republic of Benin, on the north by the Republic of Niger and on the east by the Republic of Cameroon and on the south by the Atlantic Ocean. The size of Nigeria is about 923,768.64 sq.km and occupies about 14% of West Africa, but supports more than 60% of the population of the region. Nigeria is the most populous black nation in the world with a population of over 140 million (National Population Commission, 2006).

2.0 GNSS MEASUREMENT AND RTK NETWORK DESIGN
2.1 GNSS Measurement

The GNSS signal is a composite signal that contains a high frequency carrier radio wave and a low frequency code that is modulated onto the carrier. Therefore, the GNSS observables are made up of *Carrier Phase*, *Code Pseudorange* and *Doppler Shift* measurements:

2.1.1 Carrier Phases
Carrier-frequency tracking measures the phase differences between the Doppler-shifted satellite and receiver frequencies. The phase differences are continuously changing due to the changing satellite earth-orbit geometry. However, such effects are resolved in the receiver and subsequent data post-processing. The deterministic model for the carrier phase measurement in meters is given by equation (2.1) (modified after: Misra and Enge, 2001; Wu et al, 2006; Wu et al (n.d); Ojigi et al, 2014).

$$\Phi(Li) = R^t + c(dt - dT) + d_{orb} + d_{trop} - d_{ion/Li} + \lambda_i N_i + \lambda_i(\phi_r(t_0, Li) - \phi_s(t_0, Li)) + d_{mult/\Phi(Li)} + \varepsilon_{\Phi(Li)} \qquad (2.1)$$

where $\Phi(Li)$ is the measured carrier phase on Li (m); R^t is the true geometric range (m); c is the speed of light (m/s); dt is the satellite clock error (s); dT is the receiver clock error (s); d_{orb} is the satellite orbit error (m); d_{trop} is the tropospheric delay (m); $d_{ion/Li}$ is the ionospheric delay on Li(m); λ_i is the wavelength on Li(m); N_i is the integer phase ambiguity on Li (cycle); $\phi_r(t_0,Li)$ is the initial phase of the receiver oscillator; $\phi_s(t_0, Li)$ is the initial phase of the satellite oscillator; $d_{mult/\Phi(Li)}$ is the multipath effect in the measured carrier phase on Li (m) and **ε** is the receiver dependent errors known as carrier phase measurement noise (m) (Wu et al, 2006; Ojigi, et al, 2014). But, by simplification and re-arrangement, equation (2.1) can be written inform of equation (2.2). Note: the term ***T*** refers to time of signal reception at the receiver, while **t** refers to time of signal transmission from satellite.

$$\Phi(Li) = R^t + c\Delta t_{rs} + d_{orb} + d_{trop} - d_{ion/Li} + d_{mult/\Phi(Li)} + \lambda_i N_i + \lambda_i \Delta\phi_{rs} + \varepsilon_{\Phi(Li)} \qquad (2.2)$$

2.1.1.1 Ambiguity Resolution

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Ambiguity resolution is the process that allows the integer ambiguity to be determined computationally through the processing of GNSS carrier phase data. The operations that take place in figure 2.1 include (i) the satellite broadcasts a sine wave carrier signal with a certain phase, (ii) the signal is received by the GPS antenna with another phase at the time of reception, and (iii) the receiver generates an identical copy of the signal as the one generated by the satellite and compares the generated phase with the observed one to derive the phase observation.

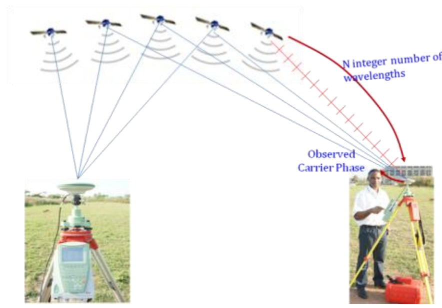

Figure 2.1: Physical Meaning of Ambiguity

However, the integer number of wavelengths between the satellite and the receiver during the travel time of the signal is not known. This number is called integer ambiguity and is denoted by the letter N. It is essential that the integer ambiguity is known in order to achieve centimeter level positioning and the integer ambiguity resolution is a process central to the Network RTK concept.

2.1.2 Code Pseudo ranges

A pseudorange is the time delay between the satellite clock and the receiver clock (fig. 2.2), as determined from Coarse-Acquisition (C/A) or Precise (P)-code pulses; which equals the range measurement, but is called a pseudorange since at the time of the measurement, the receiver clock is not yet synchronized to the satellite clock; The deterministic model for the pseudorange is given by equation (2.3)

$$P(Li) = R^t + c(dt - dT) + d_{orb} + d_{trop} + d_{ion/Li} + d_{mult/(Li)} + \varepsilon_{P(Li)} \qquad (2.3)$$

Where P*(Li)* is the measured pseudorange on *Li*(m); $d_{mult/P(Li)}$ is the multi-path effect in the measured pseudorange on Li(m), while $\varepsilon_{P(Li)}$ is the pseudorange measurement noise. Other definitions of variable are as earlier defined. In this determination, the integer ambiguity resolution is completely absent. Also, by simplification and re-arrangement, equation (2.3) can be written inform of equation (2.4)

$$P(Li) = R^t + c\Delta t + d_{orb} + d_{trop} + d_{ion/Li} + d_{mult/(Li)} + \varepsilon_{P(Li)} \qquad (2.4)$$

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Comparing equations 2.2 and 2.4 the ionospheric refraction effect is reversed. The multipath and pseudorange measurement noise terms replaced their carrier phase counterparts, and since ambiguity is unique to the phase, it is not present in the pseudorange observation equation in (2.4). Figure 2.2 illustrates the concept of code measurements, and equation 2.4 can be simplified as in (2.5).

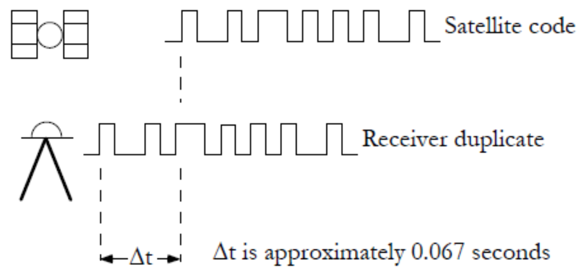

Figure 2.2: Measurement of the GPS Pseudo range

$$R_i = R^t + c(\Delta t) + d \qquad (2.5)$$

Where R_i = observed pseudo-range, R^t = true range to satellite (unknown), c = velocity of propagation, Δt = clock biases (receiver and satellite), d = propagation delays due to atmospheric conditions. The true range R^t is the 3D coordinate difference between the satellite and user, and it is expressed by equation (2.6) and equal to the 3D coordinate difference between the satellite and user.

$$R^t = \left[(X^s - X^u)^2 + (Y^s - Y^u)^2 + (Z^s - Z^u)^2\right]^{1/2} \qquad (2.6)$$

The substitution of equations (2.6) in (2.5) gives the estimate of the observed pseudo range from finite number of satellite (1, 2,..n) as given equation (2.7).

$$\left.\begin{aligned} R_1 &= \sqrt{(X_1^S - X_1^U)^2 + (Y_1^S - Y_1^U)^2 + (Z_1^S - Z_1^U)^2} + c\Delta t + d_1 \\ R_2 &= \sqrt{(X_2^S - X_2^U)^2 + (Y_2^S - Y_2^U)^2 + (Z_2^S - Z_2^U)^2} + c\Delta t + d_2 \\ R_n &= \sqrt{(X_n^S - X_n^U)^2 + (Y_n^S - Y_n^U)^2 + (Z_n^S - Z_n^U)^2} + c\Delta t + d_n \end{aligned}\right\} \qquad (2.7)$$

2.1.3 Doppler Shifts

This a change in the frequency of GNSS signals as the distance between the satellite and the observer or receiver changes, which is basically due to the change in motion of the satellites. Therefore, the frequency of the received signal is slightly shifted from that of the primary carrier frequency, $\boldsymbol{L_1}$ or $\boldsymbol{L_2/L_5}$, because of the Doppler Effect. From Equation (2.2), the

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difference between two subsequent in time phase measurements can be written in distance units as in equation (2.8).

$$\Delta\Phi_{t,T} = \Delta R^{t}_{t,T} + \lambda\Delta\phi_{t,T} + \varepsilon \qquad (2.8)$$

Where $\Delta\Phi_{t,T}$ is the Doppler frequency shift and it is an additional output measurement in some receivers; $\Delta R^{t}_{t,T}$ is the rate of change of the satellite to receiver distance through a linear velocity term; $\lambda\Delta\phi_{t,T}$ represents the frequency deviations of the satellite and receiver oscillations through a linear frequency deviation. For short time intervals atmospheric refraction, multipath and equipment delays can be neglected. In this case, the change in carrier phase measurement is mainly related to changes in satellite and receiver position and to changes in the satellite and receiver clock errors (modified after Teunissen and Kleusberg, 1998; Zinas, 2011).

2.2 Network RTK Design and Processes

The principle of Network RTK begins with all reference stations within the RTK Network continuously streaming satellite observations to a central server running Network RTK software. The aim of this is to correctly measure the correlated errors for a region, to predict their effects for users. Errors are estimated using information from more than one reference stations so their effect is significantly reduced compared to the single reference station approach. In figure 2.3 the data in network mode will require four (4) or more stations for the same area of interest to determine the position of. The advantage of this approach is the significant reduction of costs of infrastructure.

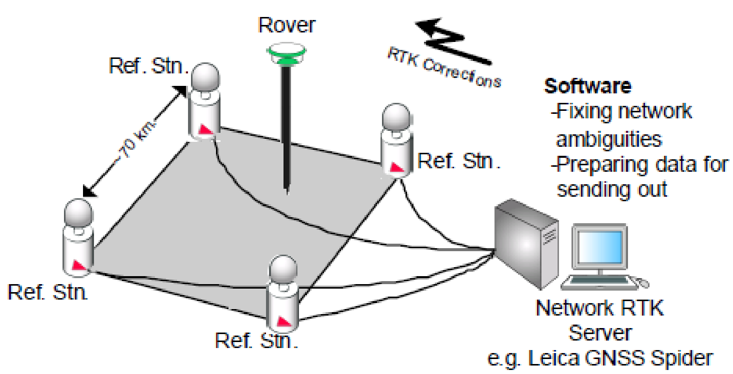

Figure 2.3: Principle of Network RTK (Source: Leica GeoSystem: www.leicageosystem.com)

The design of NRTK for Nigeria, places the CDPF examplified by figures 2.3 in Abuja, Federal Capital Territory. The new architecture includes densification of the reference stations, and the need to establish regional data processing and back-up system.

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2.3 Network RTK Processes

Network RTK is a three step process that consists of generation of *(i) the network's correction, (ii) interpolation of these corrections at the user's position, and (iii) the transmission of the information to the users*. These three processes are the basis for any Network RTK technique; hence they define the steps that should be integrated in any RTK approach.

2.3.1 CORS-RTK Correction Techniques and Operations

Three techniques are commonly used for CORS corrections to rovers, namely the Flachen Korrectur Parameter (FKP) Area Correction, Virtual Reference Stations (VRS), and Master Auxiliary Concept (MAC) Techniques. It is also important to identify the actions that need to be taken in order to ensure a continuous and reliable service, and with respect to the priory design components that define them. The key actions required as background work include standardization, common view and non common view Networks, centralized and decentralized Network approach, One-way transmission and two-way transmission, and transmission bandwidths.

Based on previous studies, the RTK data communications by Radio Technical Commission for Maritime (RTCM) Services via the Networked Transport of RTCM via Internet Protocol (NTRIP) is preferred; which enables the implementation of centralized network architecture. Centralized network architecture provides the opportunity for different data handling than using broadcast means for data transmission. Also, mobile receivers connected to the Internet via Mobile IP-Networks like GSM, GPRS, EDGE, etc can receive real time GNSS positioning data (Fan et al, 2004; Wegener and Wanninger, 2005; Weber et al, 2006). The user needs to know its accurate position at the same instant and in the case where this information is transmitted from the CDPF, the processing power at the control centre has to be sufficient to keep the processing time at minimum level and profitable (Lim and Rizos, 2008; Van Cranenbroeck, and Lui, 2012.).

2.4 Strategies for sustainable Network RTK Services in Nigeria

The sustenance of Network RTK implementation in Nigeria is looked at from two key perspectives, namely CORS network densification model and return on investment planning scheme

2.4.1 Network densification

The existing number of CORS are about 15, and assuming a minimum of three CORS infrastructure are provided for each of the 36 states and the Federal Capital Territory, will give

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a total of 111 CORS. The Administrative map of Nigeria was used to extrapolate proposed location for each of the balance of 96 CORS in Nigeria.

2.4.2 Return on Investment Planning Scheme

It is important to develop ways of recouping network infrastructure investment in Nigeria by establishing profitable service businesses for the data generated by the GNSS receivers. However, the return should not be measured in terms of revenue earned only, but justified as a means of keeping the costs borne by potential beneficiaries and the local industries lower than having no geodetic infrastructure. The number one invaluable return on the investment is national network and geodatabase standardization, which benefits both the governments and all other stakeholders and users. The return on investment shall be viewed from the following two perspectives:

i. *Income scheme for users who are prepared to pay for the NRTK services, which according Rizos and van Cranenbroeck (2006) are only feasible if the number of users, and the fees charged, are sufficient to generate a reasonable return-on-investment;*
ii. *Consider the GNSS Infrastructure as the 'fifth utility', and should be seen as public infrastructure in a similar manner as roads, health facilities, water and housing, ports and other utilities.*

A mixed approach to financial planning scheme implemented in this study includes Standard GNSS RTK and Reverse GNSS RTK (Client-Server based model). Table 2.1 provides the assumptions for the estimates of financial returns of Network RTK over Nigeria for 2015

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Table 2.1: Assumptions for Estimation of RTK financial Return for 2015

Number of Proposed Services	**No. of CORS-RTK Data Service request by Users**	**Cost Value per service/year (N)**
Client-Server Based NRTK	2,000	240,000
NRTK-Corrections ($\Delta x, \Delta y, \Delta z, \Delta t$) only	5,000	52,000

3.0 RESULTS AND DISCUSSIONS

3.1 Results

In figure 3.1 shows the centralized Network RTK data processing model for Nigeria. The CDPF is proposed for Office of the Surveyor General of the Federation (OSGoF), Garki Abuja. There are regional data processing centres as back-up for the CDPF proposed for Ile-Ife, Kebbi, Toro, Enugu, Port-Harcourt, and Lokoja. Figures 3.2a and 3.2b show the NRTK

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data streaming and data communication models for Nigeria, respectively. Fig.3.3a presents the proposed Optimal Network RTK architecture for Nigeria, in order to enhance shorter baseline network system and robust VRS within the country. Fig. 3.3b provides a graphic illustration of the estimates of financial return for CORS-NRTK in Nigeria for 2015 only.

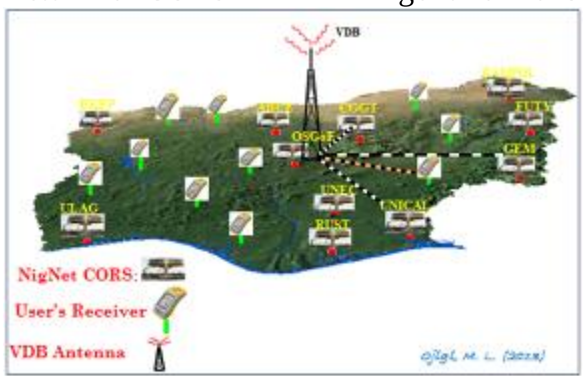

Fig.3.1: Centralized Network RTK data processing Model for Nigeria

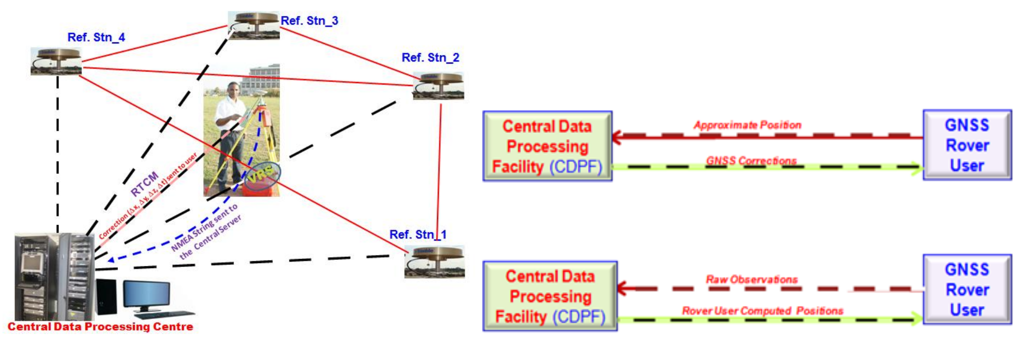

Fig.3.2 (a) Centralized Network RTK data streaming/processing Model for Nigeria, (b) Proposed Network RTK Data Communication Model for Nigeria

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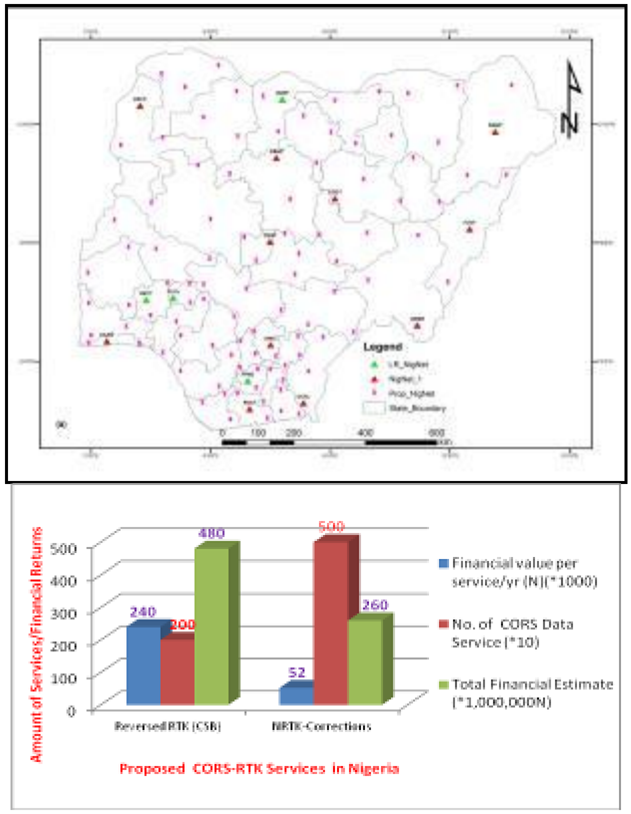

Fig.3.3: (a) Proposed Optimal Network RTK for Nigeria; (b) Estimates of Financial Return for NRTK in Nigeria for 2015.

3.2 Discussions of Results

In order to implement the proposed NRTK Nigeria in Figures 3.1-3.3, the communication and computing facilities necessary for sustainable NRTK services would include high speed computers, GNSS solution software, mobile communications (Radios/GPRS services), broadband fiber optic Internet service(s), uninterrupted power supply, and security of infrastructure. From Figure 3.3a, three reference stations were proposed for each of the 36 states of the Federation and the FCT. However, states where reference station(s) already exist, only the balance to equal three shall be provided, giving a total newly required reference stations of 96. In order for sustainable use of the infrastructure, the proposed regional CDPF will help coordinate and optimize applications to users. Therefore, all supporting infrastructure and accessories necessary for data transmission at regional and national scale must be ensured.

Based on service scheme provided in figure 3.3b, a total of about ₦740 million was estimated for both standard (*NRTK-Corrections-Δx, Δy, Δz, Δt*) and reversed NRTK (*Client-Server*

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Based) services in Nigeria for year 2015. Assuming there is an annual increase of NRTK data service at the rate of 1.5% between 2015 and 2020 at fixed financial value, the sum of about ₦4.6Billion Naira would be generated for all round RTK services in Nigeria. This estimated financial return did not however take into consideration the over-head and running cost of the service generation and delivery for the period in view.
The standard GNSS RTK, though faster for the user to simply receives the broadcast corrections to his provisional coordinates, but the providers of GNSS-RTK corrections have no control over the quality of the final results of various users in the field due to proprietary software and hardware errors. The advantages of the ***Client-Server based*** are that, the NRTK provider can exercise control over the generated products and, as a result, place a commercial value on the service, especially as the typical user is free from the obligation of learning complicated GPS surveying techniques or software. Therefore, the challenge the OSGoF must tackle is the marketing strategy to convince potential users in Nigeria to subscribe to these proposed services when operational.

3.3 Potential Benefits of Network RTK for Nigeria

The benefits of this proposed Network RTK for Nigeria include the following amongst others:

1. Enhance the provision of fast, economical and accurate position, velocity and time services for relevant users on a variety of platforms;
2. Maximize the socio-economic benefits of satellite positioning and timing information for Nigeria
3. Allow for full optimization and exploitation of the potential GNSS applications *e.g., navigation, aviation, precision agriculture, review of national datum, mapping, infrastructure monitoring, traffic and asset management, mining, oil and gas exploration, GIS and land information system, town planning and engineering surveying and construction, etc.*
4. Enhance national scientific and technical capabilities in GNSS technology and services
5. For adequate dataset for continuous modeling of the effects of different error sources in the GNSS

4.0 CONCLUSIONS

Network RTK data processing option is a more integrated, robust and economically viable approach to GNSS positioning and applications in Nigeria. This however, requires wide-spread and dense CORS network with data processing done in real-time, and the positions of the users anywhere in the country derived right in the field during observations, and transmitted to them for instantaneous field solutions. NRTK enabling Infrastructure such as the communication and computing facilities/high speed computers, GNSS solution software, mobile communications (Radios/GPRS services), broadband fiber optic Internet service(s), uninterrupted power supply, and network security must be provided for sustainability.

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The realistic approach of placing and making huge commercial return on NRTK services is for OSGoF and collaborators in NRTK service provision to plan for full exercise of control over the generated products. This will enhance commercial value on the services, especially as the typical users are free from the obligation of learning complicated GNSS techniques or software.

In order to introduce non-uniform charges as a function of frequency and quality of services enjoyed by different users, OSGoF or any designated service providing companies must integrate user monitoring applications into their software products by including the display of user positions, recording the number of requests for specific services, and generating statistical information that form the basis for charging users. However, the return on the original investment on GNSS Infrastructure in a developing country like Nigeria should not be measured in terms of revenue earned only, but justified as a means of keeping the costs borne by potential beneficiaries and the local industries lower than having no geodetic infrastructure for mapping and navigation services.

4.1 Recommendations

The following are therefore recommended for the comprehensive implementation of Network RTK in Nigeria:

i. All State Survey Departments across the Country should join efforts and resources with OSGoF in providing more CORS infrastructures in the states, in order to accomplished network spread of 10-15km required for cadastral and large scale engineering applications of NRTK in the country;

ii. The surveying community in Nigeria must leverage on her leading role in basic GNSS applications to advance the collateral services and applications of GNSS to all relevant sectors of the economy;

iii. There is need for cooperation and team work between public-private sector in the area of resource sharing, if Network RTK is to be realised and sustained in Nigeria**.**

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