NIGNET – The new permanent GNSS network of Nigeria

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SUMMARY

OSGoF (Office of the Surveyor General of the Federation), which is the National Mapping Agency of Nigeria, initiated in 2008 a project to establish NIGNET (NIGerian GNSS Reference NETwork) This network, formed by state-of-the-art CORS (Continuously Operating Reference Station) GNSS (Global Navigation Satellite Systems) equipments, intends to implement the new fiducial geodetic network of Nigeria.

NIGNET will serve many different applications at national and continental levels. In fact, the first motivation to implement NIGNET was to contribute for the AFREF (African Reference France) 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). At national level, NIGNET will serve primarily as the fiducial network that will define and materialize a new reference frame based on space-geodetic techniques and linked to AFREF.

Currently, NIGNET is formed by nine CORS stations covering the entire country. The selection of the locations was carried out considering different theoretical and practical criteria.

In our presentation, we summarize NIGNET by describing the motivations, preparation, implementation and current operations of NIGNET. We detail the difficulties faced with the implementation of this modern network, which undoubtedly will contribute for the development of Nigeria in particular and Africa in geneeral. We will also discuss our future plans to density and optimize NIGNET.

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1. INTRODUCTION

The NIGNET (NIGerian GNSS Reference NETwork) project, promoted by OSGoF (Office of the Surveyor General of the Federation), has the goal to implement a new reference frame for Nigeria 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 installation is being done in collaboration with SEGAL, a collaborative project between University of Beira Interior and Institute Geophysical Infante D. Luíz in Portugal. The core of NIGNET is formed by a network of GNSS (Global Navigation Satellite Systems) CORS (Continuous Operating Reference Stations). The new reference frame, which will be connected to the current existing reference frame of Nigeria, will be suitable for the use of the modern space techniques of positioning and it will be tied to the international system, namely to ITRS (International Terrestrial Reference System) using the latest realization (currently ITRF2005 – International Terrestrial Reference Frame, solution 2005).

The national geodetic network is a pivotal infrastructure of any country by providing the foundation for all geo-referencing activities. It is the base for coherent multipurpose Land Information System (cadastre) and its subsequent maintenance. Such system plays a vital role in the economic development of the country by delimiting and monitoring changes in property, environment, and biodiversity.

The geodetic network services include but are not limited to land management, urban development, physical planning, the construction industry, mineral exploration, investment and road construction. It is also vital to both air and water transport. The geodetic network is very important in the management of land in a decentralized system. It is vital in the smooth implementation of the National Land policy and can also help in generating direct revenue to the local governments.

The consistency and accuracy associated with NIGNET will be better than the actual network. The first geodetic surveys of Nigeria were performed by the British Royal Engineers in 1910-1912 (Foreign Maps, 1963). The existing geodetic networks (horizontal and vertical networks) in Nigeria started to be observed in the late 1920's (Mugnier, 2009) and most of the network was materialized between the late 1940's and early 1960's (Arinola, 2006). The common reference system in use until recently is the Minna Datum (λ = 9 º 38' 09".000; φ = 6 º 30' 59".000) and the Clarke 1880 ellipsoid (modified) (Mugnier, 2009). However, during the last decades, many geodetic pillars materializing the reference frame have been destroyed, and only a small percentage of beacons are still usable. Furthermore, the original network was implemented using techniques having lower accuracy and requiring the installation of points at locations of difficult access (e.g., top of hills).

Consequently, OSGoF, the National Mapping Agency of Nigeria, initiated in 2008 a project to establish NIGNET.

NIGNET will directly contribute for the AFREF (African Reference France) project. Only recently, a first GNSS station was installed in Nigeria (e.g., Fernandes et al., 2009). This was clearly insufficient to support the AFREF project, which requires baselines shorter than 1000Km between the stations of the network.

NIGNET will serve primarily as the fiducial network for Nigeria. It will create in the new future a new reference frame. NIGNET will be also used for future densifications of the CORS networks in Nigeria at state level (Nigeria is a federation of 36 states plus one Federal Capital Territory).

The NIGNET network is being installed with capabilities to support RTK positioning, both in single and network modes. The data from the permanent stations will be collected at a central station located in Abuja where corrective data for the location of rover stations will be computed and will be provided to the users. Although the number of stations to be implemented in this phase will not permit to stream RTK corrections in network mode, the system was designed in order to expand the network to a multiple-station RTK system in the future. The information to the user will be transmitted using different processes. The preferable access will be done by accessing the Center of Control using cellular modems with data transfer capabilities (via GPRS or UMTS).

2. NETWORK

The initial phase (in progress) considered the installation of nine stations covering the entire country (cf. Figure 1). Since the design of the network is not anymore a major constraint when establishing a fiducial network (as it was on the classical triangulations), the objective was to cover Nigeria with a relative homogenous distribution in order to optimize the densification of the network in the future (with permanent or sporadic points). Simultaneously, it was also considered the location at Universities and Research Centers in order to also link NIGNET to the scientific community and foster the use of this network by more applications. In addition, the selected partners also offer more guarantees of local support for the installation and maintenance of the network. Last but not least, the location close to large urban areas also contributes to optimize the use of NIGNET (surveying applications).

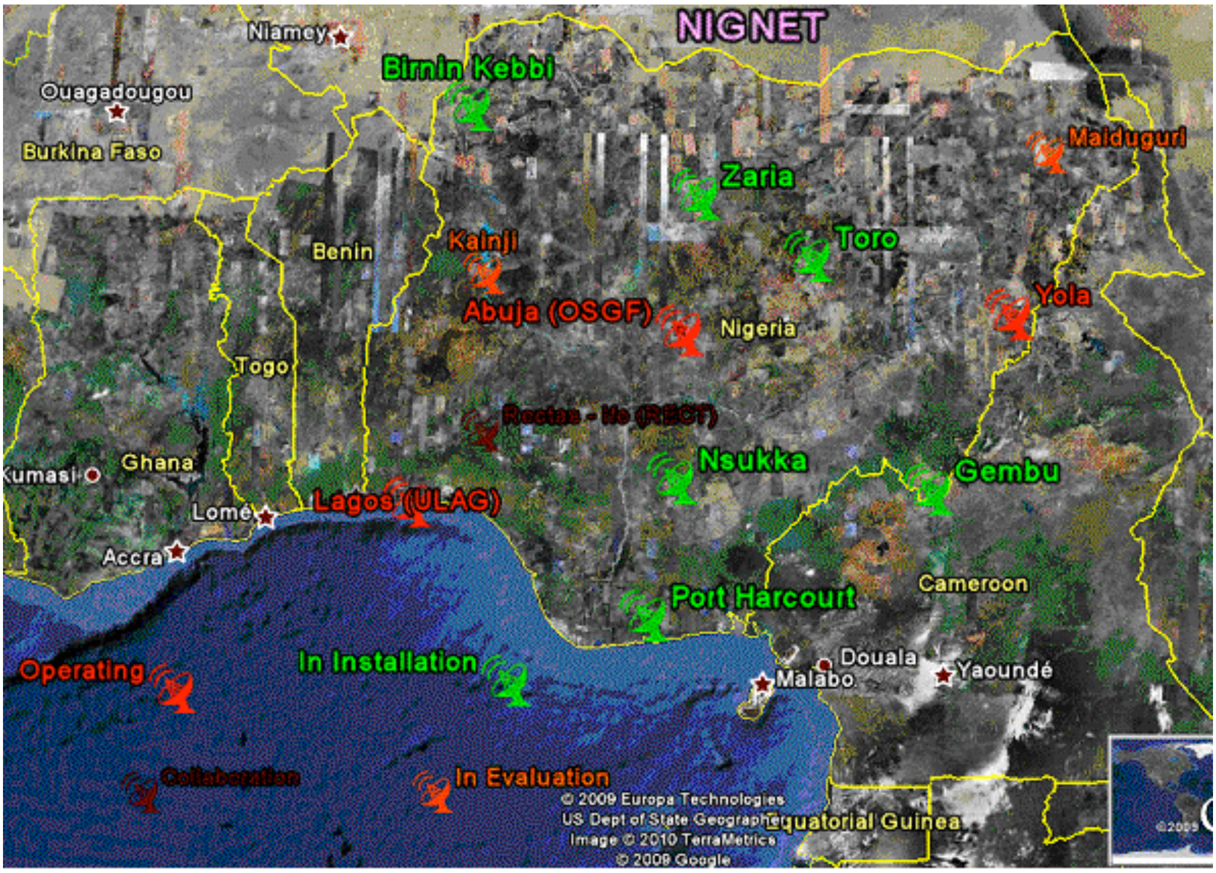

Figure 1 – Distribution of the NIGNET stations. Red – stations already installed (December 2009). Green – stations being installed in January/February 2010. Magenta – existing station to be incorporated in NIGNET. Orange – locations to be evaluated for Phase 2.

ULAG (University of Lagos) and OSGF (Headquarters of OSGoF at Abuja) are operating since October 2009. On December 2009, a third station was installed at Yola, FUTY. Currently, January 2010, the SEGAL team is directly collaborating with OSGoF and the other partners at each location to finish the installation of Phase 1, which is expected to end by February 2010.

Figure 2 shows some aspects of the stations already installed. NIGNET will be served by state-of-art geodetic equipments, namely the latest version of Trimble CORS stations, NetR8 with Choke-ring antennas. The complete system is composed by the receiver/antenna plus a usb modem (the communications with the Centre of Control will be done using the GSM cellular network), a router (to manage the communications), and a solar panel system (the systems are completely independent of the national electricity grid). The optimization of the power consumption was a priority in the design of the system. The solar panels have 160W of power (charging a battery with 100AH) that permit to support consumptions up to 20W for an expected constant consumption of 11W.

Most of the stations (the exceptions are Toro, cf. Figure 2, and Gembu) will be installed on the roof of buildings. As previously mentioned, NIGNET will also support surveying activities by providing RTK differential corrections. Therefore, to locate the stations close to the center of cities was important in order to optimize the coverage provided by each station. In addition, many of the local institutions (Universities, Research Centers) partnering with OSGoF are located at urban areas with many constructions around. This made difficult, or even impossible, to install the stations on the ground. Last, but not least, security of the equipment was also a major criterion on site selection.

Figure 2 – Details of the installed stations. Top – OSGF station installed at OSGoF headquarters, Abuja. Middle – ULAG station installed at the campus of University of Lagos. Bottom Left –FUTY station installed at Federal University of Technology of Yola. Bottom Right – selected location at Toro.

3. INITIAL RESULTS

Positional solutions have been computed already for the stations OSGF and ULAG using the three months of available data (between October and December 2010). The computation of the Cartesian coordinates for these stations with respect to the latest realization of the global reference frame, ITRF2005 (Altamimi et al., 2007) was done using the GIPSY academic software package (Webb and Zumberge, 1995). Details how this is done using a global network of reference stations can be found in Fernandes et al. (2008).

The daily solutions were first combined into a single weekly solution. This provides a good estimative of the quality of the solutions by looking at the r.m.s. of the residuals of the daily solutions with respect to the weekly solution, as it is shown in Table 1:

Table 1 – r.m.s. of the combination of the daily solutions into unique weekly solutions

GPS week	ULAG – Lat, Lon, H (mm)	OSGF – Lat, Lon, H (mm)
1552	3.3, 1.4, 7.6	----
1553	3.2, 2.2, 7.1	4.0, 2.9, 4.6
1554	3.8, 1.8, 11.9	2.1, 3.6, 9.9
1555	1.6, 1.7, 8.7	2.6, 1.5, 7.4
1556	2.4, 2.0, 11.9	2.2, 1.7, 7.7
1557	3.2, 1.5, 12.5	4.2, 2.1, 9.5
1558	2.3, 0.9, 6.3	2.2, 1.5, 5.0
1559	2.9, 1.9, 13.0	2.7, 1.4, 5.0
1560	3.3, 2.5, 8.4	1.2, 1.5, 5.0
1561	3.0, 1.5, 12.5	1.2, 1.5, 6.0
1562	2.8, 1.7, 3.5	1.6, 1.3, 3.7
1563	5.9, 1.4, 5.0	3.2, 0.9, 5.3

Table 1 shows that the stations show a good repeatability with few millimeters on the horizontal component and, as expected, higher residuals on the vertical component. OSGF is performing slightly better than ULAG, particularly on the vertical component. Several reasons can explain this difference. Although both stations are located at 3-store buildings (the other stations will be installed at lower structures), the OSGoF headquarters are situated in rocky soil where the University of Lagos is located on a sedimentary area nearby the ocean. Although the ocean tide loading is modeled during the data processing, the influence of the proximity to the ocean can still affect more ULAG than OSGF. Finally, the structure of the building at the OSGoF headquarters is more robust than at ULAG. But, note that at both stations we are observing small residuals similar to the values of the majority of the IGS stations (the fundamental global GNSS network).

The next step was to compute a unique solution based on the entire set of weekly solutions. Although the time-series is still too short to compute any reliable secular motion due to the plate tectonics, the residuals of the weekly solutions with respect to the estimated motion (necessary to compute the solution at the reference epoch 01.JAN.2010) are very small, as can be observed at Table 2:

Table 2 – r.m.s. of residuals of the weekly solutions with respect to the best-fit trend (accounting for the secular motions due to plate tectonics)

Station	Lat (mm)	Lon (mm)	H (mm)	# Weekly Solutions
ULAG	1.1	1.3	3.6	12
OSGF	0.7	1.3	3.3	11

The residuals are at 1-millimeter level for the horizontal components and 3-millimeters level for the vertical component. This assesses the quality of the estimated coordinates with respect to ITRG2005 for the selected reference epoch 01.JAN.2010 that are shown in Table 3 and Table 4:

Table 3 – Cartesian Coordinates (ITRF2005) at the reference epoch 01.JAN.2010

Station	X (m)	Y (m)	Z (m)
ULAG	6326097.300	375576.090	719131.667
OSGF	6246471.260	820848.725	994267.907

Table 4 – Geodetic Coordinates (ITRF2005) at the reference epoch 01.JAN.2010

Station	Lat (º ‘ “)	Lon (º ‘ “)	H (m)
ULAG	6º31’02.03751”	3º23’51.04438”	45.568
OSGF	9º01’39.05964”	7º29’10.08298”	533.642

4. FINAL REMARKS

At the present, NIGNET is on the implementation phase. However, OSGoF is already planning the future. New stations (cf. Figure 1) are on evaluation and it is planned that they will be installed by the end of 2010 in a common effort between OSGoF and other Institutions, in particular the NASRDA (National Space Research and Development Agency).

The future plan is to implement a new reference frame for Nigeria based on the NIGNET stations. This will create a modern frame that will be full compatible with the modern systems and observation techniques. However, for the moment, OSGoF also plans to incorporate the CORS stations in the Minna Datum. This will be done by computing local parameters for each station since a unique national transformation parameter set would cause too large errors due to the internal deformation of the classical datum.

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BIOGRAPHICAL NOTES

Barde Jatau graduated at Ahmadu Bello University, Zaria (1980) in Nigeria. He later studied International Institute for Aerospace Surveys and Earth Sciences, Enschede, Holland (1987 to 1991) and Galilee College, Israel (2001). Surv. Jatau holds the following qualifications: B. Sc (Land Surveying) (1980), PGD (LIS) (1988), M. Sc. (GIS) (1991) and Certificate in Urban Economic Development (2001). He is registered to practice Surveying by Surveyors Council of Nigeria in 1989 and is a Fellow of the Nigerian Institution of Surveyors.
He was employed by the Federal Capital Development Authority of Nigeria between 1982 and 2006 and rose to the rank of Deputy Director (Surveys). In November 2006, Surv. Jatau was transferred to the Office of the Surveyor General of the Federation as deputy Director (Geoinformation). His present position is Director (Surveys).
Surv. Jatau's special interest at the moment is the successful implementation of the Nigerian GNSS/CORS Project (NIGNET).

Rui M. S. Fernandes is Assistant Professor of University of Beira Interior and Associated Researcher of Center of Geophysics of University of Lisbon / Institute Geophysical D. Luíz. He obtained the MPhil in Geomatics Engineering by University of Coimbra, Portugal (1990) and he has the Ph.D. in Earth and Space Sciences by Technical University of Delft, The Netherlands (2004). His current research topics are focused on the application of Geodetic Space techniques to Geodynamics and Reference Systems. He belongs to some organizations like American Geophysical Union and is member of IAG (International Association of Geodesy), EUREF (European Reference Frame) and AFREF (African Reference Frame) technical working groups.

Adeyemi Adebomehin is Assistant Chief Surveyor (Geo-Information) of OSGoF. He has the B.Sc. of Survey and Geomatics Engineering from University of Lagos (1992). He is the responsible for the field implementation of NIGNET.

Nuno Gonçalves has a Fellowship at SEGAL since 2009. Simultaneously, he is graduating at University of Coimbra, Portugal in Electric Engineering. He already participated at several research projects in the area of Electronics and Geomatics.

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