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Study of Reliable Seismic Data Communication Across Seismographic Stations: Case Study Nigerian National Network of Seismographic Stations (NNNSS)

Dauda Duncan, Tahir A. Yakubu, Ofonime O. Akpan,
Mohammed T. Shuaibu, Monday A. Isogun, Umar K. Afegbua
Centre for Geodesy and Geodynamics, Toro
National Space Research and Development Agency
Abuja, Nigeria

Abstract: **This paper reviews the communication technologies employed in the Nigeria National Network of Seismographic Stations (NNNSS) operated by the Centre for Geodesy and Geodynamics with the purpose of eveluating the advantages and the drawbacks inherent in the various technologies for reliable seismic data transmission. The traditional Public Switched Telephone Network (PSTN) Dial-up service which can provide intranet service capable for data transfer is most cost-effective but not viable in Nigeria. Employing Advanced Technology (AT) commands on Global System for Mobile Communications (GSM) Modem platform to transmit seismic data as Short Message Service (SMS) was first used but the dynamic and lossy nature of GSM firms posed several challenges in reliable telemetry of seismic data from remote seismographic stations to central station. Furthermore, utilizing the General Packet Radio Service/ Access Point Name (GPRS/APN) technology with mobile router tends to moderate the available resources to realize near real-time transmission of data but the lack of required applications from operators posed serious challenge on networking our seismograhpic stations. By optimizing Very Small Aperture Terminal (VSAT) link technology a seismic network operation for real-time processes and auto locating of events are largely practicable as well as reliable for the quality of data transmission.**

Keywords – Nigerian National Network of Seismographic Stations, Communication, seismic, data, transmmision, seismographic, stations, network.

I. INTRODUCTION

The Nigerian government established seismographic stations in the country for acquiring seismic data that are used for earthquake location, magnitudes determintion and other earthquake related research. These seimographic stations as shown in fig. 1 are distributed across the the country especially areas that are prone to seismic activities. From time to time, earthquake scientists and engineers move from one semograghic station to another to upload seimic data from data recorders for onward processing, analysis and interpretation in our office situated at Toro, Bauchi State. The task of going over all the stations for seismic data is quite inefficient considering the the time it takes to cover all the stations. Whenever an earthquake occurs, the very first and basic problem to solve is to make a location of the seismic event and determine its magnitude and for this purpose, we generally need at least 3 stations networked for prompt result. Therefore the need to have all the seiemograghic stations networked for easy access to seismic data becomes necessary. The Centre for Geodesy and Geodynamics now operates the Nigeria National Network of Seismographic Stations where seimic data from our semograghic stations are transmitted to the central station in Toro.

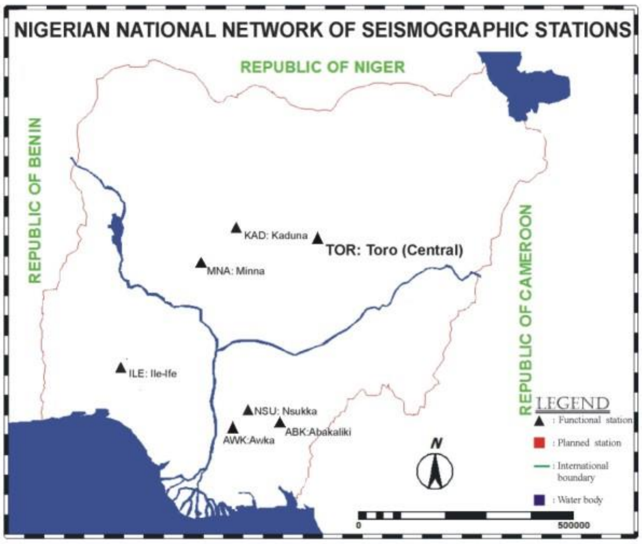

Fig. 1.Map of NNNSS workstations across Nigeria

Reliable seismic data communication may seem like a less important technical task of a seismic network, poorly selected or designed data transmission capacities are the most frequent cause for disappointments and technical failures. The distances to which data must be transmitted become unimportant with computer-based seismic networks [1]. A typical networked ready NNNSS workstation shown in Fig. 2 consists of seismometer, digitizer, data logger and filters which is made of low power devices consisting of microcontrollers for information processing.

Seismic stations communication can be achieved either physical or virtual. A physical seismic network (usually local) consists of closely linked remote seismic stations which detect the ground motion and usually send data in real time to a central recording station for storing, event detection and recording. A virtual seismic network consists of stations selected among many stations connected to the global communication network or a public switched telephone network [2].

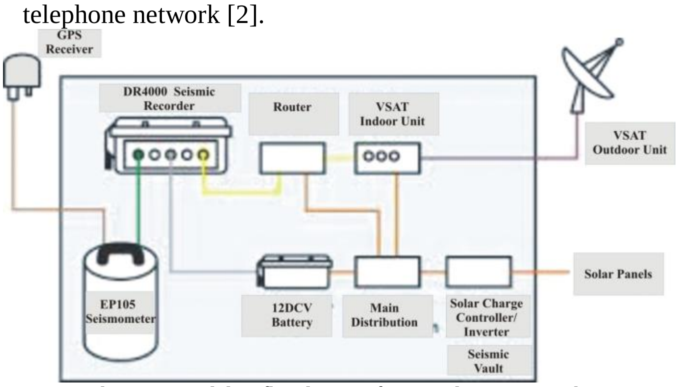

Fig. 2. The power and data flow layout of a typical NNNSS workstation

In Nigeria today, no fixed telephony (PSTN) is available and GSM only arrived in 2001. However, the GSM coverage is just as poor as the quality of the service. At the moment, SMS services are the most reliable communication service because voice conversations tend to cut off in the middle and suffer heavy noise. GSM Modem and mobile router employing APN application with very low power consumption which NNNSS exploited in the past, were unsuccessful and the present research in the area of VSAT technology progressively leading to the development of cost effective, energy efficient, and multifunctional sensor nodes. This system integrates third party software to enable it offer reliable communication of streams (graphics) seismic data from remote stations to the central station.

The primary purpose of this study is to analyze communication technologies across seismographic networks for NNNSS, have the advantages and drawbacks of the various technologies for reliable data communication. Furthermore to propose, evaluate a VSAT technology and third party software based approach for enabling guaranteed streaming of seismic data from remote stations to central station. Integration of VSAT technology and Earthquake Monitoring System(EMS) will be examined for onwards implementation of NNNSS.

II. PUBLIC SWITCHED TELEPHONE NETWORK (PSTN) FOR SEISMIC TRANSMISSION DIAL-UP

Dial-up phone lines are very often proposed for seismic data transmission because they are readily available and apparently cheap. However, they have important limitations of which one must be aware. First, continuous seismic data transmission is not possible via dial-up lines. This makes coincidence triggers hardly applicable or at least very clumsy and slow. In practice, dial-up weak-motion networks based on phone lines cannot 'digest' earthquake swarms and the numerous aftershocks after strong events [2].

In Nigeria, landline phone system has folded long ago and hence not feasible for NNNSS. Interactive dial-up connection with remote seismic stations is shown in Fig. 3. A user calls up a terminal emulator on his PC, connects to a modem with one of the PC's serial lines, dials the phone number of the modem connected to the remote station, and logs into the field Data Acquisition System.

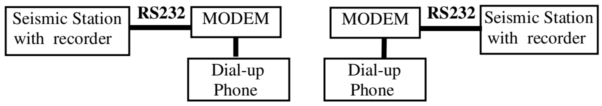

Fig. 3. Manual Dial-up to a seismic station for data inspection and/or download [2]

III. GSM TECHNOLOGY WITH AT COMMANDS PLATFORM

A GSM modem is specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone [3]. Fig. 4 shows a typical of NNNSS topology utililising GSM modem and AT commands, when a GSM modem is connected to a computer integrated with seismic equipment, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are used to provide mobile internet connectivity, many of them can also be used for sending and receiving seismic data as SMS messages based on AT Commands. GSM modem must support an “extended AT command set” for sending/receiving SMS messages. GSM modems can be a quick and efficient way to get started with SMS because a special subscription to SMS service provider is not required (https://sites.google.com/site/ vmacgpsgsm/imp). In most parts of the world GSM modems are cost effective for a seismic networking but developing country like Nigeria which hosts NNNSS, effective data rate of sending SMS is poor.

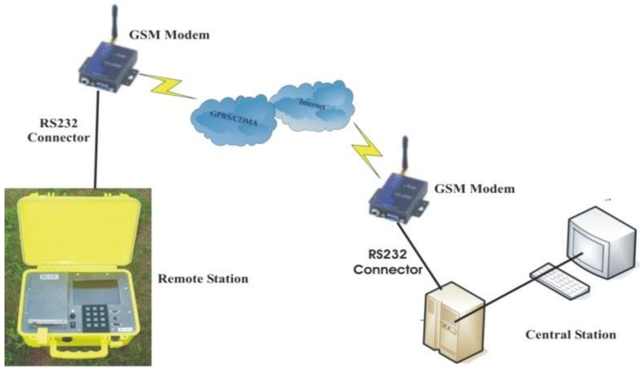

Fig. 4. Typical of NNNSS topology utililising GSM modem and AT commands.

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Fig. 4 shows a topology of GSM modem where commands can be issued to connect two modems connected to seismic recorders to transfer seismic data as text messages. AT commands are used to control a modem [4]. Some of the commands are given below:

1. ATEO – Echo off
2. ATE1 – Echo on
3. ATD – Call a dial no
   Syntax : ATD 08033539685
4. ATDL – Redial last GSM number
5. ATA – Answer an incoming call
6. ATH – Disconnect existing connection
7. AT+CMGS-To send SMS
   Syntax: AT+CMGS=”08033539685” Press enter
   Type text and press ctrl+z
8. AT+CMGR-To read SMS
   Syntax: AT+CMGR=1 ; reads first SMS in sim card
9. AT+CMGD – To delete SMS
   Syntax : AT+CMGD = 1 ; deletes first SMS in sim card

IV. GPRS/APN AND MOBILE ROUTER IN SEISMIC DATA TRANSFER

Conventionally, if GSM network is available, it is also possible to use the network for data transmission. Packet oriented standards extending the GSM, such as GPRS, UMTS and LTE support both transmission of voice and transfer of data. Some available wireless modems have built-in ability to connect to all three services in Fig. 5 Cell availability is depending on the provider and usually limited to inhabited areas.

Provided data rates differ depending on the standard used (GPRS 53.6 kbit/s; 384 kbit/s; LTE 100 Mbit/s) but also on saturation of the shared infrastructure. Especially during and after catastrophic events, such as earthquakes, congestion or complete system blackouts are common. Configuration and installation of the modem is straight forward and easy. No antenna alignment is required [5].

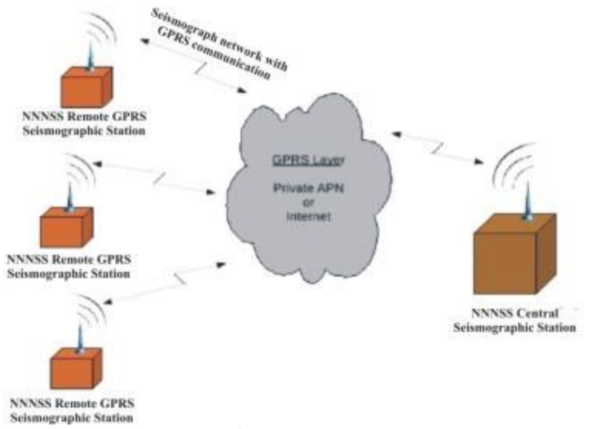

Fig. 5. Typical Topology of NNNSS GPRS/APN connection between Remote Station and Central Station

In GPRS/APN technology there are a number of technical factors (Access Point Name, Connection to the GPRS Network and Internet Protocol Address Allocation and Mobile Router) that we need to consider before GPRS/APN data transfer.

Access Point Name

An Access Point Name is the point at which an external public network (such as the Internet) or private corporate network (for example a NNNSS) connects to the GPRS network. In a NNNSS application an APN effectively provides remote devices with a single number to which they connect to the NNNSS using the GPRS network. For large systems a private APN is recommended, because an Internet APN, although cheaper, involves unknown delays due to varying internet contention ratios and queue lengths. Another important reason is that a private APN supports both static and dynamic Internet Protocol (IP) addressing [6].

Connection to the GPRS Network

Remote stations would typically connect to the GPRS network by means of GPRS/APN mobile routers that interface serially to each Remote station. However, there are a number of different ways that a corporate network could connect to the GPRS network.

Internet Protocol Address Allocation and mobile Router

Normally, when a mobile terminal initiates a new GPRS connection the terminal is assigned a dynamic IP address for the duration of the session or manually assigning IP by the user. However, DNP applications require that the DNP also initiate sessions, and that messages are correctly routed to the intended recipient. With GPRS this can only be achieved by means of static IP addresses. This requires having a private APN and VPN (Virtual Private Network). Private (can be shared) APN (Access point Node) with a point-to-point network with static IP addresses (IP=Internet Protocol). This will have to be done by the cellular service provider. It must assign a specific static IP-address to each cellular SIM-card so that when the particular SIM-card is inserted into the GPRS-modem and connects to the Private APN the network must always accessing the same IP address.

This solution makes the network independent of the internet and is much more secured. You will have a GPRS-modem at every seismic station as well as at the central station. The issues associated with this GPRS/APN are; that no quality of service guarantees and that possible future oversubscription of the GPRS service could result in unacceptable data latencies. GSM/GPRS services in Nigeria since its inception have failed to provide effective pathway for GPRS/APN connection and hence a huge challenge on NNNSS. Furthermore, in Nigeria inexistence of some technologies integrated in network coverage in rural areas makes it difficult to get high data rates.

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V. COMPARISON OTHER TECHNOLOGIES WITH VSAT FOR SEISMIC DATA TRANSFER

The most common system to use for seismic network is VSAT system. It provides an edge over terrestrial lines and other technologies. VSATs are an ideal option for seismic networking because they enable Enterprise Wide Networking with high reliability and a wide reach, which extends even to remote sites [5]. The usage of VSAT has many advantages among which are:

1. VSAT services can be deployed to any remote seismographic stations. It provides Internet access independent of the local terrestrial/wireline infrastructure, which is particularly important for backup or disaster recovery services which are essential for seismic network.
2. The services can be deployed quickly within a few hours or even minutes.
3. Most modern VSAT systems use onboard acceleration protocols and deliver high-quality Internet performance regardless of latency
4. Current VSAT systems use a broadcast download scheme which enables them to deliver the same content to tens or thousands of locations simultaneously at no additional hardware cost (Wikipedia).

Seismic Network monitoring and control of the entire VSAT network would be much simpler than a network of leased lines, GSM Technology and GPRS/APN connection, involving multiple carriers at multiple locations. A much smaller number of elements need to be monitored in the case of a VSAT network [7]

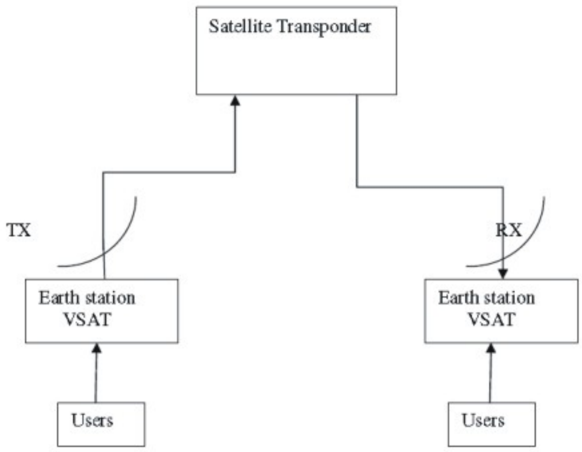

Fig. 6. Basic VSAT satellite communication system [8]

Seismic Data Communication with VSAT and Third Party Software

Any seismological service that maintains a seismic network operates an EMS, which is a combination of third party software and communication backbone capable of acquiring, processing, and archiving large volumes of real-time continuous seismic data. Crucially, the processing includes the automatic detection, location and quantification of earthquakes [9]. The third software used in NNNSS is SEISCOMP, it is a complete suite of software based on a unique database and provides modules for data acquisition, data processing, archiving, and dissemination and also includes a suite of graphical user interfaces (GUIs).

VSAT and NNNSS Network Configuration

The NNNSS network was designed specifically for remote data acquisition and consumes very little power as well as overall lifetime costs for the complete network including satellite transmission costs. In NNNSS network, remote user sites have a laptop computers and Seismic Data Acquisition System and the VSAT terminal which connects them to a centralized host computer at Toro.

Fig. 7 shows the stream of seismic data and indoor unit (IDU) of VSAT and Fig. 8 is outdoor unit of KU-band 1.2 m dish. NNNSS VSAT network is based on hybrid topology which allows a group of VSAT terminals to communicate in mesh topology while others communicate only in star topology. This topology is useful for networks in which certain terminals have larger traffic demand between themselves than the other terminals. The terminals with higher traffic demand can be accommodated in mesh to reduce the expense of extra equipment at the hub, and satellite resources required for a double hop. The rest of the network can communicate with any of these larger terminals or each other via a star topology. NNNSS uses frequency band of Ku-Band. For C-band operations, the Ku-band requires transmission at 14 GHz and reception at 11-12 GHz.

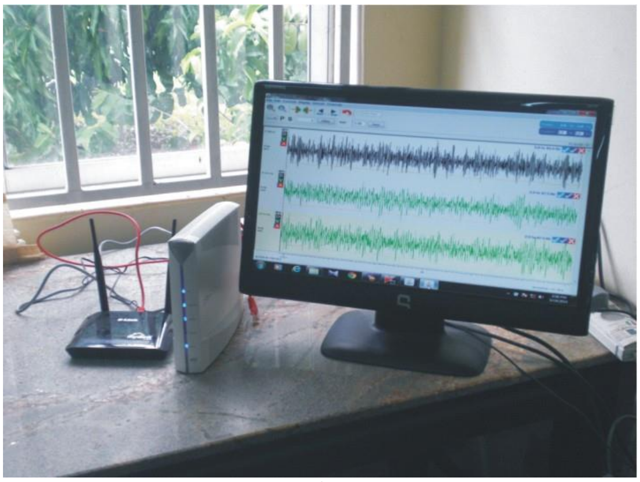

Fig 7. Indoor unit(IDU) of VSAT, CGG, Toro, Nigeria

Fig 8. Outdoor Unit (ODU) of VSAT, CGG, Toro, Nigeria

Determining the Baseline Seismic Data Rate

NNNSS Data Acquisition System is configured for 100 sps, 3 channel, 24-bit seismic data sampling with first-difference non-approximating data compression. This stream of samples constitutes the vast majority of the inbound data stream. For the purpose of determining the data rate, other inbound data streams, such as State of Health (SOH), can be ignored. NNNSS systems transfer data synchronously, using 24-bit bytes.

A three channels, 100 sps option of the digitizer will generate 300 samples each second. ncompressed samples will occupy 24 bits, or 4 bytes each. The compression algorithm will reduce the number of bytes per sample to 2 or 1 depending on the frequency and amplitude of the seismic signal quiet sites will often have 1 byte samples, while noisy sites will often have 2 byte samples. Experience indicates that an average compression of 1.2 bytes per sample is achieved in typical remote sites (this value is used for the examples in this manual). Seismically noisy sites will achieve less compression, and require higher data bandwidths [10].

A typical NNNSS remote site therefore generates an average of 926 bits of compressed seismic data each second. This data is packetized before transmission, which adds addresses, Cyclic Redundancy Check (CRC) codes and other overheads. We recommend allocating 25% of additional data capacity for these overheads, which is a conservative estimate to ensure reliability. This suggests a baseline average data rate of approximately 300 bps for 3 channels, 100 sps, compressed and packetized data [10]. The allocated bandwidth for remote stations is 64 kbps and central station is 512 kbps dedicated.

Third Party Software SEISCOMP

NNNSS network employ the task of SEISCOMP which is a combination of software capable of acquiring, processing, and archiving large volumes of real-time continuous seismic data. Data are then accessed by modules through a TCP/IP connection.

NNNSS Stations Internet Protocol

IP addresses are in static mode and implemented as shown in table 2.1 to ensure scalability and simplifies maintenance in regards to troubleshooting and routing at the data centre at Toro.

Station	Intrastation Network IP	Number of Hosts at station	Geographical Coordinates
Toro	197.242.255.24/30	2	$10^0$03.303'N $9^0$07.089'E
Kaduna	197.242.255.28/30	2	$10^0$26.103'N $7^0$38.417'N
Ile-Ife	197.242.255.32/30	2	$4^0$32.760'N $7^0$32.818'E
Awka	197.242.255.36/30	2	$6^0$14.561'N $7^0$06.693'E
Nsukka	197.242.255.40/30	2	$6^0$52.101'N $7^0$25.045'E

Table 2.1: The NNNSS implemented IP plan

Using the scheme shown in Table 2.1, a total of 5 stations currently running in NNNSS network. A private IP block chosen, because equipment at the remote stations does not access the Internet and does not need to be reachable from there. Data is directly transferred from stations to the data centre and there it is shared with other national and international observatories using a third party software SEISCOMP server, reachable from outside.

VI. DISCUSSION AND CONCLUSION

As a result, at this juncture regarding the telemetry of seismic data based on several communication technologies, only VSAT is conceivable and reliable to manage the amount of seismic data at an affordable level. In many countries, public phone networks have specific properties and special 'tricks'. Therefore one has to choose a type of modem that has been officially approved in the country and that performs well under local circumstances.

For telemetry of seismic data, testing of GSM Edge based solution should immediately start. The hardware (GSM Edge routers) should be tested for availability protocols requirements in the country to avoid wastage of funds. As was for our dial-up solutions in Nigeria there are probably going to be some start up problems because landline has gone extinct. If GSM Edge solutions turn out to be as stable as Asymmetric digital subscriber line (ADSL) solutions, it should be preferred over ADSL solutions, because it is more immune to lighting problems and can be deployed over almost the entire country but providers are tricky.

Besides, several different telecommunication solutions had been tested and failed during networking of the seismographic stations. Important circumstances which affect the decision making are services built in by each provider, coverage, initial and data transmission costs, high power consumption and installation as well as activation.

Modems react differently to each phone system's particular weak points. A modem, which works perfectly in one country, may not be the optimal solution for another

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country. We strongly recommend the purchase of modems only after consulting with local communication experts who have practical experience with digital data transmission over local phone lines in a particular country.

The VSAT modem is configured to be the default gateway for all equipment on–site (intra-station network), so waveform data is transmitted using the VSAT network. Demand for VSAT services in the seismology has increased significantly in recent years and this survey shows that that trend will continue considering seismic activities across the globe. Much of this demand is driven by researchers studying the geodynamics of the earth and they are seeking operational efficiency and improved seismic processes through the implementation of software applications.

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