NomadicBTS-2: A Network-in-a-Box with Software-Defined Radio and Web-Based App for Multiband Cellular Communication

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Abstract: The proliferation of mobile communications technologies has significantly contributed to the plausibility of emerging economies. However, there still exists a digital divide in several remote and hard-to-reach places, owing to the high CAPital EXpenditure (CAPEX) and OPerating EXpenditure (OPEX) of mobile network operators. In this study, a cost-effective software-defined base station named NomadicBTS-2 is developed and prototyped based on open-source technologies and the Software-Defined Radio (SDR) paradigm. NomadicBTS-2 comprises Universal Software Radio Peripheral (USRP) B200 as the Radio Frequency (RF) hardware front-end. The software backend comprises of open-source software such as USRP Hardware Driver (UHD) and services (i.e., OpenBTS, Asterisk, SIPAuthserve and SMQueue). In addition, we developed a new software (named NomadicBTS WebApp) to configure and monitor the UHD and software services through a web-based Graphical User Interface (GUI). NomadicBTS-2 was tested using two mobile stations (MSs) for simplex and duplex communication while the network link quality parameters were evaluated to determine users' Quality of Experience (QoE). Experimentation results showed that within a pico-cell, the link quality is sufficient for call routing and Short Messaging Services (SMSs) between user-to-user and network-to-user. The prototype provides a basis for a Network-in-a-Box that can be deployed for short-range communication in rural areas, hard-to-reach places, emergency situations, IoT sensor networks and to augment existing base stations to mitigate network congestion. It can also be a viable testbed in teaching and research laboratories to explore new frontiers in SDR, cognitive radio, and other wireless communication domains.

Keywords: NomadicBTS-2; Software-Defined Radio; Multiband Cellular Communication; Network-in-a-Box.

1. INTRODUCTION

The emergence of wireless communication technologies has witnessed significant development over the past few decades [1]–[3]. High-speed heterogeneous networks have transcended from 2G, 3G, and 4G to 5G and beyond. However, the architecture for the radio access technologies consists of the access layer,

distribution/backhaul and core network layer. Base Transceiver Stations (BTSs), which transmit and receive signals in the form of electromagnetic waves make up the access network for users to interface with the network services and resources. The upsurge in CAPEX and OPEX of mobile network operators inspires leveraging the Software Defined Radio (SDR) technology to achieve efficient, cost-effective, and most importantly, dynamic wireless communications. A SDR can be positioned at the centre of a pico/femto/micro cell, that is, the smallest geographical area of a network, to provide an alternative to the traditional BTS [4]. It can also be useful in disaster-affected areas where telecommunications infrastructure is in dilapidation and to provide short-range communication in rural areas. The High Altitude platforms (HAPs) is another system that can be easily deployed at disaster (e.g earthquake, flood, hurricane etc.) zones [5], rural or none network available areas, however, HAPs might not be as cost-effective as NormadicBTS-2.

The ubiquitous role of mobile devices and the penetration of high-speed internet technologies are the key drivers to achieving a sustainable economy. As more users subscribe to the networks daily, the demand for improved voice and text-messaging services continue to rise, leading to resource management and scalability concerns for mobile network operators. The Global System for Mobile Communication (GSM) - a 2G technology, provides the underlying architecture for circuit-switched voice and SMS services [6]. It is known as the most popular wireless technology because of its widespread use and global penetration.

As shown in Figure 1, the GSM architecture is made up of three core parts – Base Station Subsystem (BSS), Network Switching Subsystem (NSS), and Operational Support Subsystem (OSS). The BSS is known as the access network and consists of several BTSs, Base Station Controllers (BSCs) with Mobile Stations (MSs) interfacing with the BTSs. The NSS controls the switching to a home public network and serves as a gateway to other mobile networks, while the OSS gives support for the operation and maintenance of the GSM network, and also permits monitoring of various nodes of the GSM network. The BSS has a primary function of providing and managing radio transmissions between the MS and Mobile Switching Center (MSC), which routes traffic (voice, data, and SMS) to and from the GSM network. The BSS comprises two nodes - the BTS and BSC, with a radio interface (Abis) between them [7].

In a GSM network, the BTS performs over-the-air-interface radio transmission to and from mobile stations, while the BSC interconnects tens to hundreds of BTSs, coordinates frequency and channel allocation, and handover between cells. The MSC is responsible for the radio link management, routing and switching, and communication within the Public Land Mobile Network
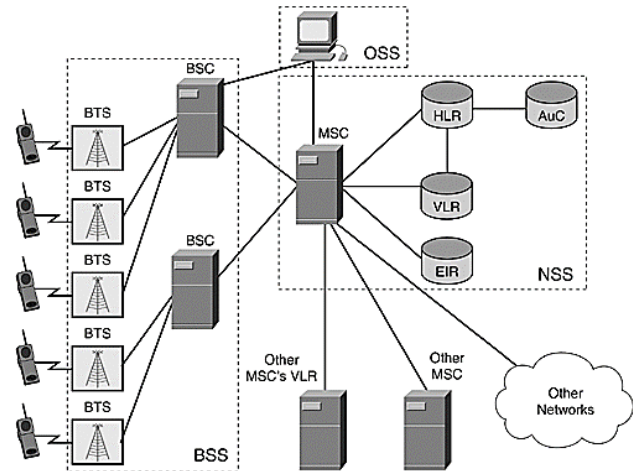

Figure 1.   Traditional GSM Architecture [24]

(PLMN). Other functions of the BTS include modulation and demodulation, encryption, ciphering, channel coding, and decoding [7]. The intricate characteristics of the traditional BTS motivated the development of the SDR technology [8], [9] a modern radio communication technology in which components that were traditionally implemented on hardware are now implemented by means of software on an embedded system or personal computer [10], [11] . SDR technology helps to mitigate the high CAPEX/OPEX challenges of the fixed infrastructures, and facilitates cross-functionality, cost-effectiveness, flexibility, and portability to drive reliable communications through to end users [4], [9], [12].

The application and use of SDR frameworks in the provisioning of wireless communication services have created several research motivations. To enable communication in remote areas, Wibisono et al. [13] designed and developed a "flying BTS" using a raspberry pi microcontroller as a webserver, a Wi-Fi dongle to serve as an access port, a 4W 2.4 GHz amplifier to amplify the signal levels, and a 2.4 GHz antenna as the radiator, all packed in a container and placed in a balloon. Hafidudin et al. [14] used the OpenBTS and USRP to provide alternative access to local mobile operators. The OpenBTS running on a Linux OS was connected to a Voice over IP (VoIP) service to form a quadruple play service and Asterisk was used to connect with other telephone networks.

In a similar study, Muslimin et al. [15] simulated the effects of the modulation process using a setup comprising of the M-PSK and M-QAM modulation schemes, in addition to the GNU Radio v3.7.8.2. running on a computer system. For the real node to transmit and capture real signals, multiple USRP N210 was used with the CBX (40 MHz) daughterboard linked to a host computer at both the receiver and transmitter sides, and a loopback cable as the communication channel of the USRPs. For efficient communication in remote areas, Prasannan et al. [16]

proposed a solution through an OpenBTS-based micro telecom model following the SDR paradigm using a USRP. Further testing and observation proved that using a small micro-controller like the Raspberry Pi and open-source technologies such as the YateBTS is cost effective and mobile. Similar to [16], Aggrawal and Vachhani [17] offered an alternatively cost-effective procedure for immediate restoration of remote connectivity in the event of disasters; a BTS was built using the USRP B200 board and OpenBTS based on the SDR technology.

Our work in [10], which is a precursor and the first version of the current work is a NomadicBTS, based on SDR technology that was designed, built, and prototyped to provide an easy to deploy and economical communication solution. The design consists of an RF frontend and a software backend. The RF frontend is the Ettus research USRP B200 which has a frequency range of 50 MHz to 6 GHz. Results from the tests carried out within the Covenant University campus showed that the appropriate cell radius of the prototype was 7.54 m. Further tests with two test phones showed that the MSs could access the network for voice and SMS with minimal delay on channel assignment. However, the configuration of the NomadicBTS involves the use of Ubuntu OS Command Line Interface (CLI), which is not efficient in practice. Also, the work also considered only one single frequency band in the 900MHz spectrum while other higher bands for GSM technology were not explored. These are the gaps being addressed in the current paper.

In NomadicBTS-2, we explored multiple GSM spectrum bands and leveraged on SDR hardware, frameworks and open services such as USRP B200, OpenBTS, Asterisks, SIPAuthserve, SMQueue and NodeManager. Furthermore, we designed and developed a web application named NomadicBTS WebApp to handle Graphical User Interface (GUI) based configuration and monitoring of the listed open-source software services, and developed and implemented a billing service capable of controlling, monitoring, recording, and charging customers' calls and text messages over the NomadicBTS network. The rest of this paper comprises of the materials and methods in Section II, results, and discussion in Section III, and finally, the conclusion is presented in Section IV.

2. MATERIALS AND METHODS

A. System Architecture

NomadicBTS-2 is based on the SDR architecture as shown in Figure 2. It comprises of hardware front-end (USRP B200), which is responsible for over-the-air communication between the MS and the BTS, and the software backend, which is installed on a general-purpose computer. The NomadicBTS-2 supports multiple frequency in the GSM band (e.g., 1800 MHz and 1900 MHz), and is used for provisioning of voice and SMS
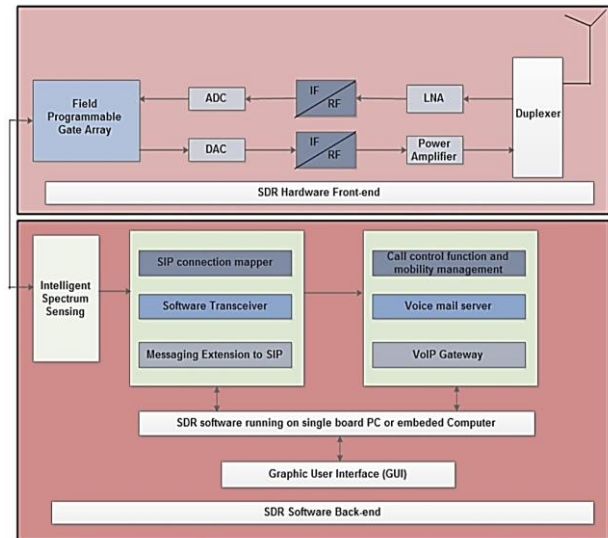

Figure 2.   Architecture of NomadicBTS-2

services. Notably, the selection of the OpenBTS over OsmoBTS and YateBTS is subject to its compatibility with a large number of SDRs.

B. Hardware Frontend

The hardware front end consists of the USRP B200 with the VERT900 antenna. The USRP B200 is a small-size Single Input Single Output (SISO) SDR radio. It has a frequency range of 50 MHz to 6 GHz and a Xilinx Spartan-6 XC6SLX150 Field Programmable Gate Array (FPGA). The RF part makes use of an AD9364 RFIC transceiver that has 56 MHz of contiguous bandwidth and is connected via a USB 3.0 port for transferring data to and from the computer. At the receiver sub-block, the VERT900 antenna receives the signal and forwards it to a Low Noise Amplifier (LNA) through the duplexer. The RF signal is then converted to a corresponding intermediate frequency (IF), which can be digitized by the Analog to Digital Converter (ADC).

The FPGA handles signal decoding, data rate conversion, and timing. At the transmitter sub-block, the processed signal from the FPGA is converted back to analog waveform by the Digital to Analog Converter (DAC), which is thereafter converted from IF to RF. The amplitude of the RF signal is then boosted by the power amplifier, and ultimately transmitted to the antenna through the duplexer. The primary function of the duplexer is to multiplex signals to and from the MSs into the USRP B200. The VERT900 antenna is an 824 MHz to 960 MHz and 1710 MHz to 1990 MHz quad-band cellular omnidirectional antenna with 3 dBi gain [18]. It is 8 inches in length and features a tilt-and-swivel SMA-Male connector, which makes it suitable for use vertically, at a right angle, or any angle in between. The SMA-Male

TABLE I.   SAMPLE TABLE IN THE SMQUEUE DATABASE

Queue Type	Queue	Queue Type	Queue
11	Dist1_PortVeh_Queue	31	Dist3_PortVeh_Queue
12	Dist1_ContToOther_Queue	32	Dist3_ContToOther_Queue
13	Dist1_RoadVeh_Queue	33	Dist3_RoadVeh_Queue
14	Dist1_ContToRoad_Queue	34	Dist3_ContToRoad_Queue
21	Dist2_PortVeh_Queue	71	Port_PortVeh_Queue
22	Dist2_ContToOther_Queue	72	Port_ContToOther_Queue
23	Dist2_RoadVeh_Queue	73	Port_RoadVeh_Queue
24	Dist2_ContToRoad_Queue	74	Port_ContToRoad_Queue
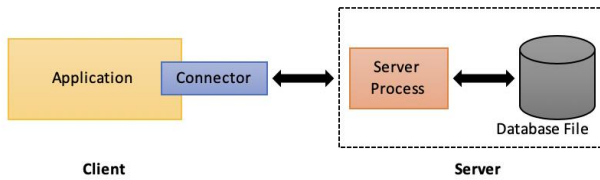
Figure 3.   SQLite Block Diagram for Database Access [25]
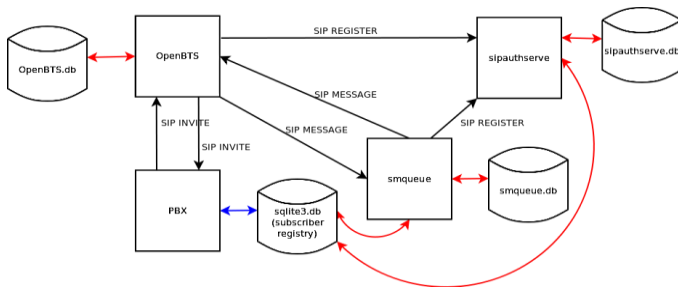
Figure 4.   Interconnection of the Backend Open-Source Services

Figure 5.   Sample of OpenBTS CLI on Ubuntu Operating System

connector also makes it compatible for use with the USRP B200 device.

C. Software Backend

The software backend is made up of the OpenBTS and its dependencies such as the SIPAuthServe, SMQueue, and Asterisk, which are all installed on the Ubuntu OS. OpenBTS implements a complete GSM stack for voice and SMS as well as supports GPRS and UMTS (3G) data standards. It permits the radio-air interface to interconnect with other nodes on the GSM network [19]. It performs various functions of a BSC and BTS independently or in tandem with other software for cost-effectiveness [20]. Asterisk is a VoIP switch that handles the Session Initiation Protocol (SIP) INVITE requests, establishing a two-party call and connecting the two ends.

SIPAuthServe is an open-source software that provides SIP authentication services. It processes the SIP REGISTER requests, which is generated by the OpenBTS every time an MS tries to join the mobile network. SQLite is a service that performs database functions in a SDR network [14], and allows network logs/files to be opened using a browser [15]. Figure 3 shows the block diagram of how the client accesses the database functions in SQLite. SMQueue is the store-and-forward message control unit that manages and handles message and messaging queue in the network. It uses logs and relevant functions to control the message flow and traffic. Table 1 shows a sample SMQueue entry table.

OpenBTS converts all signalling and media data being transferred among the various software dependencies to Session Initiation Protocol (SIP) and Real Time Protocol (RTP) messages as shown in Figure 4. Figure 5 shows the Command Line Interface (CLI) of the OpenBTS on Ubuntu OS. It has series of commands that are used to configure and monitor the status of the network. For instance, the *tmsis* command generates a table that contains the list of connected MSs with their International Mobile Subscriber Identity (IMSI), International Mobile Equipment Identity (IMEI) and other parameters as shown in Figure 6.

D. NomadicBTS WebApp

The NomadicBTS WebApp is a major developmental contribution of this work to the SDR ecosystem. The WebApp-V1 architecture is composed of two core blocks: the frontend for user interactions and the backend for core functionality. Additionally, essential insights into the system are conveyed through three key diagrams: Figure 7 showcasing use cases, Figure 8 depicting class relationships, and Figure 9 outlining sequence interactions. This comprehensive combination provides a clear understanding of the NomadicBTS WebApp's design and functionality. The application employs a request-response model to transmit administrators' user requests for configuring, monitoring, and maintaining the network. Specifically, it allows an administrator to interface between the USRP and the open software services without the command line in.
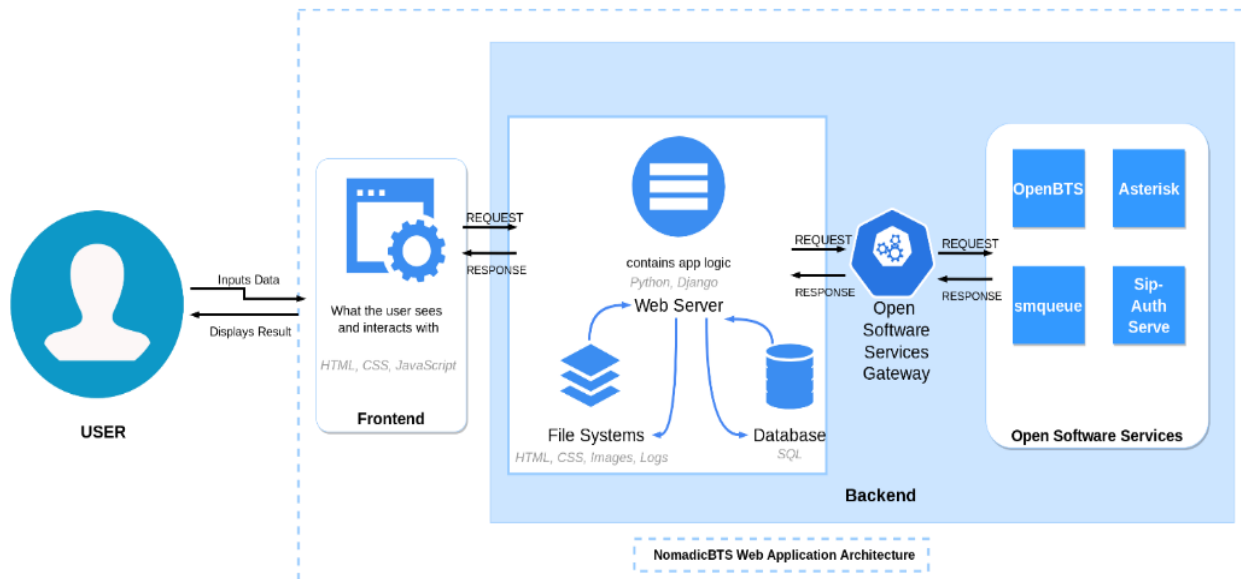
Figure 6. NomadicBTS WebApp Architecture

Figure 7. NomadicBTS WebApp Use Case Diagram

E. NomadicBTS Billing Service

This section focuses on creating a billing service for controlling, monitoring, recording, and charging calls and texts over the NomadicBTS network. It involves defining requirements, designing components, integration with voice/SMS services, and performance testing. The billing system includes charging for network-in-a-box calls and, for call monitoring, the ability to terminate calls without credit. Non-functional aspects encompass security, usability, interoperability, scalability, and data storage [21]. Figure 10 illustrates the OpenBTS system's connection network, while Figure 11 depicts the billing service's architecture, which includes the various modules and their interconnection. The detailed description of the various modules is presented in [22]. The system model is depicted with graphical representations which are based on the Unified Modelling Language (UML). The system operations is shown using a sequence diagram, which shows the interactions between items chronologically as presented in Figure 12.

The billing system monitors asterisk channels for active connections. When a subscriber initiates a mobile call, an asterisk channel activates. The billing system identifies the channel, retrieves call details, and queries the customer database for the caller's balance.
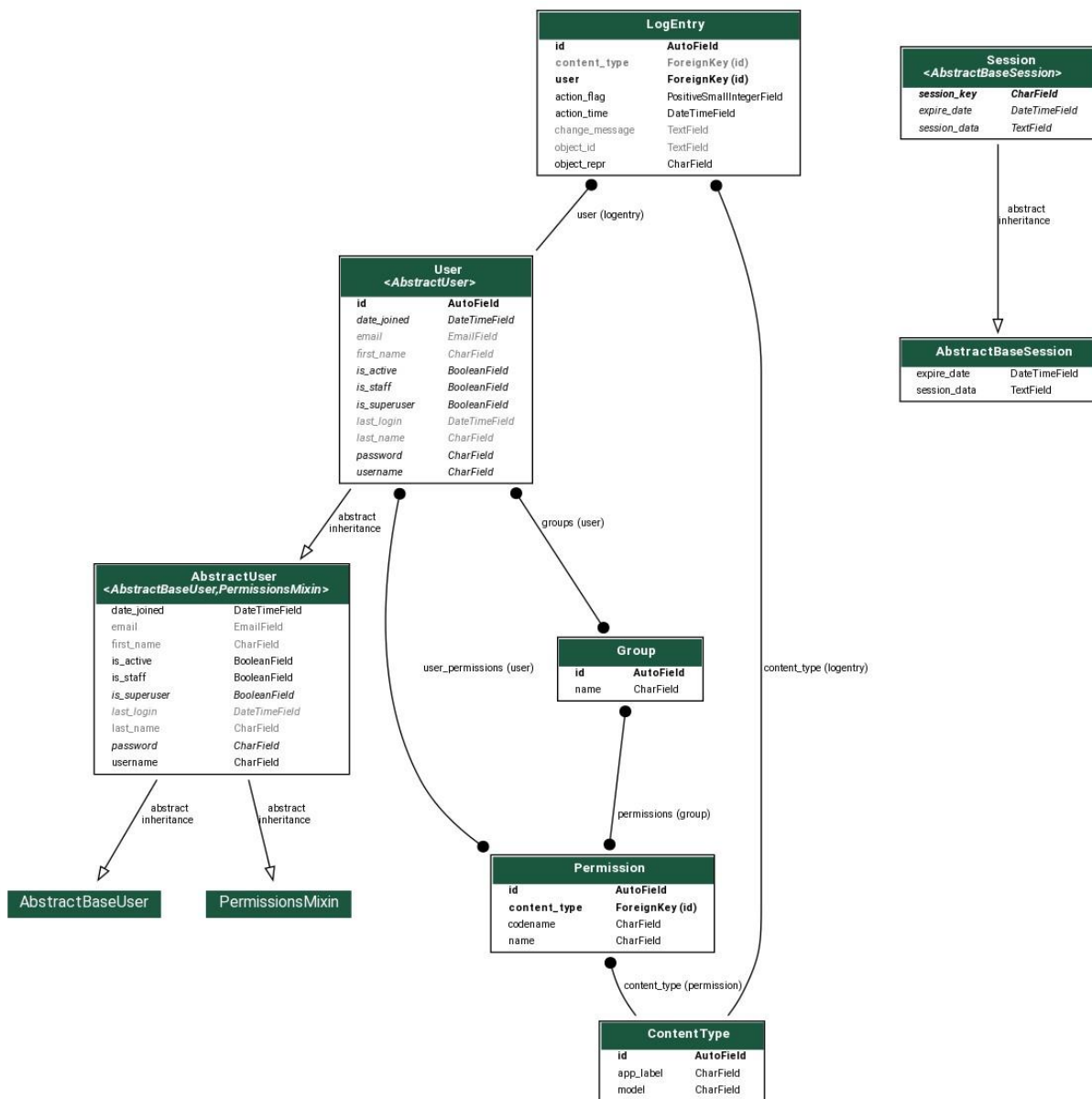

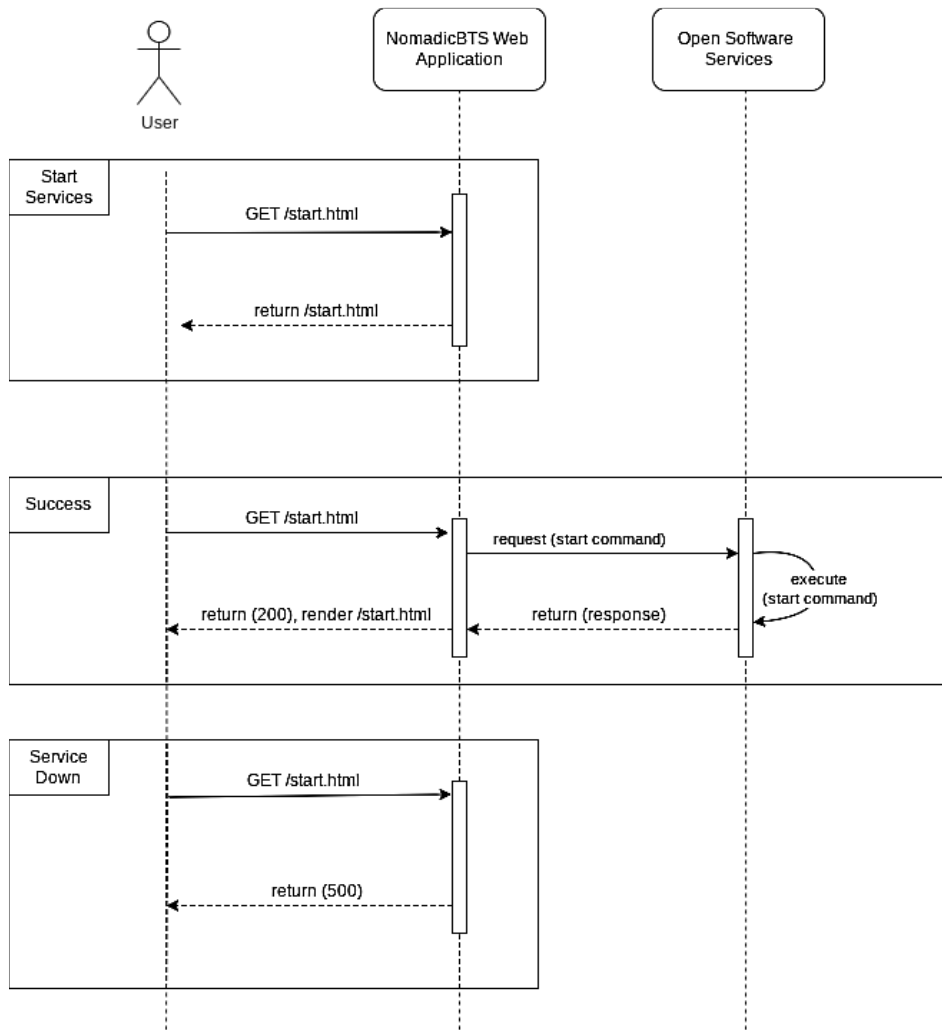Figure 8. NomadicBTS WebApp Class Diagram
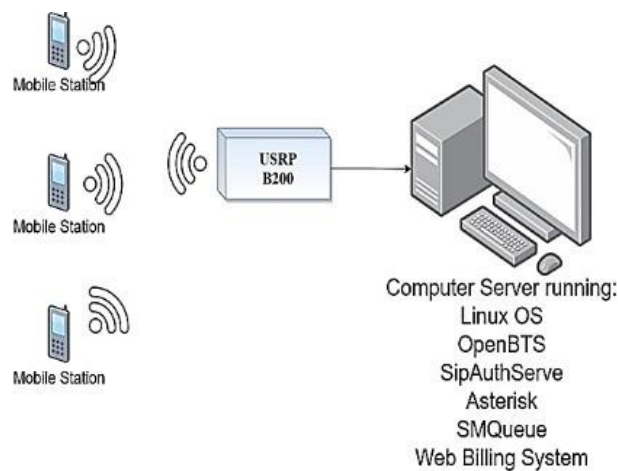
Figure 9. NomadicBTS WebApp Sequence Diagram

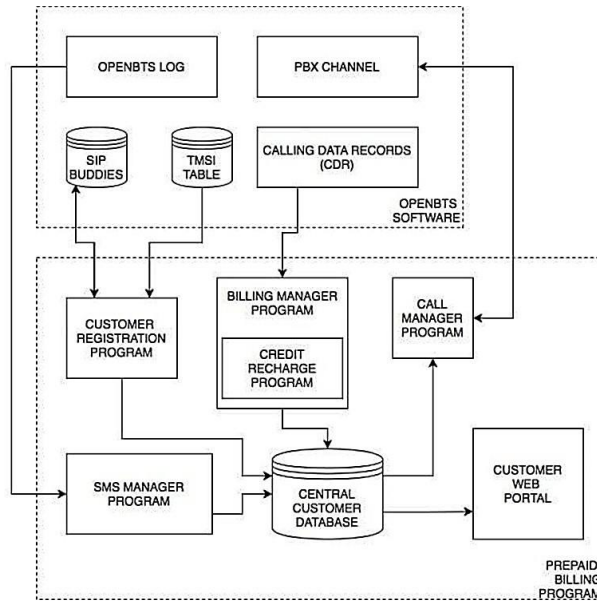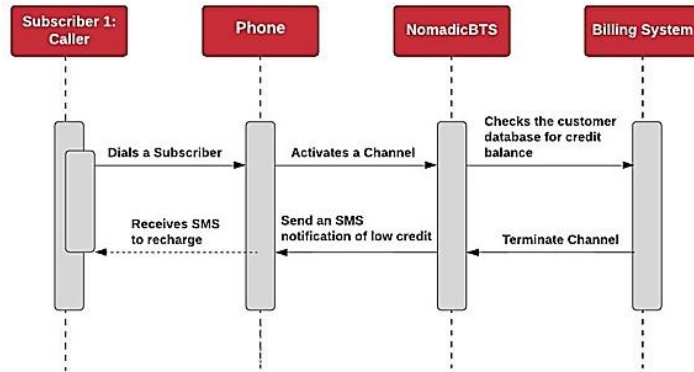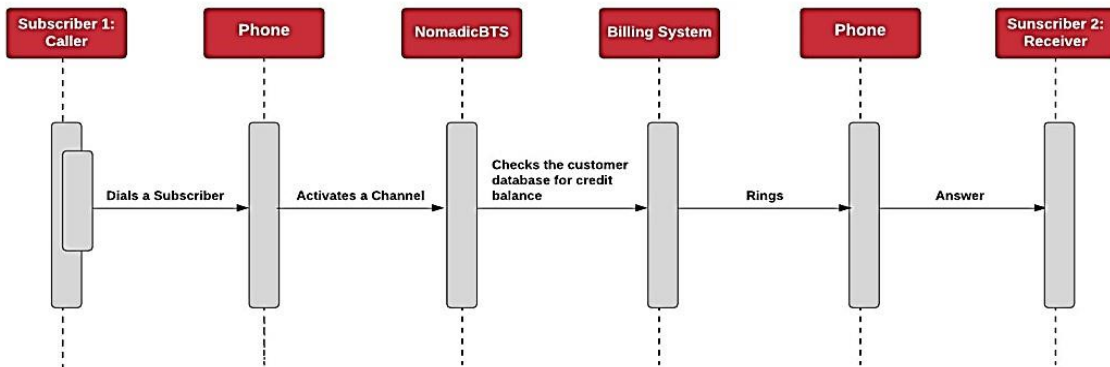Figure 10. Connection Scheme of the OpenBTS network

Figure 11. The architecture of the prepaid billing service

(a)

(b)

Figure 12. Sequence diagram (a) when there is zero credit balance (b) when credit is available and balance is not zero.
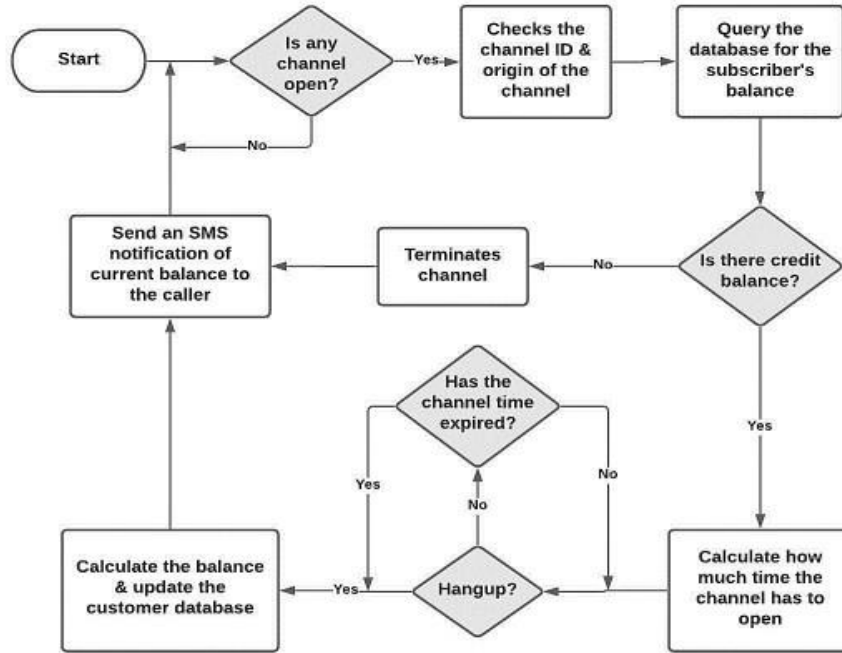
Figure 13. Flowchart of the Billing Service

TABLE 2.   SYSTEM HARDWARE AND SOFTWARE REQUIREMENTS AND SPECIFICATIONS

Hardware Requirements		Software requirements	
Components	Specifications	Requirements	Software
Computer server	Windows with Linux OS, OpenBTS, SMQueue SIPAuthServe,	Operating system	Linux operating system
USRP	B200	Programming language	Python
Antenna	VERT900	Development framework	Django
Mobile phones	Android	GSM network	OpenBTS
SIM cards	Blank SIM cards		

If balance is zero, the system ends the call, sends an SMS, and if not, allows communication. For non-zero balances, the system calculates call duration based on the 12 kobo per second rate. The flowchart in Figure 13 explains in detail the actions being taken by the billing system and the conditions it takes to get the desired goal.

F. Experimental Setup

The laboratory experimental setup of the NomadicBTS-2 platform is shown in Figure 14, while Table 2 presents the system hardware/software requirements. The figure shows an HP-ProBook-440-GS laptop running an Ubuntu 16.04 Linux OS with an Intel Core i5-321OM, 8 GB Random Access Memory (RAM)

and a processor speed of 2.50 GHz. The HP Laptop runs all the software backend services as well as the NomadicBTS WebApp. The USRP B200 with the VERT900 antenna are also seen connected with the Laptop via a USB 3.0 cable. This setup allows the MSs to perform over-the-air communication with the NomadicBTS-2 platform.

The USRP Hardware Driver (UHD), OpenBTS and other software services (i.e. Asterisk, SIPuthServe and SMQueue) can be configured and monitored graphically with the NomadicBTS WebApp. The graphical interface provides a better user experience than the Command Line Interface (CLI) configuration approach. For instance, Figure 15 shows the configuration of OpenBTS for GSM

1800 MHz using the CLI. The huge list of commands and having to type them every time and read through several lines of text is obviously cumbersome for network administrators.

3. RESULTS

This section presents the performance testing results of the NomadicBTS-2, which include the link quality tests, accessibility (two-party call) test, the SMS and the billing tests.

A. Mobile Network Search

The NomadicBTS-2 experimental cellular platform demonstrates the lack of complexity in starting the network to begin service provisioning for mobile users. Two MSs were powered on, and a network search was carried out on the two MSs. The network initialization revealed that the two MSs could find and connect on the Broadcast Control Channel (BCCH) transmitted by the experimental cell as shown in Figure 16 (a). The Test PLMN 1-1 is the ID that was broadcasted by the NomadicBTS-2 cell. Furthermore, an identifier (MSISDN) was assigned to each of the MS by sending an SMS containing the desired number, which must be between 7-10 digits to a switching number - "101', as shown in Figure 16 (b). The number assigned to the Samsung MS is "2341001," and the number assigned to the Nokia MS is "2341002".

B. Measurement of Link Quality

The ubiquitous use of mobile devices in the terrestrial telecommunications network has been a major motivation for mobile network operators to always perform up-to-date network monitoring and optimization to improve the quality of service (QoS) provisioning for subscribers. However, many factors still militate against the overall performance of the network vis-à-vis poor coverage, interference, noise, low throughput, link failure, amongst others. The NomadicBTS is not immune to these ra-dio link problems because the medium of signal propagation is unguided, hence, power dissipates over a distance.

To analyse the behavior of the network, the link quality test was performed on each of the frequency bands. It is noteworthy that the quality of a radio link is best evaluated when the traffic channel is in use at a time instance on the network as shown in Figure 17. A dial tone call was initiated, and the chans command was executed to measure the link quality as the MS moved away from the NomadicBTS. For each time instance, an active channel was observed; the uplink signal-to-noise ratio (SNR) and received signal level (RXLEVEL) decreased with distance (fading), while the transmit power (TXPWR) of the NomadicBTS increased. The results show that the higher the SNR, the better the link quality, and the lower the SNR, the weaker the link quality.

Figure 14. Experimental Setup of NomadicBTS

Figure 15. OpenBTS CLI-based Configuration

(a)   (b)
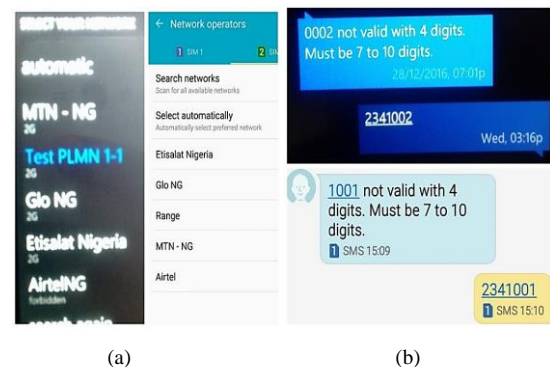
Figure 16. (a) Screenshot of Network search on the MSs, (b) Screenshot of MSISDN assignment to users

Figure 17. Channel characteristics at a time instance

TABLE 3.   LINK QUALITY SUMMARY FOR NomadicBTS.

Distance (m)	GSM 1800MHz			GSM 1900 MHz		
	Rxlevel (dBm)	TxPower (dBm)	SNR	Rxlevel (dBm)	TxPower (dBm)	SNR
1	-99	24	60.9	-92	6	59
2	-98	28	58.3	-97	8	48.8
3	-107	24	49.7	-88	10	37.9
4	-101	24	56.6	-94	18	57.4
5	-105	26	56.5	-101	22	63.6
6	-104	26	35.1	-104	26	45.7
7	-100	28	48.5	-101	28	50.2
8	-111	30	49	-103	30	60.5
9	-111	30	40	-108	28	53.8

Similar to the traditional complex GSM system, the link quality determines the quality of experience perceived by mobile users – call success rate and latency. Table 3 shows the link quality of the two frequency bands as the mobile station traversed the coverage range of the NomadicBTS.

The link quality test reveals the performance of the two bands - GSM 1800 MHz and 1900 MHz. First, the received signal power attenuates over distance; this is caused by the signal-variation in the test environment (indoor) as the transmitted signals suffer from reflection and scattering before reaching the destination. This behavior is similar in both bands, but more severe in the GSM 1800 MHz band, as shown in Figure 18. The relatively low RXLEVEL performance obtained stems from the fact that the transmit power of the NomadicBTS is designed for short-range communication, as observed in Figure 19 where the TXPWR is increased over a relatively small coverage (10 meters). Also, the GSM 1800 MHz does not provide an energy efficient transmission as high TXPWR is required for the entire communication, in contrast to GSM 1900 MHz where a low TXPWR is leveraged to give permissible voice transmission up to 5 meters of the coverage.

This is a comparative justification on the relationship between RXLEVEL and TXPWR in mobile communications as shown in Figure 18 and Figure 19 respectively. Another link quality metric is the SNR - the ratio of the signal power to the noise power. In mobile communications, the goal is to maximize the SNR for reliable data or voice transmissions [23]. The measurement of the SNR over a dedicated traffic channel reveals that the maximum signal power is stochastically distributed over distance as shown in Figure 20. The variation in the SNR is a function of the inherent channel noise caused by erroneous transmissions from other devices. However, since our approach is tailored towards exploiting the open-source technologies and SDR paradigm for short-range communication; in this study, the GSM 1900 MHz provides a more pragmatic solution leveraging the NomadicBTS.

C. Operation and Maintenance using NomadicGUI

As discussed in Section II, the web server responds to the user's requests, loads objects such as scripts, images, and logs from the machine's file system.
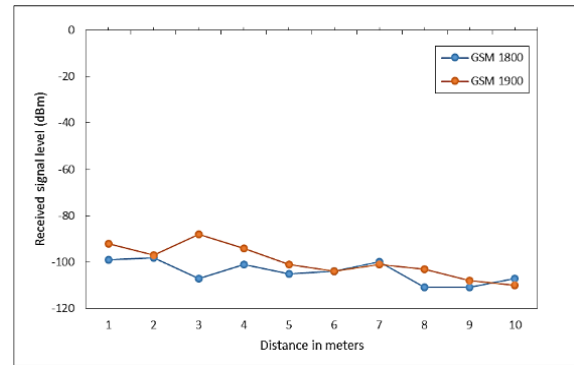

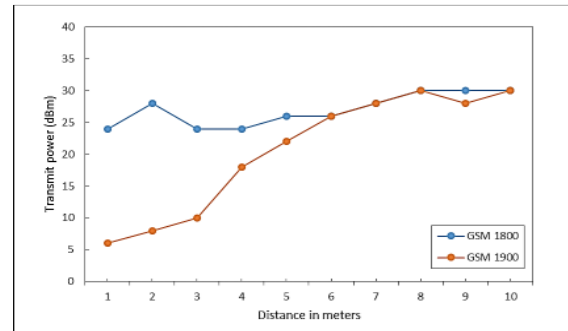Figure 18. Received signal strength measurement for the NomadicBTS

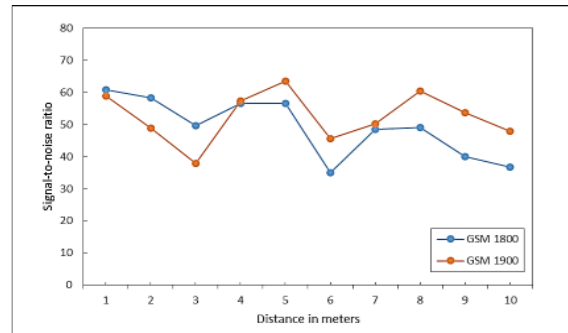Figure 19. Transmit power measurement for the NomadicBTS

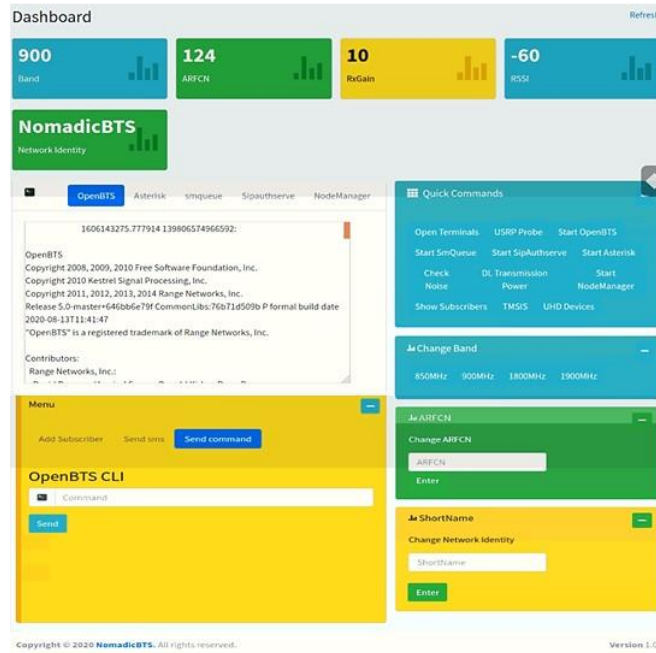Figure 20. SNR measurement for the NomadicBTS
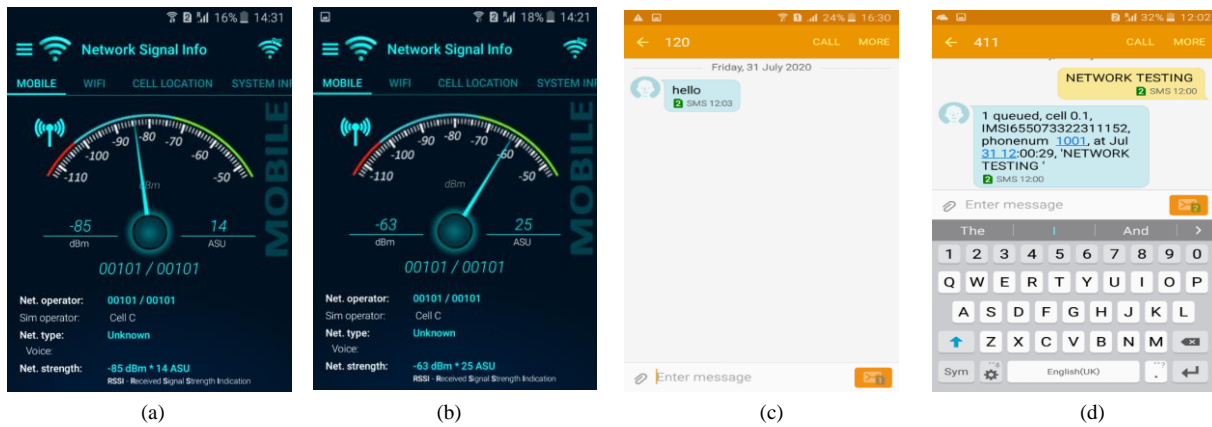
Figure 21. NomadicGUI frontend.

Figure 22. (a) RSS on GSM 1800, (b) RSS on GSM 1900 MHz, (c) SMS Test, and (d) Echo SMS Test
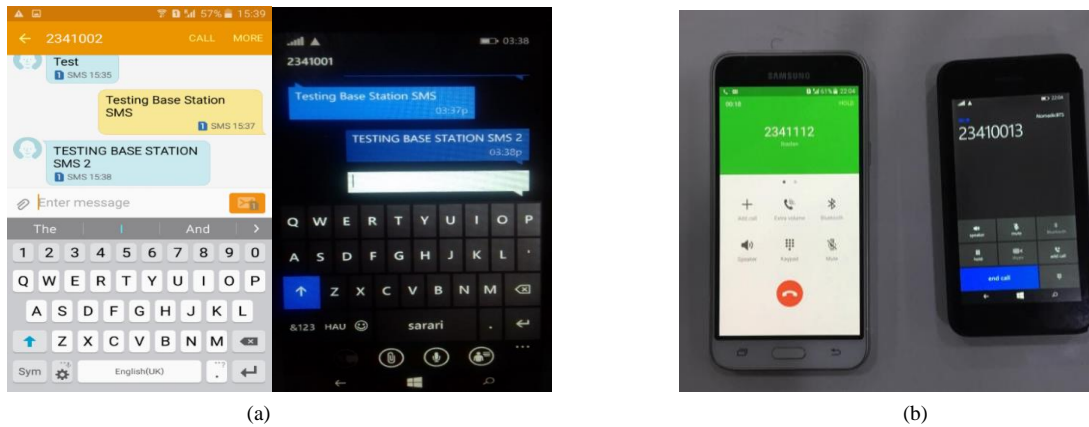
Figure 23. (a) Two-party SMS test (b) Two-party call test
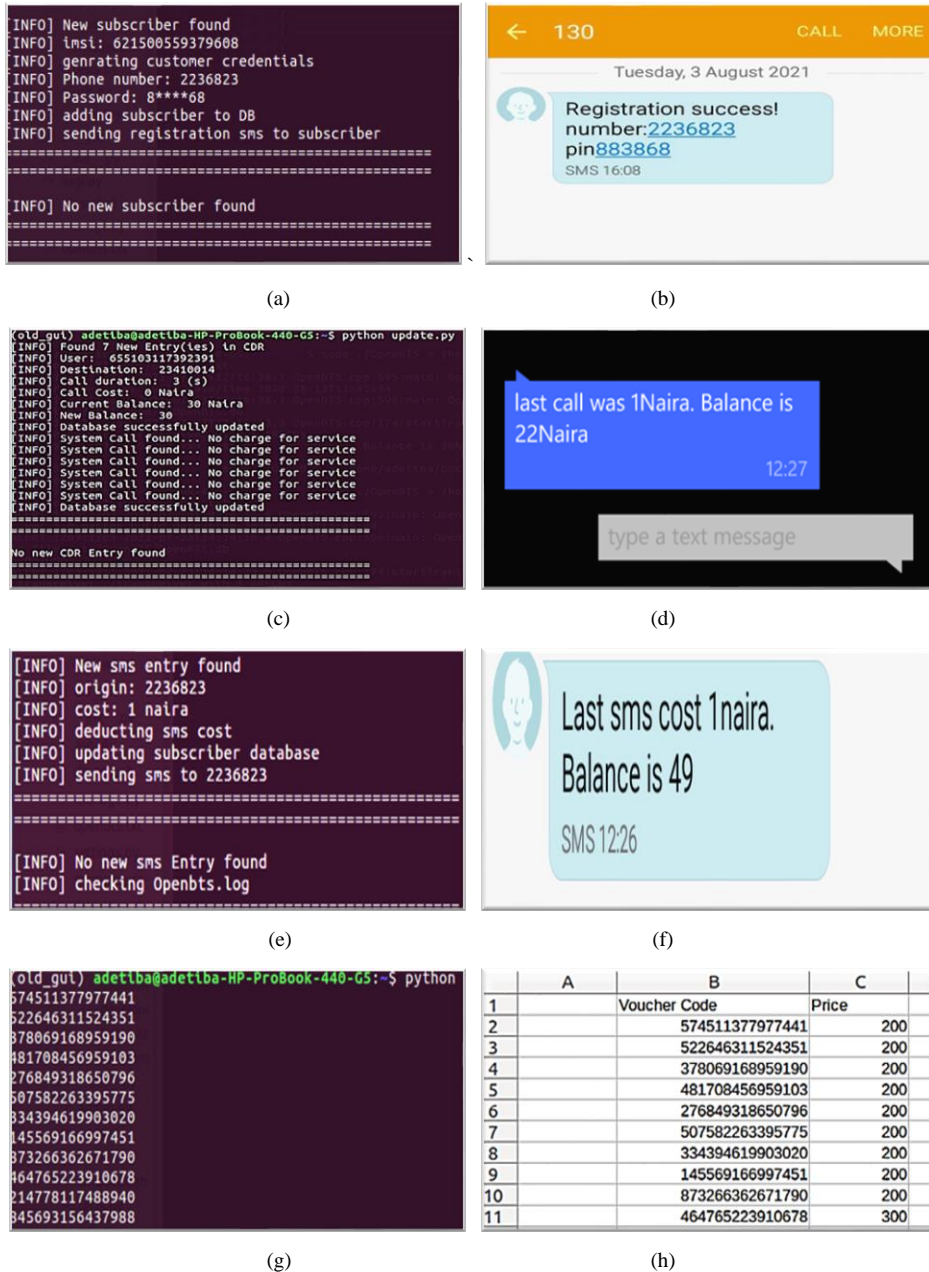
Figure 24. Screenshot of (a) the output of the registration script (b) SMS notification for a successful registration (c) the billing system (d) SMS showing the bill of a call (e) the output of the SMS billing script (f) SMS notification of new balance sent to the subscriber (g) the output of the voucher generation program (h) spreadsheet used to store the vouchers and their prices.

The frontend of the NomadicGUI application presents to the user a modern interface rendered by a web browser. The web interface is achieved by a combination of HTML, CSS and Javascript. These scripts are delivered to the web browser as response to requests made by the user as shown in Figure 21. The operation and maintenance of the NomadicBTS is carried out efficiently using the NomadicGUI application; the administrator or a support staff in real-practice case, is eased of writing multiple lines of network-level codes in the Ubuntu OS CLI.

D. Mobile Network Testing

The signal strength of the base station was monitored using the Network Signal Info Pro tool installed on the test phones. The signal strength was observed for the two frequency bands - GSM 1800 MHz and 1900 MHz. The received signal strength at a time instance when operating

on the GSM 1800 MHz and 1900 MHz, as shown in Figure 22 (a) and (b), are -85 dBm and -63 dBm respectively. For SMS routing and delivery, the SMSQueue was started, and SMS tests were performed. To confirm that the SMQueue works, a "hello" message was sent from the network to MS1 from the defined network switching number "120". The next test performed was the echo SMS. To perform an echo SMS, a message "NETWORK TESTING" was sent from the MS1 to a network switching number 411. The switching numbers are randomly generated for each session, and stored in the SMQueue, which echoes back whatever message it receives. The SMS test and echo SMS are shown in Figure 22 (c) and (d) respectively.

The MS-to-MS (two-party) communication flow shows good-level performance for the SMS tests, and call tests. This was carried out after assigning unique MSISDN to each mobile subscriber. For the two-party SMS tests, a message "Testing Base Station SMS" was sent from the MS1 to MS2, while a separate message "TESTING BASE STA-TION SMS 2" was sent from the MS2 to the MS1 as shown in Figure 23 (a), and for the call tests the two MSs exchanged communication over a period of 18 seconds, as shown in Figure 23 (b).

E. Billing System Performance

During customer registration, the Temporary Mobile Subscriber Identity (TMSI) database logs the International Mobile Subscriber Identity (IMSI) number of new users. The program adds this IMSI to the sip_buddies database, assigns a number to the sub-scriber, and generates a password for web app access. The program executed success-fully, populating the sip_buddies table and generating credentials. Figure 24 (a) and (b) display the process. Moreover, it acquires call details like origin, destination, and caller's balance. Channel monitoring is continuous, assessing active channels and IDs. This program verifies active channels' call origin and destination. It calculates call costs, deducts from client's balance, and sends SMS with new balance post-call. It ends calls on balance depletion. The call duration and 12 kobo/sec rate and notifying through SMS. Figure 24 (c) and (d) exhibit billing script output and SMS balance update.

This software manages SMS billing and fee deduction from subscriber balance. It successfully charged SMS senders based on call duration and a 1 Naira/SMS fee, then sent an SMS balance update. Figure 24 (e) and (f) showcase the SMS billing script output and balance update. The software also generates recharge numbers with various costs, deleting used vouchers. Figure 24 (g) and (h) display voucher generation and deletion.

4.   CONCLUSION

This study has presented a comprehensive overview of the NomadicBTS system, encompassing its design,

operational functionality, billing, and management through the utilization of the NomadicGUI (v1.0). The findings underscore the system's potential to effectively address the challenges inherent in mobile communication networks operating in rural and remote locations. While GSM remains the dominant wireless communication technology, issues like network congestion, base station damage, and base station unavailability have hindered the accessibility of fundamental telecommunication services. In this context, our innovative approach emerges as a solution that is not only cost-effective but also attuned to mobility requirements, offering a marked departure from traditional GSM architecture.

The significance of this approach lies in its adaptability and potential for widespread application. Telecommunication companies can leverage the insights provided in this research to deploy a scalable mobile Software-Defined Radio Base Transceiver Station (SDR-BTS) version. This streamlined and intuitive design facilitates implementation and holds the potential to revolutionize access to telecommunication services, particularly in areas where conventional infrastructure falls short. Additionally, governmental agencies and other stakeholders can readily adopt and expand upon this system, particularly in scenarios demanding swift and efficient communication solutions, such as ad-hoc or mission-critical situations. The demonstrated feasibility of this approach establishes a promising avenue for enhancing connectivity in underserved regions and contributing to the advancement of communication networks in challenging contexts.

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