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SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

Estimation and Analysis of Network Capacity under the Introduction of Mobile Banking: Case of Ethiopia

By

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa

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Declaration

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in this or any other university, and all sources of materials used for the thesis have been fully acknowledged.

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This thesis has been submitted for examination with my approval as a university advisor.

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Advisor's Name

Signature



Abstract

This thesis work is based on a value added cellular technology service called mobile banking (m-banking). Mobile banking is a term used for performing balance checks, account transactions, payments, credit applications via a mobile device such as a mobile phone. Since mobile banking is a new avenue in Ethiopia for bringing financial service to the unbanked, how the additional traffic generated by mobile banking will impact the existing telecom network by forecasting its traffic demand is done in this particular paper. Therefore by clearly understanding the mobile banking system and platform implementation, network capacity audit is performed for the existing telecom system against the additional capacity this service requires for the case of Ethiopia. So this way one can recommend the best business model or technology option that suits the country the most.

Network performance analysis and evaluation is normally done to keep subscribers satisfied with the delivered quality of service. In this thesis, the existing network is studied and evaluated whether or not it can handle the additional traffic introduced by mobile banking. Network performance audit for the radio access network is done using a comparative process with an initial baseline of Key Performance Indicator (KPI). The performance indicators used to evaluate the radio access network are: Traffic Channel (TCH) and Standalone Dedicated Control Channel (SDCCH).

The experience of several African countries was taken into account to create the scenarios used in this research due to the fact that previous work to bridge the two areas, i.e. mobile banking and network capacity hasn't been made in the country. For this study two sites in Addis Ababa are selected. One of the sites is considered to have a very high traffic volume or congestion rate and the other is with a moderate traffic



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volume. As a result, the impact of additional traffic demand that comes about with the introduction of mobile banking can clearly be seen. With this, using bearer technology option like short message service (SMS), unstructured supplementary service data (USSD) or SIM toolkit (STK) appear to fit in high load traffic area and on the other hand, interactive voice response (IVR) seems to suit areas with low traffic load considering the network infrastructure capacity on hand in the country.

Key Words: Mobile Banking; Network Performance; Erlang-B; TCH; SDCCH; SMS; IVR; USSD ;STK



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Abbreviations

ATM	Automated Teller Machine
BHCA	Busy Hour Call Attempt
BMS	Business Mediation Server
BSC	Base Station Controller
BSP	Bank Secure Platform
BTS	Base Transceiver Station
EFT	Electronic Funds Transfer
DTMF	Dual Tone Multiple Frequency
FACCH	Fast Associated Control Channel
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HLR	Home Location Register
HSM	Host Security Module
ITU	International Telecommunications Union
IVR	Interactive Voice Response
J2ME	Java to Micro Edition
KPI	Key Performance Indicator
LA	Location Area
MFS	Mobile Financial Service
mFSP	Mobile Financial service Provider

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MNO	Mobile Network Operator
MS	Mobile Station
MSC	Mobile Switching Center
OSG	Online Service Gateway
OTA	Over the Air
PCH	Paging Channel
PDA	Personal Digital Assistants
POS	Point of Sales
QoS	Quality of Service
RACH	Random Access Channel
RF	Radio Frequency
SACCH	Slow Associated Control Channel
SDCCH	Stand-alone Dedicated Control Channel
SIM	Subscriber Identity Module
SMS	Short Message Service
SMSC	Short Message Service Center
STK/S@T	SIM Application Toolkit
TCH	Traffic Channels
TRX	Transceiver
USSD	Unstructured Supplementary Service Data
WAP	Wireless Application Protocol

1. Introduction

Over the last decade, the mobile and wireless market has been one of the fastest growing markets in the world and it is still growing at a rapid pace. This opens up huge markets for financial institutions interested in offering *value added services*. With mobile technology, banks can offer a wide range of services to their customers such as money transfer while traveling, pay bills, receiving online updates of stock price or even performing stock trading while being stuck in traffic [1].

Mobile banking (m-banking) has emerged as an exciting new avenue for bringing financial services to the un-banked society, especially those in rural areas. The spread of mobile network in developing countries, along with the rapid growth in mobile phone subscribers (including substantial numbers of low income people), has given rise to innovative mobile banking programs, such as G-Cash and Smart Money in the Philippines, WIZZIT in South Africa, and M-PESA in Kenya and Tanzania [2], [3]. The rapid spread of mobile phones means that the number of mobile users may already exceed the number of banked people in many low income countries.

Mobile banking has revolutionized banking. For example, MPESA (“Pesa” is a Swahili word for cash, “M” is for Mobile) was first introduced in Kenya in 2005 by the Vodafone Group, targeting customers who did not have bank accounts. The banking infrastructure in Kenya is not well developed, and this lead to the implementation of MPESA, hoping that this would increase the number of locations where cash could be collected and deposited [3].

As stated above, the pivotal enabler for mobile banking is the rapid uptake in cellular coverage and mobile phone penetration in developing countries. As a consequence, the mobile phone has become the delivery channel to approach society in sub-Saharan Africa. Each mobile media channel has its strengths and weaknesses, so it is important to identify the delivery mode that is most appropriate for each banking service. Coverage measures geographic reach of mobile networks, or the area in which the mobile phone can pick up a signal. Penetration indicates the percentage of the population who are subscribers [4].

1.1 Literature Review

To the best of my knowledge, no thesis work has been done to bridge the two area that I have tried to study here i.e., mobile banking and telecom network capacity. Therefore, I endeavor to survey literatures that have been done for these two areas independently and tried to incorporate them for my thesis work.

On their journal, Barnes and Corbitt established the idea that recent innovations in telecommunications have enabled the launch of new access methods for banking services, one of these is mobile banking; whereby a customer interacts with a bank via a mobile device such as a mobile phone or personal digital assistant [3]. Karjaluoto et al. also found that there is vast market potential for mobile banking due to its *always on* functionality and the option to do banking virtually any time and anywhere [5]. Rao and Prathima [6] proposed for banks to expand their thinking about mobile banking beyond online banking and start to view mobility as one powerful and compelling delivery channel that can help deliver new value added services such as immediate access and additional control of personal finances to end users.

There have also been discussions on what really hinders the pace of spreading mobile services. Kumar [7] claim that it is because of the low data transfer speed and some other researchers claim that it lacks of quality services and others state business models are antiquated [8].

Regarding the capacity of a network, various attempts have been made to define it; the Erlang capacity, which has been used in telephony networks, is a probabilistic definition [9]. It specifies the arrival rate of calls that the system can allow so that the probability of blocking of calls on arrival is lower than some threshold. In giving another definition to capacity, which is more appropriate for wireless phone, declares that capacity is taken to be the rate of calls that the system can allow so that the probability that the quality of service not attained is sufficiently minimal. Here calls are not blocked when exceeding the limit of the system to provide the required quality of service.

Mas [4], Lyman, Pickens & Porteous [10] identified on their studies that there are a large number of different mobile phone devices and it is a big challenge for banks to offer mobile banking solution on any type of device. Some of these devices support java to mobile edition (J2ME) and others support wireless application protocol (WAP) browser or only Short Message Service (SMS); presetting a serious challenge.

Technical Information Bulletin (TIB) done by national communication systems in Virginia explains that SMS has also demonstrated as an alternative to voice communications [11]. However, it may be possible for extremely high volumes of SMS traffic, when combined with high numbers of voice call attempts, to interfere with a wireless network's performance. In this TIB multiple aspects of SMS technology, including wireless network reliability, capacity and congestion handling, security and vulnerability, priority services, and new SMS-related developments are demonstrated.

1.2 Statement of the Problem

Mobile banking has proved to be a rewarding venture in the developing world, where large parts of the population belong to the so-called "unbanked" [4]. In Ethiopia mobile banking technology providers such as BelCash and M-Birr have been setting up mobile banking and mobile money services for the last three years. With this at hand, it's predicted this companies will face several challenges in Ethiopia since half of the population is said to be illiterate, the telecom coverage in the country is far from perfect. The pressure on the telecom network will increase as the number of Ethiopians owning a mobile phone increase. In this research the available network capacity provided by ethio telecom and the availability and reliability of the communications network to meet the demand of mobile banking at sufficient quality of service levels will be analyzed.

1.3 Objective

1.3.1 General Objective

The main objective of this thesis is to evaluate and analyze the existing telecommunication network capacity under the introduction of mobile banking in Ethiopia.

1.3.2 Specific Objectives

Particularly, the thesis focuses on

- ✓ Studying mobile banking technologies and identifying mobile banking bearer technology options so that ethio telecom's current network capacity for the different technology options could be evaluated.

- ✓ Predicting how fast mobile banking technology will penetrate the population of Ethiopia so that one can determine if the required reliability and availability of the communication network by mobile banking could be met by the existing mobile network operator.
- ✓ Assessing the performance of the network based on the current network capacity, predicted number of subscribers for mobile banking, business model chosen and technology requirement.
- ✓ Drawing possible recommendation regarding the business model or the technology option that best suits the country.

1.4 Methodology

Various literature reviews on mobile banking technology, traffic engineering and wireless communication by different authors which help to understand the necessary theoretical background for the thesis work is made.

Traffic statistics data used for network evaluation purpose and site selection were collected from ethio telecom's network management system. Network performance audit to judge the network capacity and maintain QoS is done using a comparative process with an initial baseline of Key Performance Indicator (KPI). The performance indicators used to evaluate the radio access network are: Traffic Channel (TCH) and Standalone Dedicated Control Channel (SDCCH). The popular radio channel configuration model Erlang-B is used for traffic volume measurement. Afterwards, data analysis has been done to identify the limitations of the existing infrastructure.

1.5 Scope and Limitation

1.5.1 Scope of the Thesis

In this thesis a case study for Ethiopia regarding mobile banking technology is done. This paper should be able to point out how the possibility of rapid adoption of mobile banking simply makes it more important to consider risk factors upfront in two areas – the capacity of the mobile financial services providers (mFSP) own systems and the congestion on the mobile network operator (MNO) networks.

1.5.2 Limitation of the Thesis

Considering the fact that mobile banking is a new technology in Ethiopia, finding information related to area was challenging therefore it is the experience of other countries that is taken into account. On top of that, this thesis is done based on the data of existing GSM cellular network of Addis Ababa partially provided by ethio telecom. As a result, due to the unavailability of specific data concerning the number of subscribers and traffic distribution in the selected case study area, some of the parameters used for calculating the network capacity is roughly estimated which might affect the accuracy of the result obtained.

1.6 Contribution

In this thesis work my contribution will be,

- Study mobile banking architecture & parties involved to enable this technology in the context of Ethiopia.

- Predict the number of potential mobile banking subscribers depending on the experience of several African countries.
- Identify mobile banking bearer technology options and review ethio telecom's existing network capacity for the different technology options.
- Determine the network performance by considering the current capacity, technology requirement, business model chosen and number of estimated subscribers.
- Recommend the best business model and bearer technology for the adoption of mobile banking in Ethiopia so that it could be as extensive as it is for the case of Kenya.

1.7 Thesis Layout

The thesis work is done in such a way that it gives a clear flow and understanding regarding mobile banking. Chapter one presents the objectives, scope and limitation, methodology and a short introduction with problem explanation. Chapter two presents the theoretical fundamentals of mobile banking and background knowledge necessary for the study; and Chapters three and four focuses on mobile banking platform implementation and bearer technology options starting from mobile banking high level architecture. Chapter five is all about network traffic theory, fundamental air interface problems and radio access network capacity. The practical radio network performance audit analysis and evaluation of the different bearer technology options is done in Chapter six; and the results are presented with essential explanation. Finally, conclusions are given followed by points of recommendation and future work in Chapter seven.

2. Mobile Banking

Mobile banking is a revolution that is driven by one of world's fastest growing sectors, mobile communication technology. Mobile Banking refers to provision of banking and financial services with the help of mobile telecommunication infrastructure. The scope of offered services may include facilities to conduct bank transactions, to administer accounts and to access customized information [12]. In the broader sense mobile banking is an execution of financial services in the course of which within an electronic procedure the customer uses mobile communication techniques in conjunction with mobile devices [13].

Electronic banking, the execution of financial services via the Internet, changed the business of retail banks significantly at the same time reducing costs and increasing convenience for the customer. The ever-increasing spread of Internet-enabled phones and personal digital assistants (PDA) made the transformation of banking applications to mobile devices a logical development of electronic banking. Mobile banking is a subset of electronic banking which underlies not only the determinants of the banking business but also the special conditions of mobile commerce. [13].

2.1 Mobile Banking Services

One way to categorize the mobile banking services, gives two kinds of services, transaction based and enquiry Based. So a request for bank statement is an enquiry based service and a request for fund transfer to some other account is a transaction-based service. Transaction-based services are also differentiated from enquiry-based services in the sense that, they require additional security across the channel from the mobile phone to the banks data servers.

The other way to classify these services depending on the originator of a service session is the 'Push/Pull' nature. 'Push' is when the bank sends out information based upon an agreed set of rules, for example, your bank sends out an alert when your account balance goes below a threshold level. 'Pull' is when the customer explicitly requests a service or information from the bank; so a request for ones last five transactions statement is a pull-based service.

Banks offering mobile access are mostly supporting some or all of the following services:

Account Information

- Bank statements and checking of account history;
- Alerts on account activity or passing of set thresholds;
- Monitoring of term deposits;
- Access to loan and card statement;
- Insurance policy management;
- Pension plan management.

Payments & Transfers

- Domestic and international fund transfers;
- Mobile recharging;
- Commercial payment processing;
- Bill payment processing.

Investments

- Portfolio management services;
- Real-time stock quotes;
- Personalized alerts and notifications on security prices.

Support

- Status of requests for credit, including mortgage approval, and insurance coverage;
- Check (cheque) book and card requests;
- Exchange of data messages and email, including complaint submission and tracking.

Content Services

- General information such as weather updates, news
- Loyalty-related offers
- Location-based services

2.2 Mobile Banking Business Models

A wide spectrum of mobile/branchless banking models are evolving. These models differ primarily on the question that who will establish the relationship (account opening, deposit taking, lending etc.) with the end customer, the bank or the non-Bank/Telecommunication Company (Telco).

There are usually four main parties involved in mobile banking: financial institutions (FI), mobile network operators (MNOs), third-party providers, and different types of retail agents. The business models for these initiatives can be categorized in four groups (see Figure 2-1 below) that generally describe which actor is in control of the revenue from mobile money transactions:

- 1) Bank-led
- 2) Telco or MNO-led
- 3) Joint venture/partnership and
- 4) Third party-led

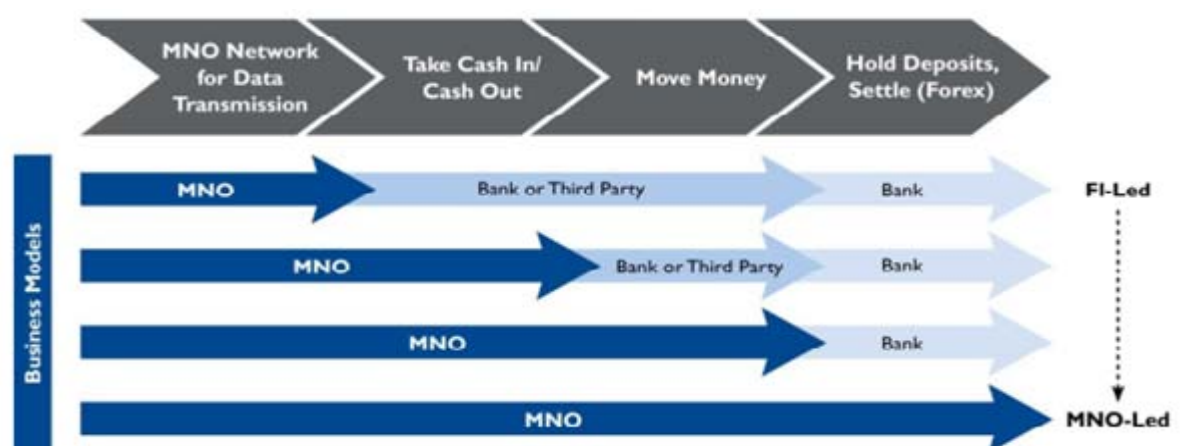


Figure 2-1: Mobile banking business models

These business models depend on the following critical factors: volume (capturing a large number of relatively small transactions); speed (generating momentum among users and merchants); and coverage (being able to use it anytime to send money to anyone, anywhere).

It is also important to distinguish between bank-based and nonbank-based models from a regulatory perspective. In bank-based models, clients have a direct contractual relationship with a regulated financial institution; in nonbank-based models, instead of a relationship with a supervised financial institution, the client deals with a nonbank, such as a Telco [14].

2.2.1 Bank-led Approach

In this model, a bank offers financial services to its clients using a mobile phone as the platform. This is the model seen most often in developed countries, though it has been used in some developing countries. It tends to be additive (i.e., not transformative), because clients reached in this model are usually existing bank customers [15].

There are a number of incentives for banks considering mobile banking: reducing costs by using technology, increasing the client base, improving client retention (through greater customer satisfaction), and remaining competitive with other banks that offer mobile banking. Additionally, an advantage for banks is that since it is already under the supervision of the regulator, it is familiar with key regulatory requirements. However, the bank-led model is based on the assumption that clients have bank accounts. This is its major constraint to expansion in developing countries. Currently it seems like this is the model being practiced in Ethiopia.

2.2.2 Telco-led Approach

The telco-led model is widely known and has significant potential for transformational impact because using mobile phones as a channel for financial services allows outreach to the millions of clients who have access to phones but not to bank accounts. In this case, the MNO may act as bank by providing mobile financial service, usually mobile money transfer, to its clients. This probably is the riskiest option yet potentially the most profitable since this model places the most regulatory responsibility on the MNO. Some of the challenges of the telco-led model arise in navigating the regulatory environment and developing a viable agent network [16].

The incentives for MNOs to offer m-payment services directly are based on four main advantages:

1. Reduced customer turnover or churn
2. Better brand positioning based on service creation and innovation
3. Distribution cost reduction
4. Additional revenues from mobile transactions

MNOs have also already established large distribution networks to sell air time to their low-income and rural clients, and they can leverage this to offer additional services. Most important, the business model of mobile operators is to make profits from a high number of transactions with low margins, which is the same model needed for successful mobile money initiatives.

The most prevalent mobile banking programs in developing countries are run by telecommunications companies commonly referred to as the “Telco-led” model [2].

Phone companies have the advantage of owning the cellular networks and Subscriber Identity Module (SIM), which gives them greater control over key technology components.

2.2.3 Joint Venture/Partnership Approach

Increasingly, large MNOs offering m-money platforms are also investing in developing joint venture agreements with banks to more rapidly increase the range of services and uptake of mobile financial service (MFS). This model is attractive to financial institutions because they can reach out to large numbers of mobile subscribers who are not necessarily bank clients [17]. Examples include Telenor and Tameer Bank (Pakistan), Orange and BNP Paribas, and Orascom and Ora Bank.

This model may be beneficial because it permits cost-sharing between the MNO and bank. It also allows both parties to leverage each other's strengths (e.g., an MNO's brand recognition and a bank's knowledge of regulations). However, the pure joint venture model also faces challenges, such as who owns the customers and other governance issues.

2.2.4 Third-Party Provider Approach

This model entails outsourcing some of the bank's or MNO's functions to a third-party service provider. An interesting feature of this model, particularly for donors, is that it is MNO and bank agnostic and therefore could be established as an interoperable, mobile banking system. Examples include PayPal or Obopay [16].

The main drivers for a third-party service provider are profitability and potential revenue. However, these firms face constraints, including high costs for technology infrastructure

and platforms, low or no brand recognition, and sometimes vague regulatory environments. Furthermore, questions have been raised about the long-term sustainability of third-party providers and this model.

Summary of the different business models is shown in Table 2-1 below.

	Third-party	Bank-led	Joint venture	Telco-led
Churn Reduction	No reduction in Churn as any MNO can offer the service	Reduction in churn	Definite reduction in Churn	Definite reduction in Churn
Regulatory and License Constraints	No impact	Low impact	Banks typically facilitate regulatory compliance	High regulatory and license requirements
Brand	Not used	Not used	MNO Brand	MNO Brand
Banking Systems	None required	Financial Switching	Some required	High infrastructure requirement
Distribution Chain for cash handling etc.	Not used	Not used	MNO and Bank	MNO only
Transactional Risk	None	Some	Half of the risk	All of the risk
Cost	Marginal	Some cost	High cost	Very High Costs
Revenue	Low	Good	High	High

Table 2-1: Mobile banking options

2.3 Mobile Banking Vendors

The delivery of a mobile banking service to a customer in general involves the participation of four primary players; A Bank, Mobile Network Operator (MNO), a Mobile Banking Technology Vendor, and the customer.

In most instances the mobile banking technology vendor has been the pioneer in shaping industry adoption and lobbying the other two principle stakeholder, bank and mobile network operator on the value of extending the banking franchise to mobile. The mobile Banking Vendor supplies the technology that integrates the mobile banking participants (MNO, banking systems, user applications, access channels) and facilitates the translation of the banking instruction from the customer's mobile phone to that of a financial message that can be understood by the banking systems [18].

The mobile banking vendors have also been the innovators behind mobile banking and have been doing mobile initiated transactions for around 10 years. Examples of this are Fundamo, Cointel (Simplus), SMART (GFG), and G-Cash (Utiba). Each being pioneers in their markets. The mobile banking vendors play an integral part in the delivery of mobile banking to the customer [18].

In summary, the Mobile Banking system Vendor facilitates the integration of the bank system with that of the MNO bearer channel, and provides the mobile banking platform or the mobile banking application, that enables the customer to bank using their mobile phone. The mobile banking vendor plays the pivotal role of integrating the bank and the MNO and technically delivering the application to the customer.

3. Mobile Banking Platform Implementation Options

Mobile banking is seen to be an extension to the existing bank payment infrastructure to mobile phones as a channel. This leverages the mobile network and its reach, to deliver banking services to customers. The mobile banking infrastructure, thus, sits in a similar technical environment to the banks automated teller machines (ATM), point of sales (POS), branch and internet banking service offerings.

A bank's core banking system, the system that houses the customer's account and related transaction management and history, would require a means to translate banking instructions, received from customers, through one of the bank channels such as ATMs or the internet, into a format that the core banking system can process. This translation is normally performed by an electronic funds transfer (EFT) channel switch [18]. The EFT channel switch would switch transactions from the channel to the appropriate area within the core banking system and this is depicted on Figure 3-1.

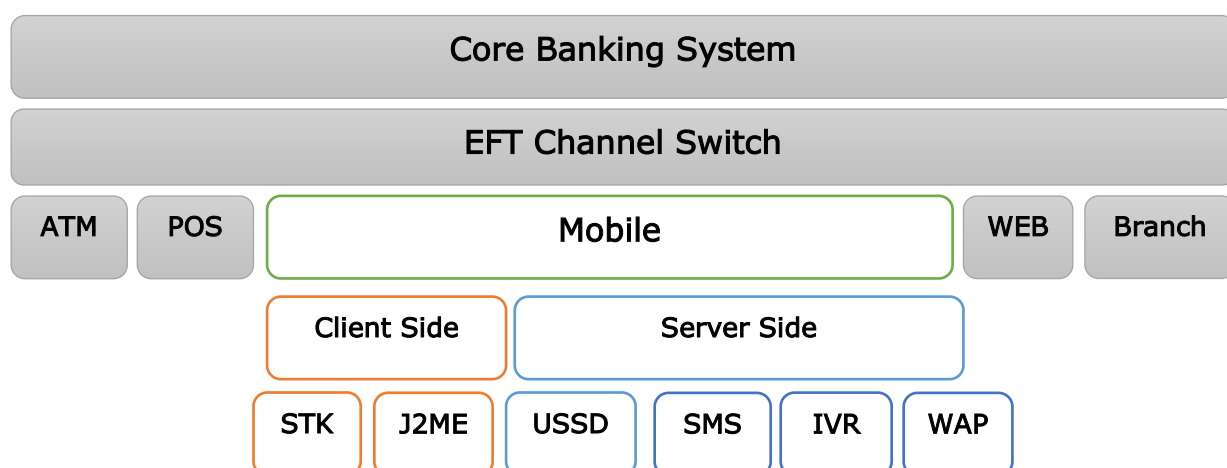


Figure 3-1: Mobile banking in the overall banking architecture

The mobile banking channel can be delivered to the customer through two bearer or application environments. Client-side applications are applications that reside on the customers SIM card or on their actual mobile phone device. Client-side technologies include java to micro edition (J2ME) and SIM application toolkit (STK/ S@T). Server-side applications are developed on a server away from the customer mobile phone or SIM card. Server-side technologies include unstructured supplementary service data (USSD), interactive voice response (IVR), short message service (SMS) and wireless application protocol (WAP).

The bank could choose from these bearer channels, or bearer channel strategies, for implementation depending on the regulator issue and the availability of network infrastructure in a country. However, in some markets it would be wise to implement more than one bearer channel in order to manage customer take up and the risk associated with non-take up of a specific technology. The selected bearer channel does not have an effect on where the mobile banking platform should sit [18].

An Electronic Funds Transfer, EFT, or Financial Switch accepts, translates and forwards transactions from multiple channels to the bank's core systems. This can sit within the bank or the bank's third party processor.

3.1 Levels of Mobile Banking Platform Implementations

The extension of the payment franchise to mobile can be as simple as a bank channel enablement or as complex as a complete bank system implementation depending on what infrastructure already exists, and that which can be re-used as part of the implementation [18]. The detail is provided in Figure 3-2.

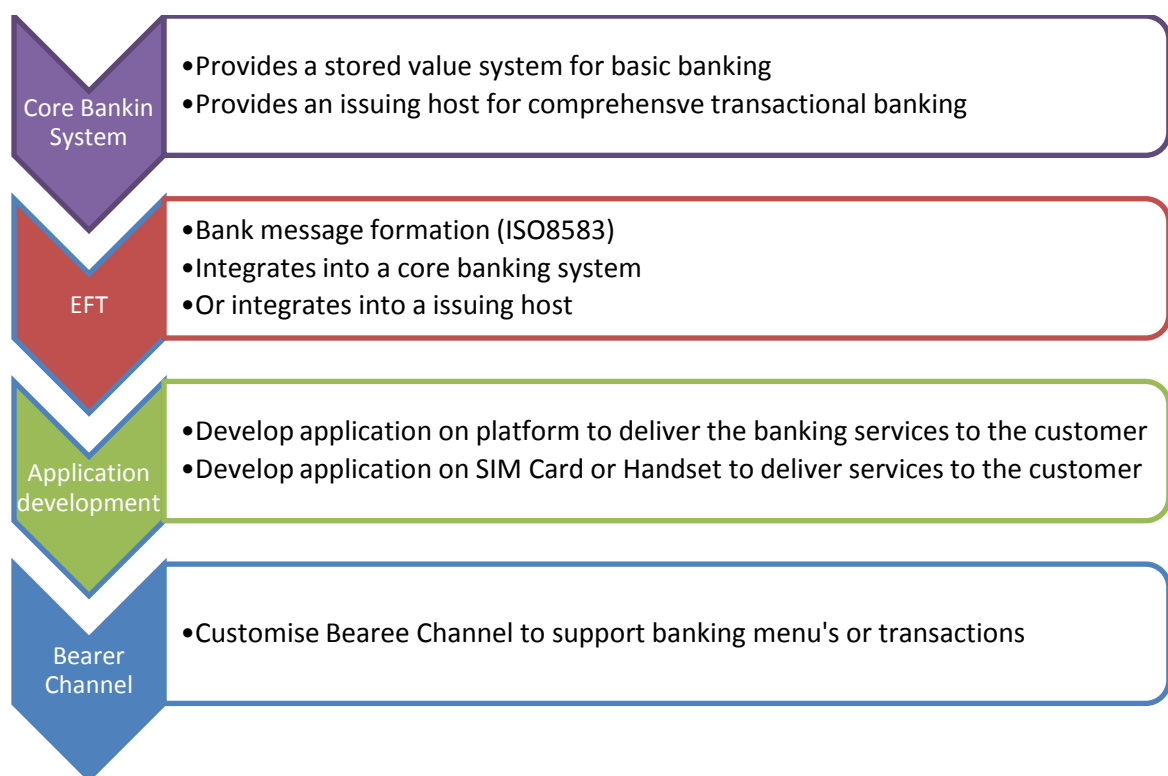


Figure 3-2: Mobile banking solutions layers in mobile banking enablement

3.2 Mobile Banking Platform High Level Architecture

If we look at a typical bank as one that already has a core banking system, then the mobile banking platform that the bank would use, or integrate with, would have the following components shown in Figure 3-3:

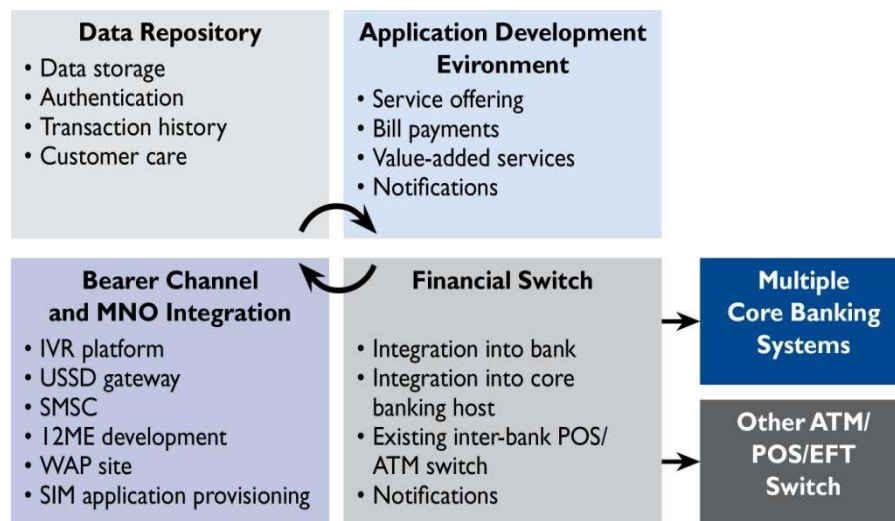


Figure 3-3: Components of a mobile banking platform

The diagram above reflects a mobile banking service. The service would require integration into an MNO to facilitate the usage of the network's bearer channels and in order to access the customer's mobile phone.

The data repository stores enough customer information, to facilitate the processing of financial transactions. The data repository would also house sufficient information to authenticate the customer in each transaction. By housing transactional and customer data, the repository would also facilitate customer care, and the reconciliation of certain financial transactions that use the application development environment to fulfill services e.g. selling airtime would require reconciliation between the transactions processed and the airtime loaded by the network operator [19].

The Application Development Environment facilitates the actual service development to the customer, such as banking menus and commands. It may house the integration of third parties in supporting value added services such as bill payments or airtime sales. The application development environment fosters the intelligence delivered to the customers handset, whether client or server side [20].

The Financial Switch would act as the interface to the bank's core banking system. Instructions collected by the application development environment through the MNO interface, and using data from the data repository, are translated through the financial switch into a transaction format that the bank can use.

3.3 Sample High-level Mobile Banking Architecture

Given that most vendors have similar mobile banking architectures, subsequent discussion are based on Gemalto's mobile banking system, a world leader in digital security. Gemalto, provides a comprehensive set of financial services alongside full mobile banking and security features [21]. Here it is used to explain components of mobile banking architecture in general.

Gemalto mobile banking is enabled in the mobile phone through a secure applet located in the end-user's SIM card as it's going to be explained in the following section. Secure transfers over the wireless network and financial transaction processing are managed by the SIM card and a distributed platform, deployed at the mobile operator's site and at the financial institution. The platform includes the following components: the Business Mediation Server (BMS), the Bank Secure Platform (BSP) and the Host Security Module (HSM). Additionally, an adaptor may be required to enable communication over non-standard interfaces to bank systems.

3.3.1 Mobile Banking Components

Gemalto's mobile banking architecture is shown in Figure 3-4 and it's discussed below. This way one can see requirement of mobile banking technology as a system and it could be replicated for the case of Ethiopia.

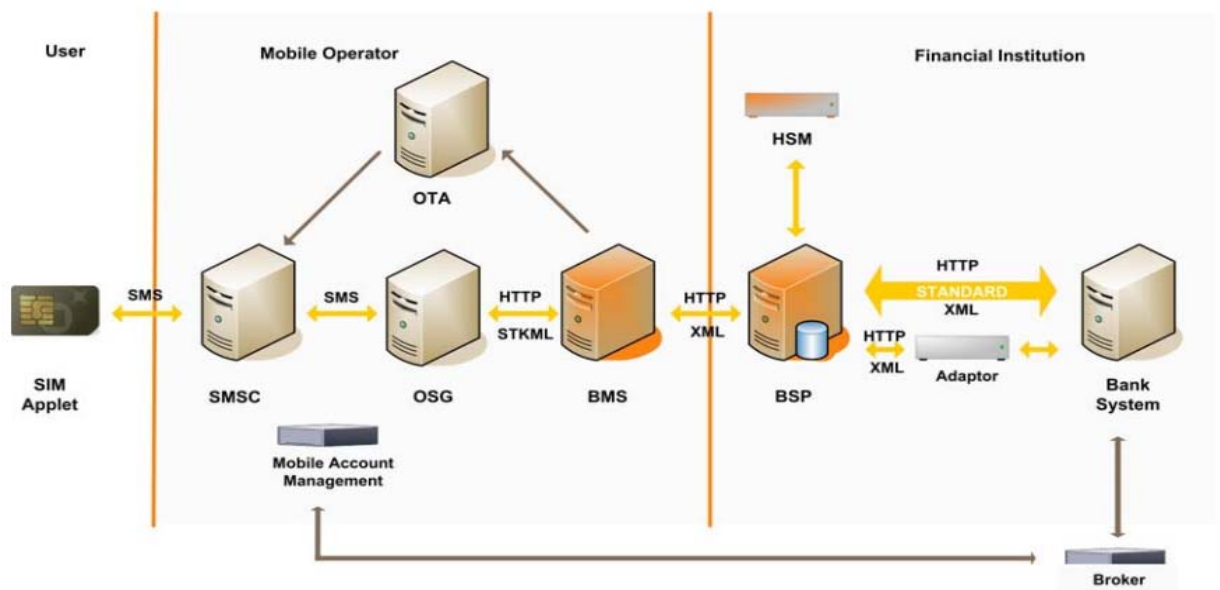


Figure 3-4: Mobile banking architecture

I. Secure SIM card Applet

The SIM card includes an applet with an intuitive graphic user interface (GUI) and security features that ensure the same level of security and confidentiality as if the operations were performed at the bank. The Secure Applet is pre-installed on the SIM card, readily available to the end-user. The applet:

- Formats and displays mobile banking menus and data
- Prompts the user for information and collects user input
- Generates transaction keys, ciphers sensitive information and signs data to be sent

- Provides the means for key management
- Sends banking requests using SMS messages

II. Business Mediation Server

On the operator's side, the business mediation server (BMS) ensures communication between mobile subscribers and financial institutions, and routes mobile banking transactions exchanged between the SIM card in the mobile user's phone and the bank secure platform (BSP) at the user's bank. The BMS:

- Receives subscribers' mobile banking requests, interprets them, formats and forward the requests to the subscribers' bank for processing
- Maintains the status of the requests
- Logs transaction results for auditing and billing purposes
- Receives the bank's responses and sends them to the SIM, via LinqUs online service gateway
- Maintains the list of financial institutions available on that operator's services

III. Bank Secure Platform

On the financial institution side, the business secure platform handles transactions between mobile users and the bank's systems. More specifically, the BSP:

- Facilitates communication between bank systems and end-users
- Hosts response templates
- Authenticates mobile customers
- Maintains connectivity between the wireless telecom world and the banking environment

- Ensures that financial transactions and customer data are secure, using the services of the Host Security Module.

IV. Host Security Module (HSM)

The host security module (HSM), a tamper-proof hardware component, provides state-of-the-art cryptographic functions to the BSP. Upon receiving a request from the BSP, it performs cryptographic operations, generating transaction keys, encrypting and decrypting sensitive information. The HSM also manages the cryptographic keys used to secure mobile financial transactions. The HSM is further enhanced with the mobile shield firmware for secure business transactions.

V. Adaptor

The Adaptor, required only when non-standard interfaces to the bank systems are used, is a customizable module that translates messages to and from the format used by the bank's back-end. The Adaptor seamlessly insulates the BSP from the specifics of the bank systems' interfaces.

Several operator-owned modules also participate in delivering the Mobile Banking functionalities:

VI. Online Service Gateway

Helps operators offer SIM card-based services to their subscribers by connecting them to remote content in a session mode. In the context of mobile banking, online service gateway (OSG) relays mobile banking messages between the mobile phone and the BMS and translates them from SMS to HTTP format.

VII. Over-The-Air

Over the air (OTA) is an optional component that offers operators the convenience of remotely provisioning and managing SIM cards.

VIII. Short Message Service Center

A short message service center (SMSC) is a standard global system for mobile (GSM) network element that delivers SMS messages.

3.3.2 Working Principles

Mobile banking components use standard protocols and interfaces to exchange information and to communicate with other network elements and bank systems, thus facilitating the integration of Mobile Banking into the existing infrastructure.

A high-level view of the protocols used to exchange messages between different mobile banking, operator and bank components to process a request is as follows [21]:

- The SIM card sends mobile banking requests using SMS (S@T protocol) messages;
- OSG translates these messages into HTTP requests before sending them to the BMS;
- The BMS forwards the HTTP requests to the BSP of the selected bank;
- The BSP interacts with the HSM for the cryptographic operations;
- The BSP communicates with the bank's systems, possibly through an adaptor, using a series of web services;
- The bank system (or adaptor) responds;
- BSP ciphers the necessary information (using the HSM) before proceeding;

- The BSP forwards and formats the response and then sends it to the BMS;
- The BMS sends the response to the OSG;
- OSG compiles the response and sends it to the SIM using the SMS channel.

3.4 Mobile Device

The kind of handset used in a country impact the adoption of mobile banking. If one offers application based mobile banking that means, only those people with advanced mobile can use the service leaving users with standard handset unmerited. The handset consists of several layers of components [19] as shown in Figure 3-5.

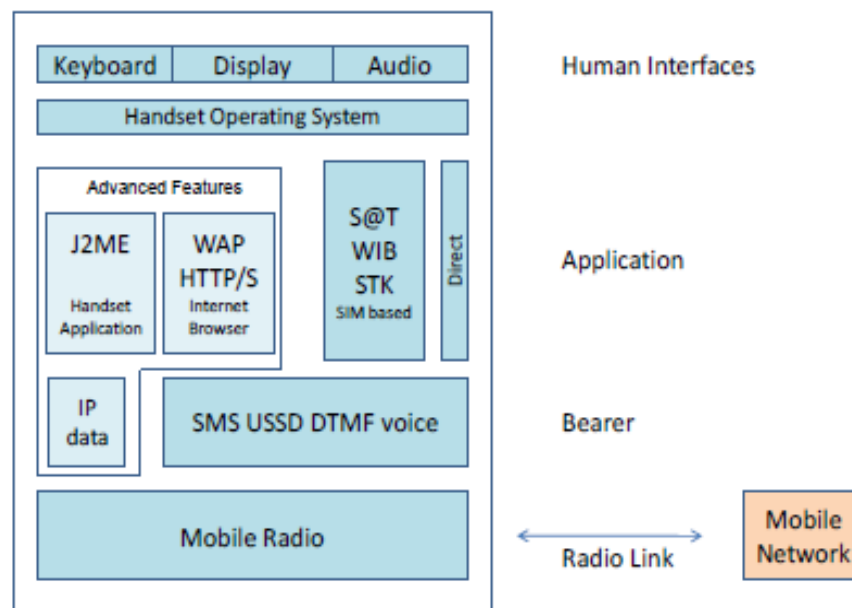


Figure 3-5: Elements of the mobile handset

- I. **Standard handsets** are plain ordinary devices that contain:
- A mobile radio to communicate to the mobile network

- The capability to send Voice, SMS, unstructured supplementary service data (USSD), and dual tone multiple frequency (DTMF) over the radio interface
- An operating system that ties all the elements on the handset together
- Human interfaces for audio (speaker and microphone), a keyboard and a display
- At the Application level the standard handset passes the SMS, USSD, DTMF and voice directly between the display, the keyboard and the audio human interfaces and the bearer services. A capability to interface via SIM toolkit to SIM based applications also exists.

Standard handsets do not provide:

- Facilities to secure or encrypt data before sending it to server based applications at mFSPs
- Ability to run programs on the handset.

II. Advanced handsets fall into two sub-types:

Feature phones– handsets that have browsers and J2ME environments.

They are usually locked down, in that they do not have easily accessible programming environments and often are MNO controlled in what software they may run.

Smart phones– handsets with programmable environments.

Operating systems such as Symbian, Windows Mobile and Mobile Unix (iPhone) and Android are used. The handsets typically can perform full function Internet browsing. Examples of these phones are HTC, iMate, Apple iPhone etc. Advanced handsets provide facilities to secure data. This security is provided by the browsers and J2ME environments on the phones. Application based data security can also be provided on the advanced handset using the SIM.

4. Bearer Technology Options

This section addresses the front-end component or customer-facing mobile banking technologies. This component of the end-to-end mobile banking value chain is typically supplied or customized by either a mobile banking vendor or the specialized technology unit within a bank. These mobile banking technologies can be categorized into two environments: Server-side and client-side technologies.

These customer-facing technologies have differing characteristics and processes. Each of these technologies requires that the customer register or activate the application with the bank/MNO/vendor offering the service in the market.

This registration process is defined by the service provider and serves as an initial identification of the customer to ensure ongoing trust in, and security of, the transaction. There are numerous methods of registering or activating customers in existence, all of which require the endorsement of the bank offering the service [22]. Customer registration often creates a barrier to customer adoption, but serves as a necessary step in the process of eliminating fraud and potential transactional risk in the offering (as well as being a regulatory requirement).

4.1 Server-side Technologies

Server-side technologies are those applications built on a server, away from the customer's SIM or Mobile handset [19]. Examples of server-side technologies would be short message service (SMS), interactive voice response (IVR), unstructured supplementary service data (USSD2) and wireless application protocol (WAP).

In server-side applications, customer data that enables the processing of transactions, such as account/card details, are typically stored in a secured environment, on a server at a bank or at their allocated service provider/vendor.

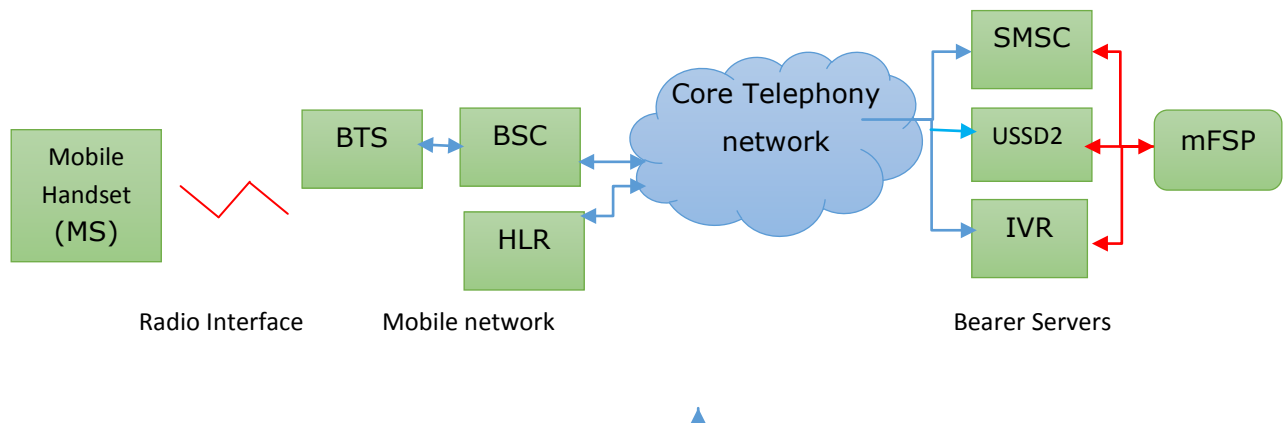


Figure 4.1: The mobile channel for SMS, USSD and IVR

4.1.1 SMS Banking Solutions

SMS uses the text-messaging standard to enable mobile application based banking. The way this works is that the customer requests for information by sending an SMS containing a service command to a pre-specified number [22]. The bank responds with a reply SMS containing the specific information as shown in Figure 4-1.

SMS allows users to send and receive text messages on a mobile phone using the numbered keypad on the handset to input characters. Each message can be up to 160 characters long and sent to and from users of different operator networks. All mobile phones available today support SMS.

In addition to the person-to-person SMS, a large variety of content-based texts messaging services are available. The majority of GSM operators offer users the ability to subscribe to services that send news, sport and entertainment content direct to a mobile phone in the form of an SMS [18].

SMS banking requires a registered customer to initiate a transaction by sending a structured SMS (SSMS) message to the mobile banking service. This SSMS requires a tag word identifier to instruct the SMS gateway to submit the message to the correct SMS application. A tag word is the first word in the SSMS.

The balance of the SSMS would hold the instruction from the customer to the mobile banking application.

E.g.: *'bank_transfer_cheque_savings_100.00_PIN'* for a transfer from a cheque account to a savings account of an amount of 100.00.

In the example above, SSMS would be sent to a SMS short code or address (a shorter version of a phone number). The SSMS would pass from the customer's handset through the GSM Network to the MNO Short Message Service Centre (SMSC).

A SMSC stores and forwards the SSMS to the SMS Gateway allocated to the short code used by the Mobile Banking Service Provider. The Mobile Banking Service Provider would use the customer's mobile number, forwarded by the SMSC with the SSMS, to identify the customer and respond to the customer's request. The response would follow the same return path and, in the examples given above, would respond to the customer with an SMS confirmation message. E.g. 'Transfer from cheque to savings of 100.00 successful'.

4.1.2 Interactive Voice Response

Interactive Voice Response (IVR) service operates through pre-specified numbers that banks advertise to their customers. Customer's make a call at the IVR number and are usually greeted by a stored electronic message followed by a menu of different options. Customers can choose options by pressing the corresponding number in their keypads, and are then read out the corresponding information, mostly using a text to speech program [19].

In telephony, interactive voice response, or IVR, is a phone technology that allows a person, typically a telephone caller, to select options from a voice menu and interact with the phone system. A pre-recorded voice prompt is played and the caller presses a number on a telephone keypad to select an option, e.g. "press 1 for yes, press 2 for no". Speech recognition can also interpret the caller's simple spoken answer such as "yes", "no", or more complex words, sentences and business names or a number as a valid response to the voice prompt.

DTMF signals (entered from the telephone keypad) and natural language speech recognition interpret the caller's response to voice prompts. DTMF is a tone signaling scheme often used for various control purposes via the telephone network, such as remote control of an answering machine. GSM supports full-originating DTMF. IVR is the oldest form of customer-facing mobile banking technology. IVR has been used prior to the existence of mobile phones in the form of telephone banking and is still in use today. IVR requires a registered customer to make a call to a published telephone number and be answered by a pre-recorded voice that presents various menu options to the customer [23].

The IVR system would then take the necessary instructions from the customer by recording the tones of the number selections that the customer enters on the key pad, or through spoken commands, and creates an instruction that is given to the service provider/bank.

The service provider would use the customer's mobile number forwarded by the network operator to identify the customer and as a factor of authentication. The channel can be used by any mobile device and any customer capable of making a call. The service provider is required to have an IVR system.

IVR systems are user friendly but may prove expensive to maintain and expensive to the customer who needs to make what can be a relatively lengthy call. Of course, this is dependent on who pays, depending on whether it is a free phone number or not.

4.1.3 Unstructured Supplementary Service Data

In its simplest definition, unstructured supplementary service data (USSD) is a menu driven form of SMS where a customer would receive a text menu on their phone as

opposed to a string of words. USSD is a data bearer channel in the GSM network [19]. Like SMS, it transports small messages of up to 160 characters between the mobile handset and the network. Unlike SMS, which is 'store and forward', USSD is session-based and can provide an interactive dialog between the user and a certain set of applications. In other words, both sides of the dialogue happen during a session whereas an SMS based interaction is broken into each segment of communication between the client and the service.

USSD1 only allows one way communication to the network, USSD2 allows two way communications between the user and the network. With USSD1, the interaction between the user and the service would be broken into each communication segment, much like SMS. With USSD2 it would be held in the same session and allow for a flowing conversation between the user and the service.

USSD requires no pre-configuration on the customers SIM or handset and is already built into most GSM networks. An example of a USSD string would be *120*2265#. 2265 spells bank and therefore could be marketed as *120*bank#. Once the customer has entered, and dialed the USSD string, the customer's request for the service would be passed through the network to the USSD gateway at the MNO, which in turn would recognize who the service provider/bank was and forward the request to that service provider [24]. A text based menu similar to the one below could be used: *Welcome to BANK, reply with:*

- 1. for balance enquiries*
- 2. for inter-account transfers*
- 3. for person to person payments*
- 4. for bill payments*
- 5. for airtime top up*

The customer would receive this menu on their screen, press the reply button on their phone and enter the number of the option that they required.

4.1.4 Wireless Application Protocol

WAP uses a concept similar to that used in Internet banking. Banks maintain WAP sites which customer's access using a WAP compatible browser on their mobile phones. WAP is best described as the internet on a mobile phone. WAP is an open international standard for applications that use wireless communication. Its principal application is to enable access to the Internet from a mobile phone or PDA [22]. Figure 4.2 below shows WAP as a mobile channel.

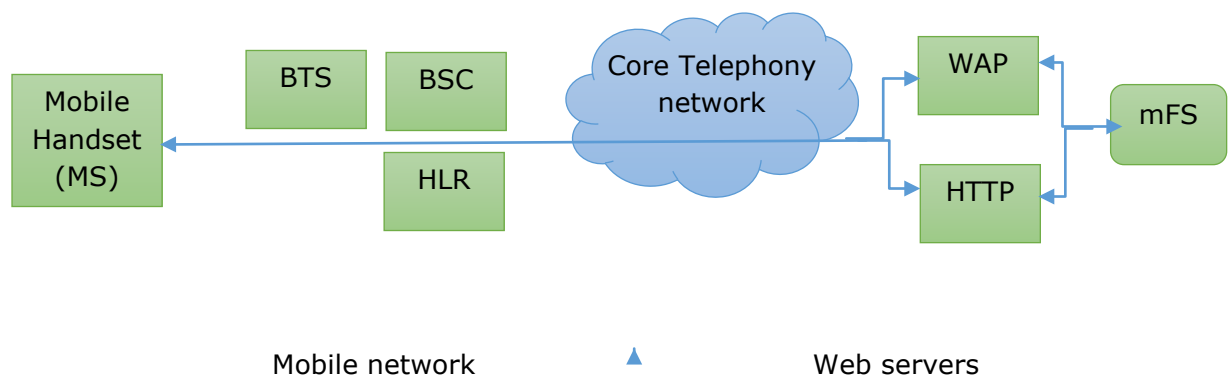


Figure 4-2: The mobile channel for IP data browsing

A WAP browser provides all of the basic services of a computer-based web browser but is simplified to operate within the restrictions of a mobile phone. WAP is now the protocol used for the majority of the world's mobile internet sites, known as WAP sites. Mobile

internet sites, or WAP sites, are websites written in, or dynamically converted to, Wireless Mark-up Language (WML) and accessed via the WAP browser [25].

WAP or mobile internet banking offers a customer a similar experience to that of internet banking. The customer would browse to a mobile internet site by accessing the WAP browser on their mobile phone and entering the website address. The actual banking application resides at the bank and is secured and monitored in the same way as an internet banking website.

The mobile phone and bearer general packet radio service (GPRS) is used to display or transmit the data between the customer and the bank. A customer's handset would need to be capable (functionality developed/loaded by the handset manufacturer), and have the right configuration (provided by the MNO), in order to support WAP Banking. MNOs often segment this functionality to post-paid customers only.

4.2 Client -Side Technologies

Client-side technologies are those applications, solutions and service offerings built or embedded on a customer SIM or mobile handset. Examples of client-side applications are S@T and J2ME (JAVA). In client-side applications, customer data is typically stored on the application, or entered by the user, and encrypted by the application in the SIM or handset.

4.2.1 Java to Micro Edition

Java 2 Micro Edition (J2ME) is a feature that allows the device to run small, user-installable software applications written especially for mobile devices such as phones [24]. J2ME requires a phone that can support the GPRS to download the initial

application, assuming the phone is not pre-provisioned with the application. The phone would have to also have enough memory capability to support or house the application, and sufficient graphic ability to display the application.

Once installed on the phone, the application would use GPRS, USSD or SMS to carry the customer data or instruction from the device to the service provider. This can be in an encrypted format. The J2ME environment can be MNO agnostic in that the application can be downloaded and used across any MNO that supports mobile internet.

The user experience is similar to that of a web site and brings the same content and graphic rich benefits of the internet to the mobile phone. But the application can impact the customer in the initial download process due to their phone not being provisioned properly by the handset manufacturer or their GPRS capability not being enabled at the network. These barriers affect all client-side applications.

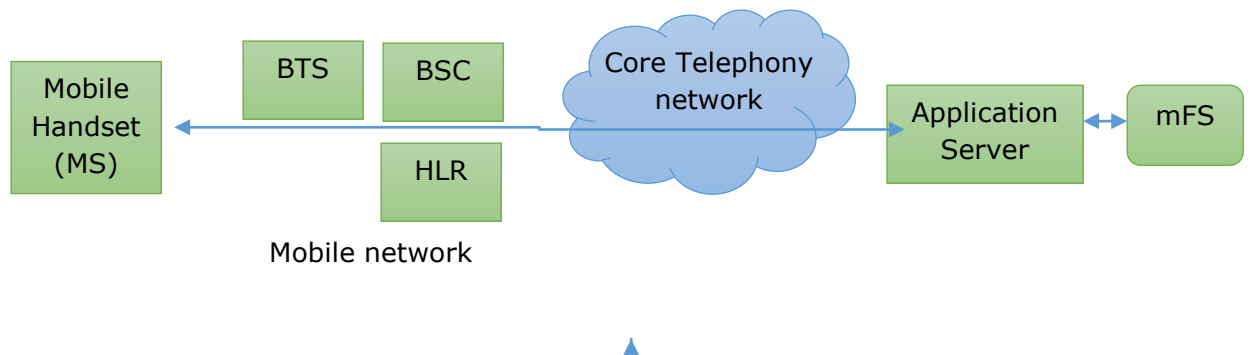


Figure 4-3: The mobile channel for IP data applications

A customer would browse through his phone menu until they find the J2ME application, select and launch the application, and follow the JAVA browser menus to complete a transaction. The data is typically encrypted prior to leaving the handset and being sent to

the service provider or bank. Once received, the service provider or bank would decrypt the message and process the customer's instruction. J2ME applications can be pushed to the mobile phone by a service provider or downloaded by a customer by accessing the service provider's mobile internet site.

4.2.2 SIM-based Applications

The SIM Application Toolkit (SAT/S@T) allows for the service provider or bank to house the customer's mobile banking menu within the SIM card. The SIM Application Toolkit (commonly referred to as STK) is a standard of the GSM system which enables the SIM to initiate actions which can be used for various value added services [20].

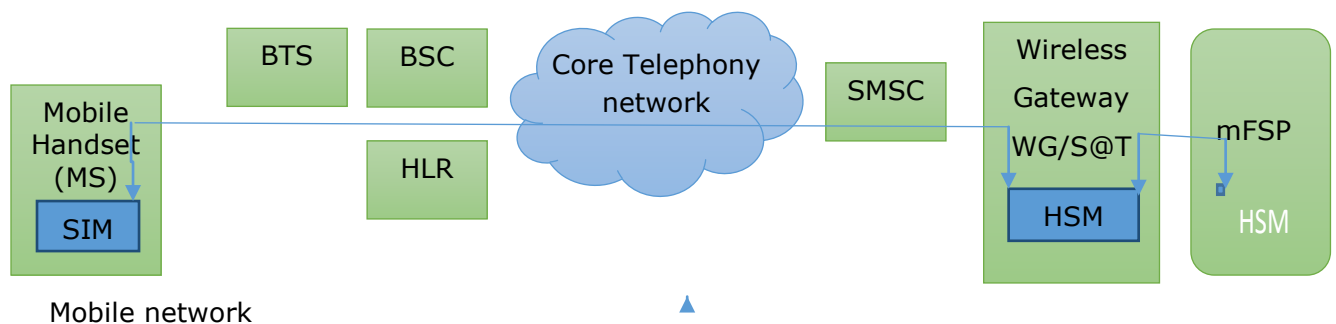


Figure 4-4: The mobile channel for SIM toolkit

The SIM Application Toolkit consists of a set of commands programmed into the SIM card which define how the SIM should interact directly with the outside world and initiates commands independently of the handset and the network. This enables the SIM to build up an interactive exchange between a network application and the end user, and access

or control access to the network. The SIM also gives commands to the handset, such as 'display menu' and 'ask for user input'. STK has been deployed by many mobile operators around the world for many applications, where a menu-based approach is required, such as mobile banking and content browsing [26].

The challenge in SIM based applications is getting the application onto a SIM card that already exists in the market. The service provider has the option of sending the application over the air (OTA), which entails the delivery of several encrypted SMS messages that self-configure the application on the SIM or provisioning a new SIM card with the application already embedded within the SIM [27]. The latter has an economic impact on the network operator and the existing customer in that the customer would have to obtain a new SIM card in order to use the application. Once the application is on the SIM, instructions from the customer can be entered, encrypted, and transported by SMS to the service provider or bank.

There may be difficulty in upgrading or making changes to the application on the SIM as the customer would have to re-provision the application in a process similar to that described above; or the network operator would have to re-load the application over the air to each and every SIM card each time they make a change to the application.

A benefit of SIM based applications is the ability of the network operator or bank to own a piece of the real estate on the SIM Card. Since the SIM card is provided by a specific MNO, this ensures the prevention of churn for that MNO, and ensures that the bank's specific application is on the SIM and therefore provides similar benefits to the bank.

Business considerations will likely drive the choice by mFSP of one (or more) of these technology options discussed above. The associated risks while using these technologies is summarized in Table 4-1 below [19].

Bearer Technology Options

Approach	Technologies	Associated Risk
Available		
"Use what is there" Use existing generic mobile bearer services provided on all phones accessible directly by a user	SMS Voice/IVR USSD	There is no encryption of information so the channel from the mobile to the mFSP is open to monitoring, replay, Modification & impersonation
"Use mobile browsing services" that are provided on phones – not MNO dependent	HTTPS = normal web browsing WAP phase 1 WAP phase 2	Same risks as for a PC on the Internet. Channel is less exposed than regular Internet as much of it is within MNOs
"Use advanced application services" provided on phones – not MNO dependent	J2ME	Same as client side applications on PCs. Mobiles less exposed to the Internet and the threats. However issues around the trust (integrity and authenticity) of the applications exist and need to be managed
Use a secure environment on the mobile provided by the MNO or MNOs	SIM Toolkit, S@T and Java cards	The highest technical end-to-end security as the application runs securely within the SIM and the encryption keys are kept within the SIM.

Table 4-1: Associated risks with the bearer technologies

5. Traffic Analysis

5.1 GSM Overview

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard. Throughout the evolution of cellular telecommunications, various systems have been developed without the benefit of standardized specifications. This presented many problems directly related to compatibility, especially with the development of digital radio technology. The GSM standard is intended to address these problems. Today, GSM is the most popular mobile radio standard in the world [28].

GSM became popular very quickly because it provided improved speech quality and, through a uniform international standard, made it possible to use a single telephone number and mobile unit around the world. The European Telecommunications Standardization Institute (ETSI) adopted the GSM standard in 1991 [28].

5.2 GSM System Architecture

This section briefly describes the functionality of the various components of GSM architecture. A GSM network can be divided into three groups (see Figure 5-1): The base station subsystem (BSS), network and switching sub system (NSS) and the operation management subsystem (OMS) [29].

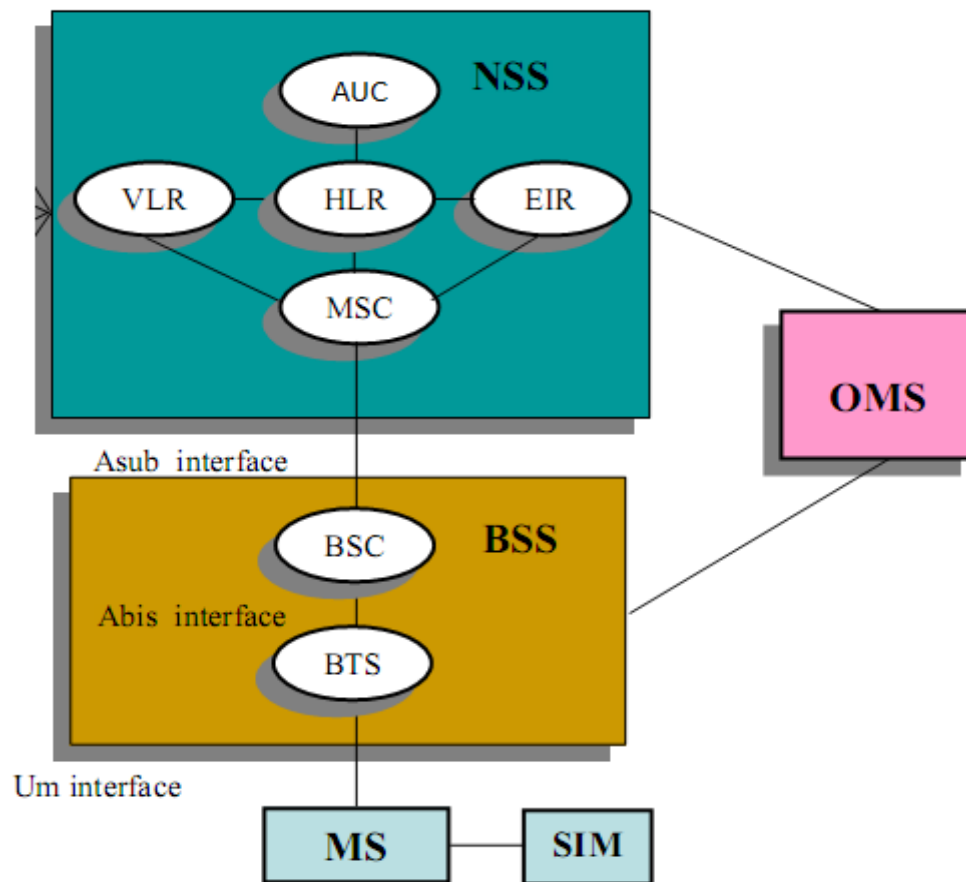


Figure 5-1: GSM network elements

Mobile Station - A mobile station (MS) may be referred to as a 'handset', a 'mobile', a 'portable terminal' or 'mobile equipment' (ME). It also includes a subscriber identity module (SIM) that is normally removable.

Base Station Subsystem

All radio-related functions are performed in the base station subsystem (BSS), which consists of base station controller (BSC) and the base transceiver station (BTS).

Base Transceiver Station: The BTS handles the radio interface to the mobile station. The BTS is the radio equipment (transceivers and antennas) needed to service each cell in the network. A group of BTS is controlled by a BSC.

Base Station Controller: The BSC provides all the control functions and physical links between the MSC and BTS. It is a high-capacity switch that provides functions such as handover, cell configuration data,, and control of radio frequency (RF) power level in BTS. A number of BSCs are served by an MSC.

Network and Switching Subsystem

NSS is responsible for performing call processing and subscriber-related functions. The switching system includes the following functional units:

Mobile Switching Center (MSC): The MSC performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It provides all the functionality needed to handle a mobile subscriber. The main functions are registration, authentication, location updating, handovers and call routing to a roaming subscriber. The signaling between functional entities (registers) in the network subsystem uses Signaling System 7 (SS7).

Home Location Register (HLR): HLR is a database used for management of mobile subscribers. HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. One HLR can serve several MSCs.

Visitor Location Register (VLR): Contains the current location of the MS and selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled

by the VLR. A VLR is connected to one MSC and is normally integrated into the MSC's hardware.

Authentication Center (AuC): A protected database that holds a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and encryption over the radio channel. The AuC provides additional security against fraud. It is normally located close to each HLR within a GSM network.

The equipment identity register (EIR): The EIR is a database that contains a list of all valid mobile station equipment within the network, where each mobile station is identified by its international mobile equipment identity (IMEI).

Operation and Maintenance Center (OMC)

The OMC is a management system that oversees the GSM functional blocks. The OMC assists the network operator in maintaining satisfactory operation of the GSM network. Hardware redundancy and intelligent error detection mechanisms help prevent network down-time. The OMC is responsible for controlling and maintaining the MSC, BSC and BTS.

5.3 The Air Interface

The air interface for GSM is the interface between the mobile stations and the base station known as the Um interface. Since radio spectrum is a limited resource shared by all users, a method was devised to divide the bandwidth among as many users as possible. The method chosen by GSM is a combination of time- and frequency-division multiple access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25 MHz allocated bandwidth into 124 carrier frequencies spaced 200 kHz

apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The fundamental unit of time in this TDMA scheme is called a burst period and it lasts approximately 0.577 ms. Eight burst periods are grouped into a TDMA frame (approximately 4.615 ms), which forms the basic unit for the definition of logical channels. One physical channel is one burst period per TDMA frame. Logical channels are discussed on the next section [28].

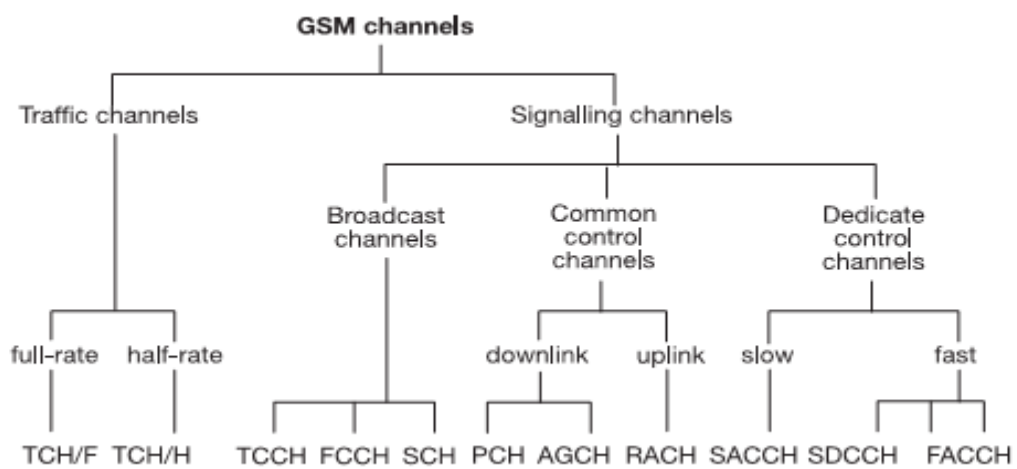


Figure 5-2: GSM logical channels

5.3.1 Logical Channels on the Air Interface

Several logical channels are mapped onto the physical channels. The organization of logical channels depends on the application and the direction of information flow (uplink/downlink or bidirectional). A logical channel can be either a traffic channel (TCH), which carries user data, or a signaling channel.

I. Traffic channel (TCH)

TCH is used to carry speech and data traffic. There are two types of TCH. In addition to these Full-rate TCHs (TCH/F, 22.8 kbit/s) and half-rate TCHs (TCH/H, 11.4 kbit/s) are also defined. Half-rate TCHs double the capacity of a system effectively by making it possible to transmit two calls in a single channel.

II. Signaling channels

The signaling channels on the air interface are used for call establishment, paging, call maintenance, synchronization, etc. There are 3 groups of signaling channels:

A. The broadcast channels (BCH): Carry only downlink information and are responsible mainly for synchronization and frequency correction. This is the only channel type enabling point-to-multipoint communications in which short messages are simultaneously transmitted to several mobiles.

The BCHs include the following channels:

The broadcast control channel (BCCH): General information, cell specific; e.g. local area code (LAC), network operator, access parameters, list of neighboring cells, etc. The MS receives signals via the BCCH from many BTSs within the same network and/or different networks.

The frequency correction channel (FCCH): Downlink only; correction of MS frequencies; transmission of frequency standard to MS; it is also used for synchronization of an acquisition by providing the boundaries between timeslots and the position of the first time-slot of a TDMA frame.

The synchronization channel (SCH): Downlink only; frame synchronization (TDMA frame number) and identification of base station. The valid reception of one SCH burst will provide the MS with all the information needed to synchronize with a BTS.

B. The common control channels (CCCH): A group of uplink and downlink channels between the MS card and the BTS. These channels are used to convey information from the network to MSs and provide access to the network. The CCCHs include the following channels:

The paging channel (PCH): Downlink only; the MS is informed by the BTS for incoming calls via the PCH.

The access grant channel (AGCH): Downlink only; BTS allocates a TCH or SDCCH to the MS, thus allowing the MS access to the network.

The random access channel (RACH): Uplink only; allows the MS to request an SDCCH in response to a page or due to a call; the MS chooses a random time to send on this channel. This creates a possibility of collisions with transmissions from other MSs.

The PCH and AGCH are transmitted in one channel called the paging and access grant channel (PAGCH). They are separated by time.

C. The dedicated control channels (DCCH): Responsible for e.g. roaming, handovers, encryption, etc. The DCCHs include the following channels:

The stand-alone dedicated control channel (SDCCH): Communications channel between MS and the BTS; signaling during call setup before a traffic channel (TCH) is allocated and transfer of short text messages in idle mode.

The slow associated control channel (SACCH): Transmits continuous measurement reports (e.g. field strengths) in parallel to operation of a TCH or SDCCH; needed, e.g. for handover decisions; always allocated to a TCH or SDCCH; needed for 'non-urgent' procedures, e. g. for radio measurement data, power control (downlink only), timing advance, etc.; always used in parallel to a TCH or SDCCH.

The fast associated control channel (FACCH): Similar to the SDCCH, but used in parallel to operation of the TCH; if the data rate of the SACCH is insufficient, 'borrowing mode' is used: Additional bandwidth is borrowed from the TCH; this happens for messages associated with call establishment authentication of the subscriber , handover decisions, etc.

5.4 Trunking Services

Cellular radio systems rely on trunking to accommodate a large number of users in a limited radio spectrum. The concept of trunking allows a large number of users to share the relatively small number of channels in a cell by providing access to each user, on demand, from a pool of available channels. In a trunked radio system, each user is allocated a channel on a per call basis, and upon termination of the call, the previously occupied channel is immediately returned to the pool of available channels.

There is a trade-off between the number of available channels and the likelihood of a particular user finding that no channels are available during the peak calling time. In a trunked mobile radio system, when a particular user requests service and all of the radio channels are already in use, the user is blocked, or denied access to the system. In some systems, a queue may be used to hold the requesting users until a channel becomes available. Listed are some of the terms used in trunking theory [9].

Erlang: The fundamentals of trunking theory were developed by Erlang, a Danish mathematician who, in the late 19th century, embarked on the study of how a large population could be accommodated by a limited number of servers [30]. Today, the measure of traffic intensity bears his name.

Erlang is the basic unit of telecom traffic intensity. Strictly speaking, an erlang is what mathematicians call a “dimensionless unit” representing continuous use of one channel. However, since a single channel used continuously carries 60 minutes of calling in one hour, one erlang is usually defined as 60 minutes of traffic. E.g. If one receives 300 two-minute calls in an hour, then you received 600 minutes, or 10 erlangs, of traffic in that hour.

Busy Hour: The busy hour is based upon customer demand at the busiest hour during a week, month, or year. Servers will be busy when a call attempt is made so the average busy hour figure is used to determine the maximum number of trunks or people needed. Because of “calls bunch up” all traffic planning has to focus on peak periods [30]. It isn’t acceptable to provide excellent service most of the time and terrible service just when customers want to make calls.

The grade of service (GoS): GOS is a measure of the ability of a user to access a trunked system during the busiest hour. The grade of service is a benchmark used to define the desired performance of a particular trunked system by specifying a desired likelihood of a user obtaining channel access given a specific number of channels available in the system. It is the wireless designer’s job to estimate the maximum required capacity and to allocate the proper number of channels in order to meet the GOS. GOS is typically given as the likelihood that a call is blocked, or the likelihood of a call experiencing a delay greater than a certain queuing time [9].

5.4.1 Capacity Estimate in Trunked Systems

The traffic intensity offered by each user is equal to the call request rate multiplied by the holding time [9]. That is, each user generates a traffic intensity of A_u erlangs given by:

$$A_u = \mu H = (BHCA/3600) * H \dots\dots\dots (5.1)$$

Where: H- Average holding time of a call

μ - Average number of call requested/ hour

BHCA- Busy hour call attempts

If there are U users and an unspecified number of channels, the total offered traffic intensity is:

$$A = UA_u \dots\dots\dots (5.2)$$

In a trunks system of C channels and equally distributed traffic among the channels, the traffic intensity per channel is:

$$A_c = A/C \dots\dots\dots (5.3)$$

There are two types of trunked systems which are commonly used; namely, Erlang B and Erlang C.

Erlang B: This type of system offers no queuing for call requests. That is, for every user who requests service, it is assumed there is no setup time and the user is given immediate access to a channel if one is available. If no channels are available, the

requesting user is blocked without access and is free to try again later. This type of trunking is called blocked calls cleared. The Erlang B formula determines the probability that a call is blocked and is a measure of the GOS for a trunked system which provides no queuing for blocked calls [30]. The Erlang B formula is:

$$P_r(C, A) = \frac{\frac{A^C}{C!}}{\sum_{K=0}^C \frac{A^K}{K!}} \dots\dots\dots (5.4)$$

Where: P_r – Probability of blockage

A - Traffic intensity

C – Number of channel

K= 0, 1, 2.....C

Erlang C: The second kind of trunked system is one in which a queue is provided to hold calls which are blocked. If a channel is not available immediately, the call request may be delayed until a channel becomes available. This type of trunking is called Blocked Calls Delayed, and its measure of GOS is defined as the probability that a call is blocked after waiting a specific length of time in the queue. The likelihood of a call not having immediate access to a channel is determined by the Erlang C formula is given by:

$$P_r(delay > 0) = \frac{A^C}{A^C + C!(1 - \frac{A}{C}) \sum_{K=0}^{C-1} \frac{A^K}{K!}} \dots\dots\dots (5.5)$$

5.5 Radio Access Network Audit

Network audit is necessary to judge the network performance and maintain quality of service (QoS) standards. The network audit identifies inconsistencies or limitations in current overall network design, helps to improve processes resulting in optimized

network and improved quality of service [31]. An audit is usually a comparative process and requires an initial baseline of key performance indicator (KPI). These can be derived from the design guidelines, service requirements, customer expectation, market benchmarks and others. In this paper, radio access network audit will be done to evaluate the performance of the different cells in the existing system.

All events occurring over air interface are triggering different counters in the BSC. The KPIs are derived with the help of these counters using different formulations and these KPIs are discussed below [32].

A. Accessibility

Service accessibility is the ability of a service to be obtained, within specified tolerances and other given conditions, when requested by the user. In other words:

$$Accessibility = \frac{Total_NO_of_Successful_Calls_Setup}{Total_Calls_Accesses_to_Network} \dots\dots\dots (5.6)$$

Listed below are the KPIs related to accessibility.

Paging Success Rate: Paging success rate measures the percentage of how many paging attempts that have been answered [33].

$$PSR = \frac{Time_of_Paging_Responses}{Time_of_Paging} \dots\dots\dots (5.7)$$

SDCCH Access Success Rate: SDCCH access success rate is a percentage of all SDCCH accesses received in the BSC [33].

SDCCH Drop Rate: The statistic compares the total number of RF losses (while using an SDCCH), as a percentage of the total number of call attempts for SDCCH channels. This statistics intended to give an indication of how good the cell/system is at preserving calls.

$$SDCCH_Drop_Rate = \frac{SDCCH_Drops}{SDCCH_Seizures} \dots\dots\dots (5.8)$$

Call Setup Success Rate: The Call Setup success rate measures successful Traffic Channel (TCH) Assignments of total number of TCH assignment attempts.

$$CSSR = \left(\frac{NO_of_Successful_Calls_Setup}{Total_No_of_Call_Attempts} \right) * 100 \dots\dots\dots (5.9)$$

Call Setup TCH Congestion Rate: The Call Setup TCH Congestion Rate statistic provides the percentage of attempts to allocate a TCH call setup that were blocked in a cell [32].

$$CSCR = \frac{No_of_TCH_Blocks(Excluding_HO)}{No_of_TCH_Attempts} \dots\dots\dots (5.10)$$

B. Retainability

Service retainability is the ability of a service, once obtained, to continue to be provided under given conditions for a requested duration. In other words:

$$Retainability = \frac{Total_Calls_Completed}{Total_Successful_Calls_Setup} \dots\dots\dots (5.11)$$

Call Drop Rate: This KPI gives rate of drop call. Percent of TCH dropped after TCH assignment complete [34].

$$CDR = \frac{TCH_Dropped_Rate}{TCH_Seizure} \dots\dots\dots (5.12)$$

5.6 Air Interface Capacity

This section investigates network performance when traffic volumes significantly exceed the wireless network's designed capacity [35]. The potential for delivery process bottlenecks exists at several points in the air interface. It also discusses the capacity limits of each element of the air interface and describes what happens when these limits are reached. In GSM networks, there are four potential congestion areas and two of them which are related to this thesis work will be discussed:

- Traffic Channel (TCH) Congestion
- Standalone Dedicated Control Channel (SDCCH) Congestion
- Random Access Channel (RACH) Congestion
- Paging Channel (PCH) Congestion

Traffic Channel Congestion

TCH congestion is the most common type of congestion and occurs when all TCHs in a sector are occupied with existing calls. This leaves no capacity for new conversations, so all new voice calls will be blocked provided Erlang B trunking system is implemented. This congestion is common because traffic channels are a finite resource and are occupied for a relatively long period of time (i.e., for duration of a conversation).

In GSM, the number of TCHs available is a function of the number of TRXs in each sector and the assignment of time slots in each TRX. The number of TRXs in each sector is a function of the network's frequency plan. In many lightly populated areas, it is common to have 2 TRXs in each sector. A typical time slot assignment, as illustrated in Figure 5-3, might be as follows. One time slot is dedicated to control channels and 15 are dedicated to

voice channels. The wireless operator chooses the actual distribution of time slots between control (orange) and traffic (green) channels. -



Figure 5-3: 2-TRX configuration

In urban areas, it is common for 4 TRXs to be available in each sector. A typical time slot assignment, as illustrated in Figure 5-4 shown below. Two time slots are dedicated to control channels; in this example, the second time slot is used for 8 SDCCH channels. 30 time slots are dedicated to voice channels. The wireless operator chooses the distribution of time slots between control (orange) and traffic (green) channels.

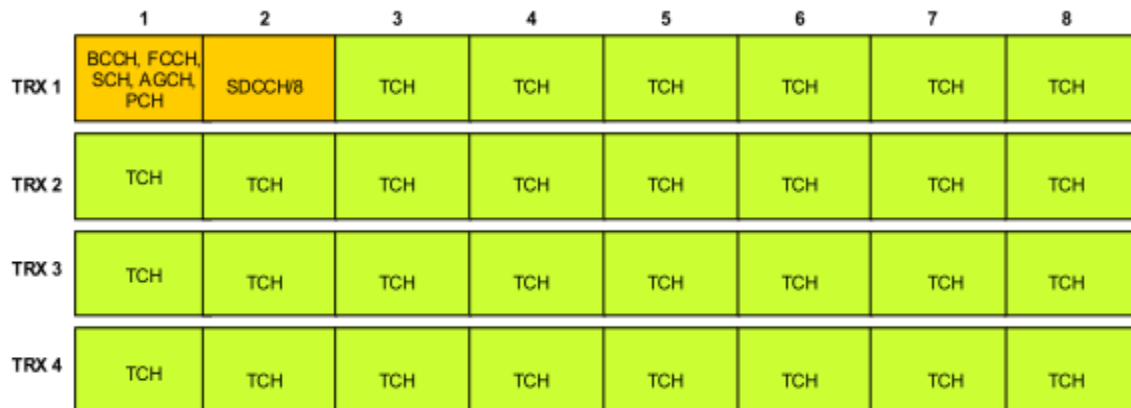


Figure 5-4: 4-TRX configuration

In order to provide necessary capacity, networks in dense urban areas may have 6 TRXs on each sector. These are usually organized as shown in Figure 5-5. Three time slots are -

dedicated to control channels; the second and third time slots provide 12 SDCCH channels and additional paging channels. 45 time slots are dedicated to voice channels. The wireless operator chooses the distribution of time slots between control (orange) and traffic (green) channels.

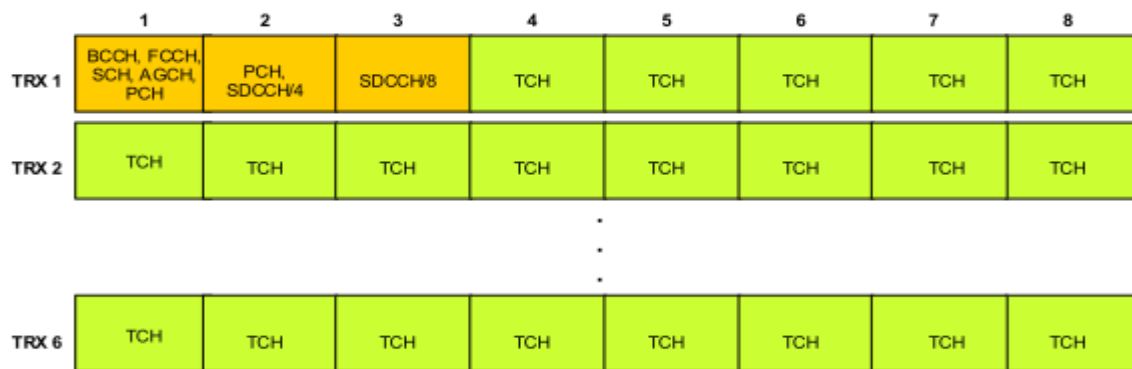


Figure 5-5: 6-TRX configuration

The best way to provide additional voice channels is to provide more TRXs at each sector. A more aggressive frequency plan can provide this, but will increase interference, leading to poor voice quality and more dropped calls.

Standalone Dedicated Control Channel (SDCCH) Congestion

Before a voice conversation begins or an SMS is sent, a number of operations are performed between the cell phone and the network [35]. These include the following:

- Authenticating the handset
- Defining and turning on encryption
- Assigning the cell phone a new Temporary Mobile Station Identifiers (TMSI) (this provides increased anonymity for the cell phone user)
- Sending the dialed digits (or SMS payload) from the handset to the network

These operations are performed on the SDCCH. The actual SDCCH data rate is quite low, 782 bps. SDCCH bursts carry 23 bytes, and as many as 8 bursts may be required to carry the payload of a single SMS message (not including the bursts required for authentication, encryption, and TMSI assignment). Once these messages are accounted for, generally 4-5 seconds are required to transmit an SMS across the SDCCH.

As described above, a typical sector configuration contains 4 SDCCHs. A higher-capacity sector with more TRXs might contain 12 SDCCHs. Assuming no other traffic, a sector with 4 SDCCHs could transmit short messages at the rate of 3600 messages per hour. A sector with 12 SDCCHs could transmit short messages at a rate of 10,800 messages per hour [36], [37].

Due to the relatively small number of SDCCH channels, their low capacity, and their relatively long hold times, it is possible for SDCCH channels in a sector to become congested. If the SDCCH channels in a sector become busy and none are free, new calls and short messages will fail, regardless of whether they are cell phone originated or cell phone terminated.

More SDCCH channels can be provisioned in each sector to prevent SDCCH congestion. Unfortunately, the air interface resources in each sector, which are a function of the number of TRXs, is constant. In order to dedicate more time slots to SDCCHs, the number of timeslots for TCHs must be reduced, decreasing the amount of voice traffic a sector can support. GSM engineers are forced to make a tradeoff - they can provision more signaling channels, or they can provision more voice channels, but they cannot do both.

6. Analysis and Results

6.1 Scenario Planning

A fundamentally different approach to judgmental forecasting is scenario-based forecasting. The aim of this approach is to generate forecasts based on plausible scenarios. The scenarios are generated by considering all possible factors or drivers, their relative impacts, the interactions between them, and the targets to be forecasted. The starting point for scenario planning is to decide on the key question to be answered by the analysis. This may well determine if scenario planning is the preferred tool over the other forecasting methods. In our case, scenario based forecasting will be used because this way one will have a better understanding of the results [38].

Building forecasts based on scenarios allows for a wide range of possible forecasts to be generated and some extremes to be identified. For most cases it is common for “best”, “middle” and “worst” case scenarios to be presented, although many other scenarios could be generated. It is also possible to limit the number of scenarios between two and four and each is given a descriptive name and a written narrative, indicating key events and probabilities. Thinking about and documenting these contrasting extremes can lead to early contingency planning. Therefore, this thesis work considers four scenarios which are summarized on Table 6-1 to study how mobile banking behaves in Ethiopia depending on the capacity of a site and penetration rate of mobile banking users.

Service Penetration Rate \ Traffic Volume	High	Moderate
	Best Case	Worst Case
	Scenario 1	Scenario 3
	Scenario 2	Scenario 4

Table 6-1: Summary of considered scenarios

6.1.1 Mobile Banking Penetration Rate

Considering the fact that mobile banking is a new avenue in Ethiopia, a survey done on March 2012 regarding domestic remittance/ transfer of funds and the channel use to transfer money for 11 countries in Africa is considered. One of the things the data shows is just how different one market is from the next, both in the level of activity and also in the channels through which money is sent.

Besides revealing a wider diversity of markets, another interesting finding from the survey is that even in markets where banks have the most outreach they are still not reaching the poor, whereas in Kenya, Uganda, and Tanzania, where mobile money systems are at scale or scaling up, a much higher percentage of mobile transfers are initiated by poor people. First, let's look at how transaction volumes vary by country in the Figure 6-1 [39].

- ✓ Kenya is clearly an outlier, with 46% of adults reporting sending a domestic remittance
- ✓ Uganda, Sierra Leone, Tanzania, Botswana, Nigeria, South Africa reasonably active countries with 18-23% of adults report sending
- ✓ Zambia, Democratic Republic of Congo (DRC), Rwanda, Mali at 7-15%.

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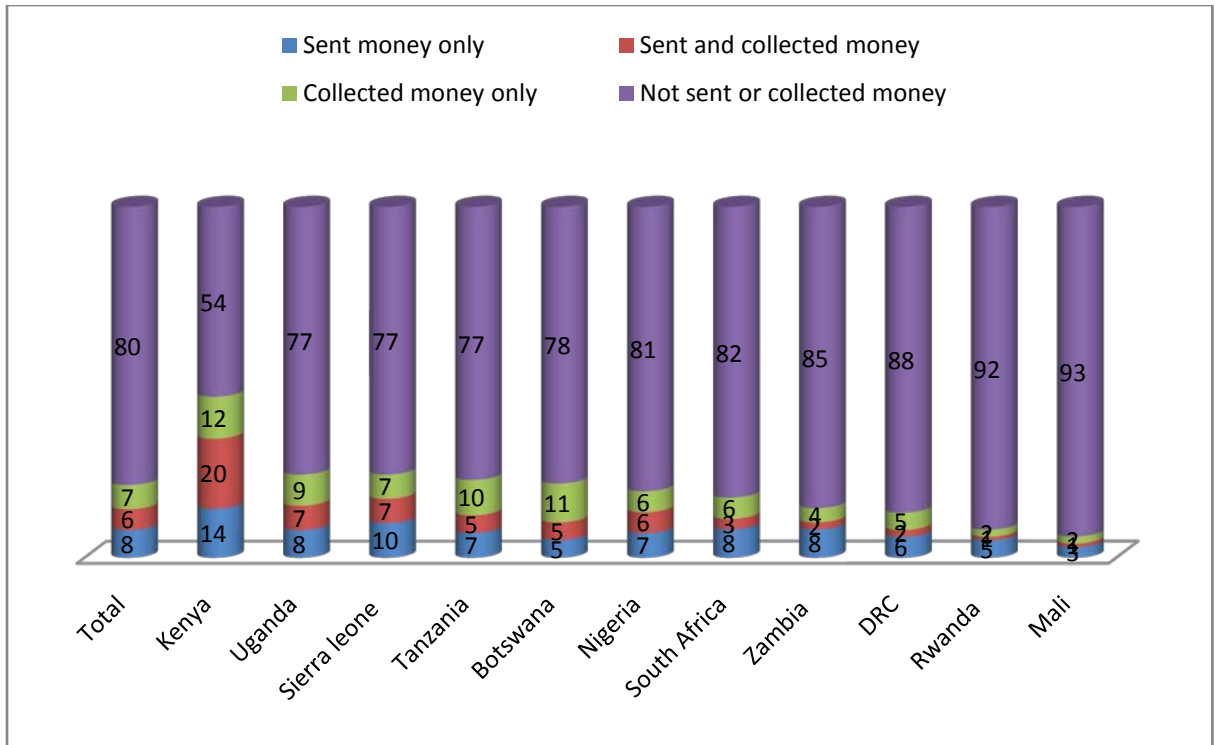


Figure 6-1: Transaction volume in the 11 countries

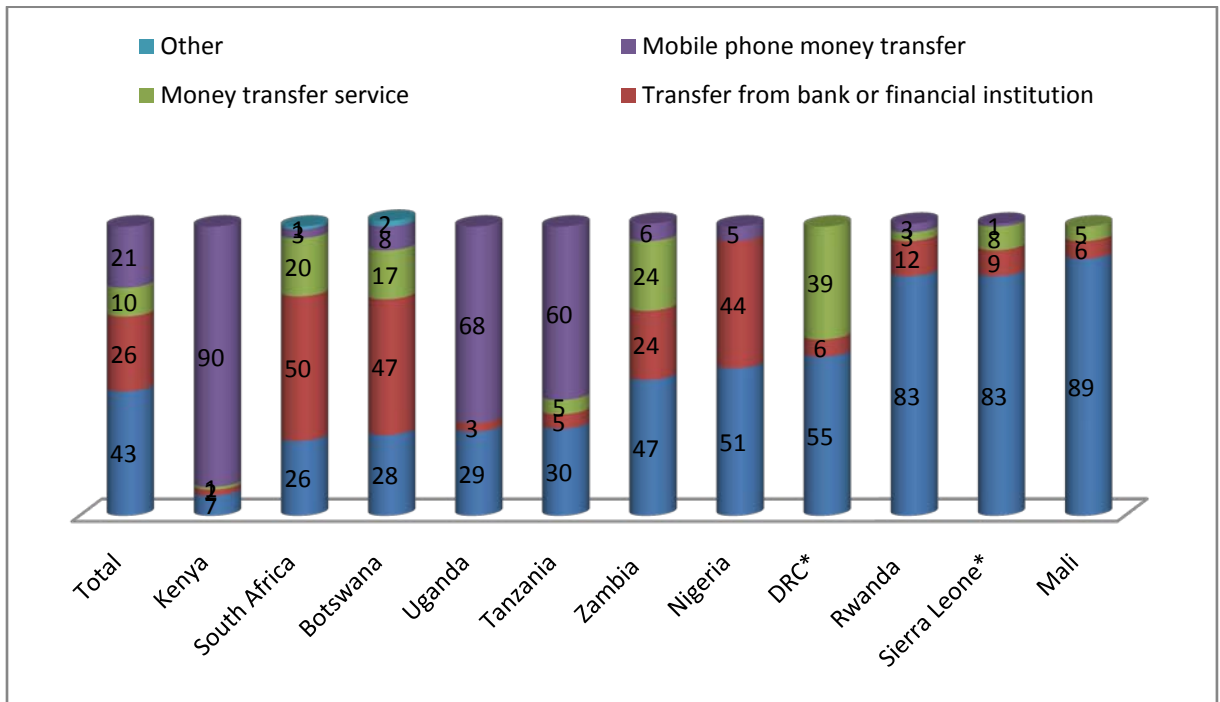


Figure 6-2: The usage of different channels across the 11 countries

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In general, as shown in Figure 6-2, among those who said they sent money rather than carrying it in person, cash again was the most popular channel (43% of senders). About one-quarter (26%) of respondents transferred money through banks or financial institutions. Two in ten (21%) sent money by mobile phone and one in ten (10%) used money transfer services such as Western Union [39].

- ✓ Using the bank-led markets in South Africa, Botswana & Nigeria around 3%, 8% & 5% of senders, respectively, used mobile phone to transfer funds.
- ✓ Telecom-led payment market in Kenya, Uganda and Tanzania over 90%, 68% and 60% senders used mobile phone money transfer.

From this one can generalize that the adoption or penetration rate of mobile banking in Ethiopia could be affected by the following factors listed below.

Household characteristics

It did not seem to be the case that only rural or only urban households in any given country had adopted the mobile banking service. Some sections of the poor seemed to be active users, others infrequent users, while others did not adopt the service at all. This could be due to location of family members, employment type, etc [40].

Services adopted

In Kenya, for instance, though information services (bank balance check, transaction history, etc.) were offered through Equity Bank's SMS banking service, money transfers and airtime top-up services were offered by M-PESA, it was only the domestic money transfer service that had seen widespread uptake. On the other hand GCash in Philippines was used primarily for international remittance transfers, and much less for domestic money transfers. This could be as a result of the pricing of the mobile banking

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service with respect to other formal and informal remittance channels available in a location, reliability with respect to informal channels, match between offerings and need, service paradigm (WIZZIT and Equity which use bank branches or M-PESA and Eko the corner shop paradigm), etc [41].

Pace of uptake

The pace at which various mobile banking services have spread in the low-income segment has differed substantially from country to country, and even between service providers. The overall pace of adoption has varied from 2 million M-PESA customers signed up in the first year in Kenya, to just over 50,000 WIZZIT customers signed up in South Africa over 2 years. There has been rapid uptake of the M-PESA service by low-income, low-literate customers in Kenya, vs. virtually no uptake by the target segment in the Philippines [42]. In both India and South Africa, the uptake of the offered mobile banking services by low-income households has been slow. This could be due to level of awareness, trust, etc.

Frequency of usage

In places like Kenya, M-PESA is used by those who have an active need as frequently as 2-3 times a month, whereas in the Philippines, the mobile banking channel is hardly used with any frequency. In South Africa, despite having accounts, low-income customers did not conduct banking transactions on their mobile phone. This is as a result of agent proximity and ubiquity, transaction time at agent stores, ability to transact on the application, etc. These agent reside on grocery store or phone kiosk.

Therefore, by considering the survey data and factors affecting the adoption of mobile banking mentioned on Section 6.1.1, we can deduce the following facts.

- ❖ M-pesa was launched in Kenya in 2007. From 2 million users after its first year, M-pesa now embraces around 19 million customers equivalent to 67% of Kenya's mobile subscriber with 63,000 agents [43].
- ❖ M-pesa was launched in Tanzania in 2008. In June 2009, 14 month after its launch registration had reached 280,000 users and about 930 agent locations. When this is compared to 2.7 million users and 3000 agents that had been registered in Kenya 14 month after its launch. But Vodacom has made a number of strategic changes that resulted in a more rapid roll out of the agent network in Tanzania [33, 34, 35].
- ❖ Vodacom aimed to replicate the M-pesa success when they introduced the program to the South African market. Unfortunately only about 1.2 million people in South Africa have registered for Vodacom's M-pesa service since its introduction. The difference is clear, with 19 million Kenyans and almost 5 million Tanzanians using M-pesa services [44].

Currently, mobile phone penetration rate in Ethiopia is around 30% which is similar to the cases for Kenya and Tanzania in the year 2008 which were 35.35 and 30.6%, respectively. Therefore, it will only be reasonable to consider the experience of these two countries back then and replicate it to the case of Ethiopia now. And since the idea of mobile banking is new in Ethiopia taking the practice of Kenya *22% penetration rate*, to see the best case scenario and the experience of Tanzania, *2.2 % penetration rate*, for the slow take up likelihood of mobile banking at its early stage will help us perceive the two possible behaviours this new technology might come across.

6.1.2 Case Study Area Selection

For this study two sites in Addis Ababa were selected i.e., one site with very high traffic volume and the other with moderate traffic volume. This way we can clearly see the impact

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of the additional traffic demand that comes about with the introduction of mobile banking. The most important KPIs used by ethio telecom such as the TCH Availability, call drop rate, TCH congestion rate and SDCCH congestion rate were used to identify these sites.

TCH and SDCCH are the most important resources where the system relies in order to accommodate the users' needs. Thus Blocking of these channels is the main performance indicator for GSM network. Table 6-1 below shows technical standards and procedures for the provision of telecommunication services specified by Ethiopian Telecommunication Agency (ETA), the regulatory body of the telecommunication services in Ethiopia. Minimum Quality of Standards and the means and how to perform measurements are specified by this body [45].

Service Type	QOS parameters	Targets/standards	Averaged over a period of
Cellular Mobile Services	Call Setup Success Rate	>98	One quarter
	Dropped Call Rate	<2%	
	Handover Success Rate	>95%	
	Blocked Call Rate	<2%	
	SDCCH Blocking Rate	<0.5%	
	TCH Blocking Rate	<5%	

Table 6-2: Network performance QOS standard threshold values set by ETA

Addis Ketema Site

This site is considered to be one of the areas where traffic intensity is high. The characteristic of this site is depicted in the graph shown in Figure 6-3.

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$$\text{SDCCH Drop Rate} = \text{SDCCH Drops} / \text{SDCCH Seizures} \dots\dots\dots (6.1)$$

$$\text{CSSR} = (\text{No of Successful Calls Setup} / \text{Total No of Call Attempt}) * 100 \dots\dots\dots (6.2)$$

$$\text{CSCR} = \text{No of TCH blocks (Excluding HO)} / \text{No of TCH Attempts} \dots\dots\dots (6.3)$$

$$\text{SDCCH Congestion Rate} = \text{SDCCH overflow} / \text{SDCCH seizures} \dots\dots\dots (6.4)$$

$$\text{Call Drop Rate} = \text{TCH dropped calls} / \text{TCH seizure} \dots\dots\dots (6.5)$$

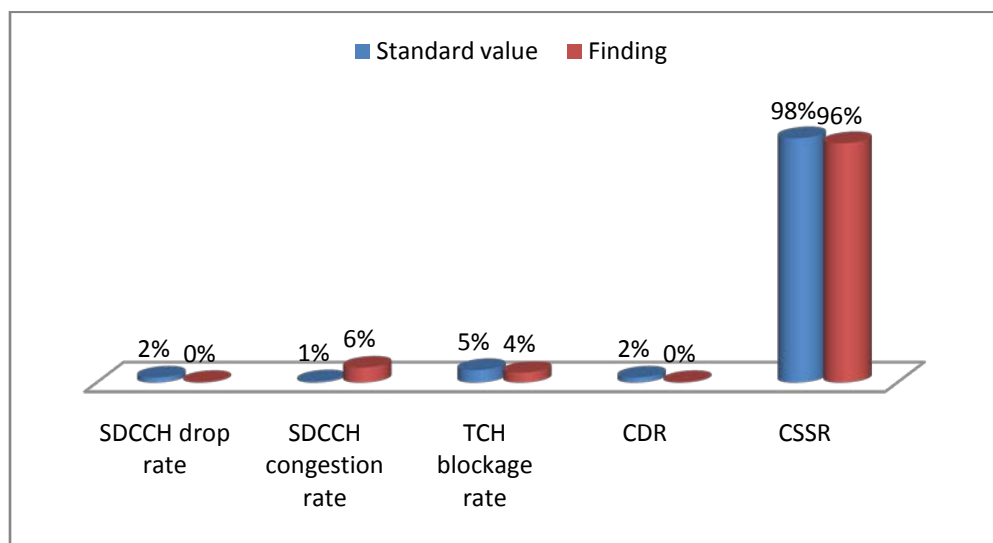


Figure 6-3: Target standard Vs. analysis finding for Addis Ketama site

By comparing the county's standard and the analysis done above for this site, we can deduce that:

- ✓ The SDCCH congestion rate which is 6% indicates blockage since the standard is 0.5%
- ✓ SDCCH drop rate which is found to be 0.24% complies with the target $\leq 2\%$
- ✓ Call set up TCH Congestion rate is 4% and this is a tolerable value the standard declare $\leq 5\%$
- ✓ Call drop rate=0.22% this value is acceptable since the standard requirement is $\leq 2\%$

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- ✓ Call set up success rate = 96 %, but it shouldn't have been less than 98%

Thus, we can see that this site has high traffic volume.

Arada Site

This site is regarded as a moderate traffic intensity area. Its network information is illustrated in the Figure 6-4.

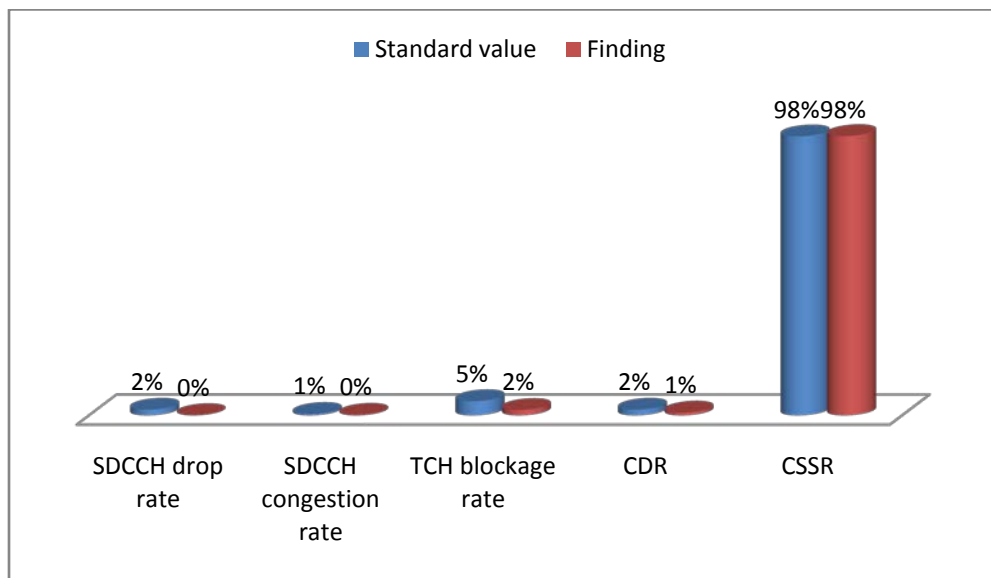


Figure 6-4: Target standard Vs. analysis finding for Arada site

We can see from the graph that all the target values for all QOS parameters are met.

- ✓ SDCCH congestion rate=0.2%, indicate allowable congestion rate since the standard is 0.5%
- ✓ SDCCH drop rate = 0.08%, this is an acceptable value since the standard is $\leq 2\%$
- ✓ Call set up TCH Congestion rate = 1.9 % normally TCH blockage rate shouldn't be $\geq 5\%$
- ✓ Call drop rate = 1% ,acceptable since it is supposed to be $\leq 2\%$

- ✓ Call set up success rate = 98.13 %, which is even better than what the expected 98%

From this we can conclude that, this site has a moderate traffic volume.

6.2 Capacity Evaluation

6.2.1 SMS as Bearer Technology Option

To determine the load that SMS traffic will place on a network, the SMS capacity on the air interface and the offered load should be considered. As a general rule, an SMS message occupies SDCCH channel for 4-5 seconds. SDCCH is occupied for a number of seconds per session establishment. Therefore, SDCCH channel could become a bottle neck. A sector with 18 SDCCH channels will have a capacity of nearly 16,200 SMSs/hour, or 270 SMSs/minute [22].

- ❖ Each message lasts 4 seconds
- ❖ Each SDCCH can handle 15 Messages /minute
- ❖ Each sector has 18 SDCCHs
- ❖ Each sector can handle 18 X 15 or 270 Messages /minute

$$C = (1 \text{ sector}) \left(\frac{18 \text{ SDCCH}}{1 \text{ sector}} \right) \left(\frac{\frac{900 \text{ msg}}{\text{hr}}}{1 \text{ SDCCH}} \right) \dots\dots\dots (6.6)$$

$$= 16,200 \text{ msg/hr} = 4.5 \text{ msg/sec}$$

For the two sites selected in our case, which are Arada and Addis Ketema, each site has:

- ❖ 3 sectors and it has 18 SDCCH configured
- ❖ Each sector has two sets of TRX one operates at 900MHz and the other at 1800MHz

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Therefore the maximum amount of SMS that could congest each sector is 4.5 msg/ sec. The average holding time being 4 sec the traffic intensity on a sector is found to be:

$$A = \mu H = (BHCA/3600) * H = (4.5 \text{ msg/sec}) * 4 \text{ sec} = 18 \text{ erl}$$

Case of Addis Ketema Site while using SMS

Looking at Sections 6.1.1 and 6.1.2, we can deduce the following assumptions for scenario type 1 and 2:

- Looking at the number of call attempts done on each sector, it's estimated that 42,305.76 mobile users exist under each sector on Addis Ketema site.
- The mobile subscribers in Ethiopia is estimated to use mobile banking at worst case (W.C) and best case (B.C) penetration rate of the service 2.2% and 22%, respectively.
- Mobile banking request arrival rate will be 1-2 calls/month/user at the worst case & 3-5 calls/month/user at the best case.
- Holding time of SMS, $H = 4 \text{ sec}$
- Busy hour of a day is 4 hr

For the worst case scenario

$$A = U \mu H = (2.2\% * 42,305.76) * 4 \text{ sec} * \frac{2 \text{ calls}}{30 * 4 * 3600 \text{ sec}} = 0.017 \text{ erl}$$

For the best case scenario

$$A = U \mu H = (22\% * 42,305.76) * 4 \text{ sec} * \frac{5 \text{ calls}}{30 * 4 * 3600 \text{ sec}} = 0.43 \text{ erl}$$

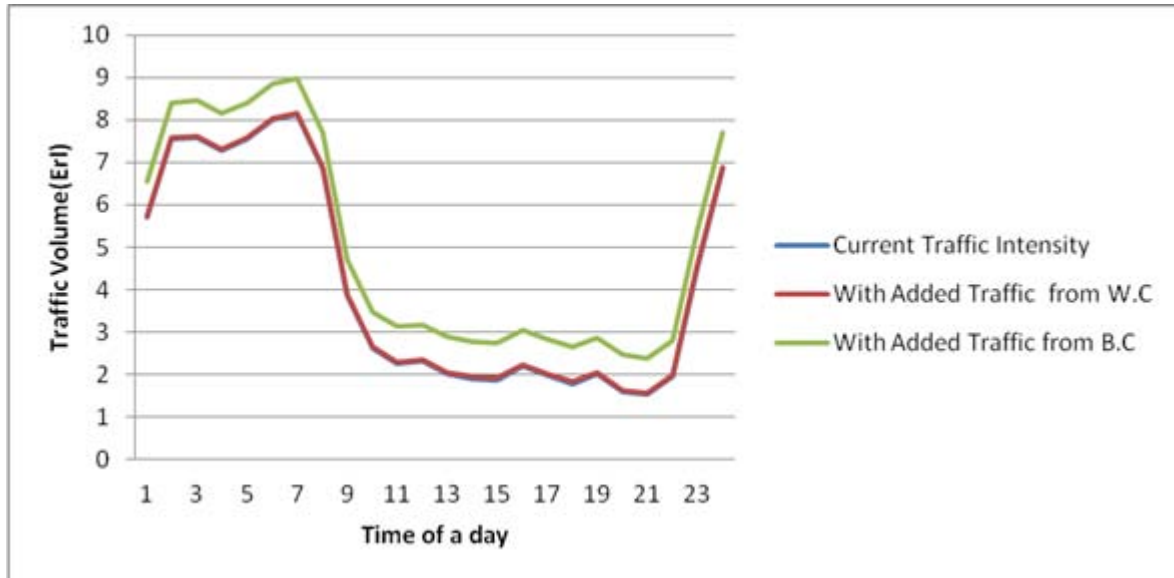


Figure 6-5: Traffic volume over a day due to SMS

From the Graph above, we can observe that:

- ✓ The existing traffic volume per sector on the selected site is not more than 9 erl at any time of a day. And earlier we concluded that the maximum traffic intensity one sector can handle is 18 erl. Therefore, in this case we can see that offered traffic can carry the request on the sector.
- ✓ As can be seen on the graph the additional traffic mobile banking introduces about when its penetration rate is on its worst case overlaps with the traffic intensity of the current demand.
- ✓ When the penetration rate is on its best point, the maximum traffic intensity per sector over a day will be no greater than 9 erl. Comparing this with the 18 erl traffic a sector can handle we can infer that even with the additional traffic demand mobile banking introduces the existing network can handle the load that comes on its way while using bearer technology option SMS.

6.2.2 IVR as Bearer Technology Option

Voice channel is taken under consideration while working with IVR. TCH congestion is the most common type of congestion and occurs when all TCHs in a sector are occupied with existing calls. Here, the effect of the additional traffic demand from mobile banking on TCH congestion rate will be seen.

Case of Addis Ketema Site while using IVR

Looking at Sections 6.1.1 and 6.1.2, we can deduce the following assumptions for scenario type 1 and 2:

- 42,305.76 mobile users exist under each sector on this site.
- The mobile subscribers in Ethiopia is estimated to use mobile banking at worst case (W.C) and best case (B.C) penetration rate of the service 2.2% and 22%, respectively.
- Mobile banking request arrival rate will be 1-2 calls/month/user at the worst case & 3-5 calls/month/user at the best case.
- Holding time for IVR, H = 3 min
- Busy hour of a day is 4 hr

For the worst case scenario

$$A = U \mu H = (2.2\% * 42,305.76) * (3 * 60sec) * \frac{2 \text{ calls}}{30*4*3600 \text{ sec}} = 0.775 \text{ erl}$$

For the best case scenario

$$A = U \mu H = (22\% * 42,305.76) * (3 * 60sec) * \frac{5 \text{ calls}}{30*4*3600 \text{ sec}} = 19.39 \text{ erl}$$

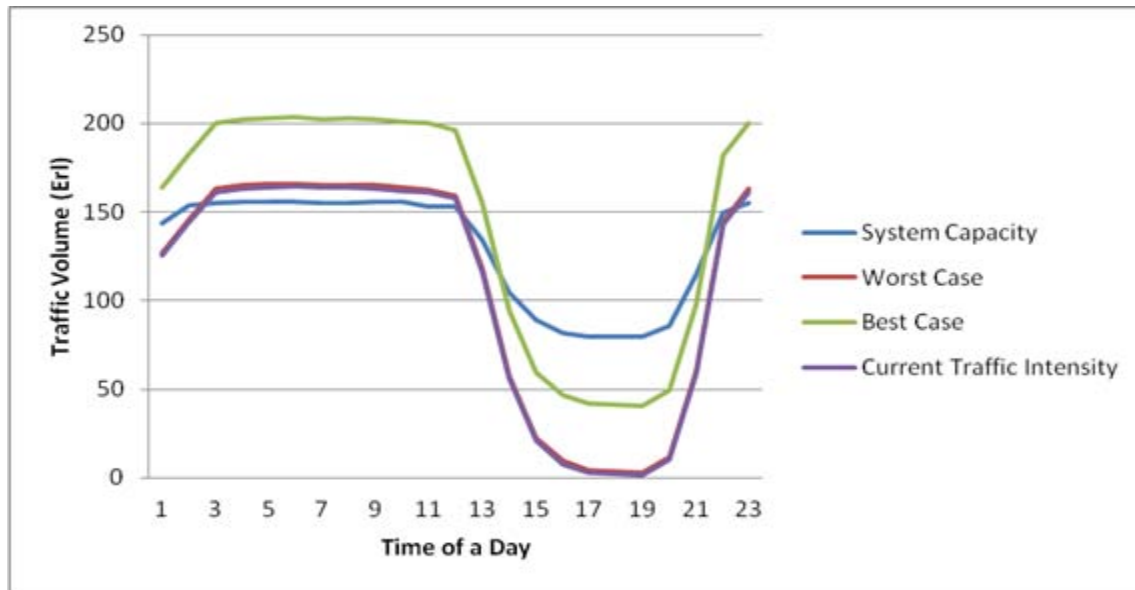


Figure 6-6: Traffic Volume over a Day on TCH at Addis Ketema Site

From the Graph above we can observe that:

- ✓ Since the area selected here is considered to be a high load traffic site, it won't come as a surprise to see the current traffic intensity not being carried via the offered traffic by the system for half the time of a day.
- ✓ When mobile banking penetration rate is at its worst, the traffic volume over a day for this case lie on top of the current traffic intensity as shown in the graph. This is because it only puts an additional load of 0.775 erl on the network.
- ✓ The system will fail short for $\frac{3}{4}$ time of a day to carry additional load, 19.39 erl, that comes with the introduction of mobile banking and when its rate of penetration rate is on its best point. Therefore, we can deduce that using IVR as a bearer technology is not an option in congested areas like this one.

Case of Arada Site while using IVR

Looking at Sections 6.1.1 and 6.1.2, we can deduce the following assumptions for scenario type 3 and 4:

- 19,468.53 mobile users exist under each sector on this site.
- The mobile subscribers in Ethiopia is estimated to use mobile banking at worst case (W.C) and best case (B.C) penetration rate of the service 2.2% and 22%, respectively.
- Mobile banking request arrival rate will be 1-2 calls/month/user at the worst case & 3-5 calls/month/user at the best case.
- Busy hour of a day is 4 hr

For the worst case scenario

$$A = U \mu H = (2.2\% * 19,468.53) * (3 * 60sec) * \frac{2 \text{ calls}}{30*4*3600 \text{ sec}} = 0.3565 \text{ erl}$$

For the best case scenario

$$A = U \mu H = (22\% * 19,468.53) * (3 * 60sec) * \frac{5 \text{ calls}}{30*4*3600 \text{ sec}} = 8.92 \text{ erl}$$

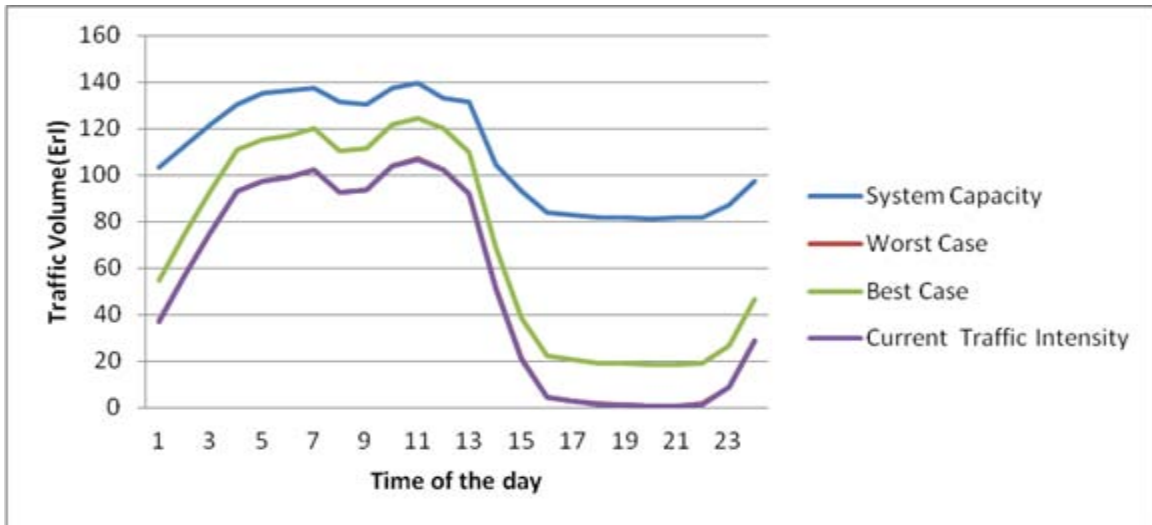


Figure 6-7: Traffic volume over a Day on TCH at Arada Site

From the graph above, we can observe that:

- ✓ At every single point of the time of a day the offered system capacity can carry the current traffic intensity along with the additional traffic generated with the introduction of mobile banking even its penetration rate is at its best possible peak. As a result, using IVR as a bearer technology option in areas where congestion rate is minimum could be practical.

7. Conclusion & Future Work

7.1 Conclusion

In Ethiopia where there is only one bank branch per 100,000 adults and where most of these branches are aggregated in urban areas leaving the rural areas underserved, the importance of introducing mobile banking is indisputable [46]. If one decides to pursue mobile phone enabled banking (mobile banking) targeting at people that are “unbanked” yet have mobile phones to formal financial services, a research like this one need to be done in order to select the most suitable environment for the introduction of this service.

The mobile banking infrastructure sits in a similar technical environment to the banks ATMs, POS, branch and internet banking service offerings. Therefore, our concern will be regarding the network capacity which mobile banking uses as a channel. And this paper generalize that, with the existing network performance, introducing mobile banking in Ethiopia is conceivable. But this depends on which bearer technology option or business model we choose to pursue and the rate of service penetration in the country.

As specified in chapter 6, the bottle neck in the existing network is found to be on the air interface or radio access network. As a result, high traffic load is caused by the limited number of traffic channels. Currently, the available signaling channels do not pose any problem. Thus, this paper proclaims that while using bearer technology options such as

Conclusion & Future Work

SMS, USSD and STK at sites which are considered to have high traffic load, these channels serves well at satisfactory quality of service. But the response time requested by service providers could impact the quality of the service that's being delivered. On the other hand, channels such as IVR are only appropriate to use on sites with low or moderate traffic load since it uses the traffic channel (TCH) it could jeopardizing quality of service otherwise. With IVR system, we can address people with low levels of education and literacy in rural areas but IVR is more expensive as compared to other channels as it involves making a voice call. Therefore, IVR is not recommended with the current network infrastructure available in the country.

The foreseeable future given the high diffusion rate of mobile telephony in developing countries SMS banking is the most practical option for offering affordable remote banking transactions. The potential for SMS mobile banking services is particularly high in countries like Ethiopia where internet infrastructure hinders the access to electronic banking services. If high security and lower technical risk is needed, then SIM based security should be considered. Implementing USSD and SMS integration attracts new subscribers and, on the other hand, takes load off the voice channels that are used in IVR-subscriber dialog. For example, in Kenya, M-PESA uses the SMS channel with SIM Toolkit (STK) technology on the phone; in Tanzania, M-PESA uses USSD. We can replicate their positive experience to our country. Consequently, we can either consider combining USSD and SMS to set a new quality standard in messaging-based service or SMS with STK for high level of security option.

To expand financial inclusion, the type of market or business model we steer toward plays a major role. In a developing country such as Ethiopia, transformational models which target initially unbanked customers is more likely to mark users with basic handsets instead of additive models which targets those who already have a bank

account and provides an alternative means of accessing the services available with that account. If we were to grow the banking sectors in the more limited markets to the level of the bank-led markets, it seems likely the market would skew toward serving the rich much more than if we were to grow a vibrant mobile sector in each of these markets. Whereas telco-led model is widely known and it has significant potential for transformational impact. Considering its success history in several African countries where mobile banking is broadly used, this model seems more viable for the case of Ethiopia. This probably is the riskiest option yet potentially the most profitable. This model places the most regulatory responsibility on the MNO. Navigating the regulatory environment and developing a sustainable agent network is the key for the realization of this model.

7.1 Future Work

Examine the performance of the existing network under the introduction of mobile banking while using bearer technology options such as WAP and J2ME.

Studying the security aspects of SMS mobile banking system by presenting mechanism for authentication, encryption and decryption for the purpose of confidentiality and security of banking information could be implemented.

Developing mobile banking applications in the context of developing countries by bearing in mind the limitations and challenges of mobile banking application that are currently available.

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Appendix

Appendix A: Arada Site Network Information Analysis

	Sectors	SDCCH congestion rate	SDDCH drop rate	Call setup TCH congestion rate	Call drop rate	Call set up success rate
Month 1	D1	8.72E-05	0.000374	0.008063	0.005316	0.991937
	D2	4.99E-05	0.000215	0.008305	0.004328	0.991695
	D3	0.000118	0.000208	0.002826	0.004119	0.997174
	G1	0.000302	0.000357	0.009539	0.003727	0.990461
	G2	0.000943	0.00027	0.007553	0.003704	0.992447
	G3	0.001056	0.000366	0.010656	0.006335	0.989344
Month 2	D1	5.71E-05	0.001092	0.048539	0.030258	0.951461
	D2	0.000598	0.001178	0.047635	0.017485	0.952365
	D3	0.000123	0.000856	0.03131	0.021953	0.96869
	G1	0.003041	0.000377	0.012965	0.00509	0.987035
	G2	0.002501	0.000276	0.011214	0.005483	0.988786
	G3	0.000982	0.000417	0.016238	0.008491	0.983762
Month 3	D1	0.000665	0.002757	0.024809	0.019196	0.975191
	D2	0.001253	0.002249	0.024241	0.013906	0.975759
	D3	0.000445	0.001669	0.013115	0.012772	0.986885
	G1	0.010197	0.000772	0.01664	0.005434	0.98336
	G2	0.010655	0.00073	0.017232	0.006145	0.982768
	G3	0.006153	0.000609	0.023935	0.008156	0.976065
Average		0.002179	0.000821	0.018601	0.010105	0.981399

Appendix B: Addis Ketema Site Network Information Analysis

	Sectors	SDCCH congestion rate	SDDCH drop rate	Call setup congestion rate	TCH rate	Call drop rate	Call set up success rate
Month 1	D1	0.10869	0.0002		0.005	0.001	0.9947
	D2	0.0128	0.0003		0.02	0.002	0.9802
	D3	0	0.0002		0.002	0.002	0.9983
	G1	0.01314	0.0003		0.035	0.005	0.9653
	G2	0.25381	0.0003		0.202	0.001	0.7977
	G3	0.00461	0.0002		0.014	0.002	0.9863
Month 2	D1	0.10884	0.0002		0.005	0.001	0.9951
	D2	0.12845	0.0003		0.074	0.001	0.9262
	D3	9.50E-05	0.0002		0.002	0.002	0.998
	G1	0.00368	0.0004		0.032	0.005	0.9684
	G2	0.2184	0.0003		0.162	0.002	0.8378
	G3	0.0188	0.0002		0.024	0.002	0.9759
Month 3	D1	0.10015	0.0002		0.004	0.001	0.9961
	D2	0.15353	0.0003		0.112	0.001	0.8881
	D3	8.20E-05	8.00E-05		0.001	0.003	0.9985
	G1	0.00092	0.0003		0.013	0.006	0.9866
	G2	5.80E-05	0.0002		0.002	0.002	0.9976
	G3	0.00392	0.0002		0.016	0.002	0.9845
Average		0.062776	0.000243		0.040278	0.002278	0.959739

Appendix C: Erlang B Traffic Table in Erlang

Trunks	0.05	0.02	0.01	0.005	0.002	0.001	Trunks	0.05	0.02	0.01	0.005	0.002	0.001
	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>		<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>
1	0.053	0.020	0.010	0.005	0.002	0.001	76	70.753	64.857	61.653	59.054	56.211	54.369
2	0.381	0.223	0.153	0.105	0.065	0.046	77	71.769	65.814	62.579	59.956	57.087	55.227
3	0.899	0.602	0.455	0.349	0.249	0.194	78	72.786	66.771	63.506	60.859	57.964	56.087
4	1.525	1.092	0.869	0.701	0.535	0.439	79	73.803	67.729	64.434	61.763	58.842	56.948
5	2.218	1.657	1.361	1.132	0.900	0.762	80	74.820	68.688	65.363	62.668	59.720	57.810
6	2.960	2.276	1.909	1.622	1.325	1.146	81	75.838	69.647	66.292	63.573	60.600	58.673
7	3.738	2.935	2.501	2.157	1.798	1.579	82	76.856	70.607	67.222	64.479	61.480	59.537
8	4.543	3.627	3.128	2.730	2.311	2.051	83	77.874	71.568	68.152	65.386	62.362	60.402
9	5.370	4.345	3.783	3.333	2.855	2.557	84	78.893	72.529	69.084	66.294	63.244	61.268
10	6.216	5.084	4.461	3.961	3.427	3.092	85	79.912	73.490	70.016	67.202	64.127	62.135
11	7.076	5.842	5.160	4.610	4.022	3.651	86	80.932	74.453	70.948	68.111	65.011	63.003
12	7.950	6.615	5.876	5.279	4.637	4.231	87	81.952	75.415	71.881	69.021	65.896	63.872
13	8.835	7.402	6.607	5.964	5.270	4.831	88	82.972	76.378	72.815	69.932	66.782	64.742
14	9.730	8.200	7.352	6.663	5.919	5.446	89	83.993	77.342	73.749	70.843	67.669	65.612
15	10.633	9.010	8.108	7.376	6.582	6.077	90	85.014	78.306	74.684	71.755	68.556	66.484
16	11.544	9.828	8.875	8.100	7.258	6.722	91	86.035	79.271	75.620	72.668	69.444	67.356
17	12.461	10.656	9.652	8.834	7.946	7.378	92	87.057	80.236	76.556	73.581	70.333	68.229
18	13.385	11.491	10.437	9.578	8.644	8.046	93	88.079	81.201	77.493	74.495	71.222	69.103
19	14.315	12.333	11.230	10.331	9.351	8.724	94	89.101	82.167	78.430	75.410	72.113	69.978
20	15.249	13.182	12.031	11.092	10.068	9.411	95	90.123	83.133	79.368	76.325	73.004	70.853
21	16.189	14.036	12.838	11.860	10.793	10.108	96	91.146	84.100	80.306	77.241	73.895	71.729
22	17.132	14.896	13.651	12.635	11.525	10.812	97	92.169	85.068	81.245	78.157	74.788	72.606
23	18.080	15.761	14.470	13.416	12.265	11.524	98	93.193	86.035	82.184	79.074	75.681	73.484
24	19.031	16.631	15.295	14.204	13.011	12.243	99	94.216	87.003	83.124	79.992	76.575	74.363
25	19.985	17.505	16.125	14.997	13.763	12.969	100	95.240	87.972	84.064	80.910	77.469	75.242
26	20.943	18.383	16.959	15.795	14.522	13.701	101	96.265	88.941	85.005	81.829	78.364	76.122
27	21.904	19.265	17.797	16.598	15.285	14.439	102	97.289	89.910	85.946	82.748	79.260	77.003
28	22.867	20.150	18.640	17.406	16.054	15.182	103	98.314	90.880	86.888	83.668	80.157	77.884
29	23.833	21.039	19.487	18.218	16.828	15.930	104	99.339	91.850	87.830	84.588	81.054	78.766
30	24.802	21.932	20.337	19.034	17.606	16.684	105	100.364	92.821	88.773	85.509	81.951	79.649
31	25.773	22.827	21.191	19.854	18.389	17.442	106	101.390	93.791	89.716	86.431	82.850	80.532
32	26.746	23.725	22.048	20.678	19.176	18.205	107	102.416	94.762	90.660	87.353	83.748	81.416
33	27.721	24.626	22.909	21.505	19.966	18.972	108	103.441	95.734	91.604	88.275	84.648	82.301
34	28.698	25.529	23.772	22.336	20.761	19.743	109	104.468	96.706	92.548	89.198	85.548	83.186
35	29.677	26.435	24.638	23.169	21.559	20.517	110	105.494	97.678	93.493	90.121	86.448	84.072
36	30.657	27.343	25.507	24.006	22.361	21.296	111	106.521	98.651	94.438	91.045	87.350	84.959
37	31.640	28.254	26.378	24.846	23.166	22.078	112	107.548	99.624	95.384	91.970	88.251	85.846
38	32.624	29.166	27.252	25.689	23.974	22.864	113	108.575	100.597	96.330	92.895	89.154	86.734
39	33.609	30.081	28.129	26.534	24.785	23.652	114	109.602	101.571	97.277	93.820	90.057	87.622
40	34.596	30.997	29.007	27.382	25.599	24.444	115	110.630	102.545	98.224	94.746	90.960	88.511
41	35.584	31.916	29.888	28.232	26.416	25.239	116	111.658	103.519	99.171	95.672	91.864	89.401
42	36.574	32.836	30.771	29.085	27.235	26.037	117	112.686	104.493	100.118	96.599	92.768	90.291
43	37.565	33.758	31.656	29.940	28.057	26.837	118	113.714	105.468	101.067	97.526	93.673	91.182
44	38.557	34.682	32.543	30.797	28.882	27.641	119	114.742	106.443	102.015	98.454	94.578	92.073
45	39.550	35.607	33.432	31.656	29.708	28.447	120	115.771	107.419	102.964	99.382	95.484	92.964
46	40.545	36.534	34.322	32.517	30.538	29.255	121	116.799	108.395	103.913	100.310	96.391	93.857
47	41.540	37.462	35.215	33.381	31.369	30.066	122	117.828	109.371	104.862	101.239	97.298	94.750
48	42.537	38.392	36.109	34.246	32.203	30.879	123	118.857	110.347	105.812	102.168	98.205	95.643
49	43.534	39.323	37.004	35.113	33.039	31.694	124	119.887	111.324	106.762	103.098	99.113	96.537
50	44.533	40.255	37.901	35.982	33.876	32.512	125	120.916	112.300	107.713	104.028	100.021	97.431
51	45.533	41.189	38.800	36.852	34.716	33.332	126	121.946	113.278	108.664	104.958	100.930	98.326
52	46.533	42.124	39.700	37.725	35.558	34.153	127	122.976	114.255	109.615	105.889	101.839	99.222
53	47.534	43.060	40.602	38.598	36.401	34.977	128	124.006	115.233	110.567	106.820	102.749	100.117
54	48.536	43.997	41.505	39.474	37.247	35.803	129	125.036	116.211	111.518	107.752	103.659	101.014
55	49.539	44.936	42.409	40.351	38.094	36.630	130	126.066	117.189	112.470	108.684	104.569	101.911
56	50.543	45.875	43.315	41.229	38.942	37.460	131	127.097	118.167	113.423	109.616	105.480	102.808
57	51.548	46.816	44.222	42.109	39.793	38.291	132	128.128	119.146	114.376	110.549	106.392	103.706
58	52.553	47.758	45.130	42.990	40.645	39.124	133	129.158	120.125	115.329	111.482	107.303	104.604
59	53.559	48.700	46.039	43.873	41.498	39.959	134	130.190	121.104	116.282	112.415	108.215	105.503
60	54.566	49.644	46.950	44.757	42.353	40.795	135	131.221	122.084	117.236	113.349	109.128	106.402
61	55.573	50.589	47.861	45.642	43.210	41.633	136	132.252	123.063	118.190	114.283	110.041	107.301
62	56.581	51.534	48.774	46.528	44.068	42.472	137	133.284	124.043	119.144	115.218	110.955	108.202
63	57.590	52.481	49.688	47.416	44.927	43.313	138	134.315	125.023	120.099	116.153	111.868	109.102
64	58.599	53.428	50.603	48.305	45.788	44.156	139	135.347	126.004	121.054	117.088	112.783	110.003
65	59.609	54.376	51.518	49.195	46.650	45.000	140	136.379	126.985	122.009	118.023	113.698	110.904
66	60.619	55.325	52.435	50.086	47.513	45.845	141	137.411	127.965	122.964	118.959	114.612	111.806
67	61.630	56.275	53.353	50.978	48.378	46.692	142	138.443	128.946	123.920	119.895	115.528	112.708
68	62.642	57.226	54.272	51.872	49.243	47.540	143	139.476	129.928	124.876	120.832	116.444	113.611
69	63.654	58.177	55.191	52.766	50.110	48.389	144	140.508	130.909	125.832	121.768	117.360	114.514
70	64.667	59.129	56.112	53.661	50.979	49.239	145	141.541	131.891	126.789	122.706	118.276	115.417
71	65.680	60.082	57.034	54.558	51.848	50.091	146	142.574	132.873	127.746	123.643	119.193	116.321
72	66.694	61.036	57.956	55.455	52.718	50.944	147	143.606	133.855	128.703	124.581	120.110	117.225
73	67.708	61.990	58.879	56.354	53.590	51.799	148	144.640	134.837	129.660	125.519	121.028	118.130
74	68.723	62.945	59.803	57.253	54.463	52.654	149	145.673	135.820	130.618	126.457	121.946	119.035
75	69.738	63.900	60.728	58.153	55.337	53.511	150	146.706	136.803	131.576	127.395	122.864	119.941

Trunks	0.05	0.02	0.01	0.005	0.002	0.001	Trunks	0.05	0.02	0.01	0.005	0.002	0.001
<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>
151	147.739	137.786	132.534	128.334	123.783	120.846	226	225.525	211.955	204.948	199.412	193.459	189.637
152	148.773	138.769	133.492	129.274	124.702	121.752	227	226.565	212.948	205.920	200.366	194.396	190.563
153	149.807	139.752	134.451	130.213	125.621	122.659	228	227.605	213.942	206.892	201.321	195.333	191.490
154	150.840	140.736	135.409	131.153	126.541	123.566	229	228.645	214.936	207.864	202.276	196.271	192.416
155	151.874	141.720	136.368	132.093	127.461	124.473	230	229.685	215.930	208.835	203.232	197.209	193.343
156	152.908	142.704	137.328	133.033	128.381	125.381	231	230.726	216.923	209.807	204.187	198.147	194.270
157	153.943	143.688	138.287	133.974	129.302	126.288	232	231.766	217.918	210.780	205.142	199.085	195.198
158	154.977	144.672	139.247	134.915	130.222	127.197	233	232.806	218.912	211.751	206.098	200.023	196.126
159	156.011	145.657	140.207	135.856	131.144	128.105	234	233.846	219.907	212.723	207.053	200.962	197.053
160	157.046	146.641	141.167	136.797	132.065	129.014	235	234.887	220.901	213.696	208.009	201.901	197.981
161	158.080	147.626	142.128	137.739	132.987	129.924	236	235.928	221.895	214.669	208.965	202.840	198.909
162	159.115	148.611	143.088	138.681	133.910	130.834	237	236.968	222.890	215.641	209.921	203.779	199.838
163	160.150	149.596	144.049	139.623	134.832	131.743	238	238.009	223.884	216.614	210.878	204.718	200.767
164	161.185	150.582	145.010	140.565	135.755	132.654	239	239.049	224.879	217.587	211.834	205.657	201.695
165	162.220	151.567	145.971	141.508	136.678	133.564	240	240.089	225.874	218.560	212.791	206.597	202.624
166	163.255	152.553	146.933	142.451	137.601	134.476	241	241.130	226.868	219.533	213.747	207.536	203.553
167	164.290	153.539	147.895	143.394	138.525	135.387	242	242.171	227.864	220.507	214.705	208.477	204.482
168	165.326	154.525	148.857	144.338	139.449	136.299	243	243.212	228.859	221.480	215.661	209.417	205.412
169	166.361	155.511	149.819	145.281	140.373	137.210	244	244.254	229.854	222.454	216.619	210.357	206.341
170	167.397	156.498	150.781	146.225	141.298	138.123	245	245.294	230.850	223.427	217.576	211.297	207.271
171	168.433	157.484	151.744	147.170	142.223	139.035	246	246.335	231.844	224.401	218.533	212.238	208.201
172	169.468	158.471	152.706	148.114	143.148	139.948	247	247.376	232.840	225.374	219.491	213.178	209.131
173	170.504	159.458	153.669	149.058	144.073	140.861	248	248.417	233.835	226.348	220.449	214.120	210.061
174	171.540	160.445	154.633	150.003	144.999	141.775	249	249.458	234.831	227.323	221.406	215.060	210.992
175	172.577	161.432	155.596	150.949	145.925	142.689	250	250.500	235.827	228.297	222.364	216.001	211.922
176	173.613	162.419	156.559	151.894	146.851	143.603	251	251.541	236.823	229.270	223.322	216.943	212.853
177	174.649	163.407	157.523	152.839	147.777	144.517	252	252.582	237.818	230.245	224.280	217.884	213.784
178	175.685	164.394	158.487	153.785	148.704	145.432	253	253.624	238.814	231.220	225.239	218.826	214.715
179	176.722	165.382	159.451	154.731	149.631	146.347	254	254.665	239.810	232.194	226.197	219.767	215.646
180	177.758	166.370	160.416	155.677	150.558	147.262	255	255.707	240.806	233.169	227.156	220.709	216.578
181	178.795	167.358	161.380	156.624	151.486	148.178	256	256.748	241.802	234.143	228.115	221.652	217.509
182	179.832	168.347	162.345	157.570	152.414	149.094	257	257.790	242.799	235.118	229.073	222.593	218.441
183	180.869	169.335	163.310	158.517	153.341	150.010	258	258.831	243.796	236.093	230.032	223.536	219.373
184	181.905	170.324	164.275	159.464	154.270	150.926	259	259.872	244.792	237.069	230.991	224.479	220.305
185	182.942	171.312	165.240	160.412	155.198	151.843	260	260.915	245.789	238.044	231.951	225.421	221.237
186	183.980	172.301	166.205	161.359	156.127	152.760	261	261.957	246.785	239.019	232.910	226.364	222.170
187	185.017	173.290	167.171	162.307	157.056	153.677	262	262.998	247.781	239.995	233.869	227.307	223.103
188	186.054	174.279	168.137	163.255	157.985	154.594	263	264.040	248.778	240.970	234.829	228.249	224.036
189	187.091	175.268	169.102	164.203	158.915	155.512	264	265.082	249.774	241.945	235.788	229.193	224.968
190	188.129	176.257	170.068	165.151	159.845	156.430	265	266.124	250.772	242.921	236.748	230.137	225.901
191	189.166	177.247	171.035	166.100	160.775	157.348	266	267.166	251.769	243.896	237.707	231.079	226.835
192	190.204	178.237	172.001	167.048	161.705	158.267	267	268.208	252.766	244.872	238.668	232.023	227.768
193	191.241	179.226	172.968	167.997	162.635	159.186	268	269.250	253.762	245.848	239.628	232.967	228.702
194	192.279	180.216	173.934	168.946	163.566	160.104	269	270.292	254.760	246.824	240.588	233.911	229.635
195	193.317	181.206	174.901	169.896	164.497	161.024	270	271.334	255.757	247.801	241.549	234.855	230.569
196	194.355	182.197	175.868	170.845	165.428	161.943	271	272.376	256.755	248.776	242.508	235.799	231.503
197	195.393	183.186	176.835	171.795	166.359	162.863	272	273.418	257.752	249.753	243.470	236.743	232.437
198	196.431	184.177	177.803	172.745	167.291	163.783	273	274.460	258.750	250.730	244.430	237.688	233.372
199	197.469	185.168	178.770	173.695	168.223	164.703	274	275.502	259.747	251.706	245.391	238.632	234.306
200	198.507	186.158	179.738	174.645	169.155	165.624	275	276.545	260.744	252.682	246.352	239.578	235.240
201	199.546	187.149	180.706	175.595	170.087	166.545	276	277.588	261.743	253.659	247.312	240.522	236.175
202	200.584	188.140	181.674	176.546	171.019	167.466	277	278.630	262.740	254.636	248.274	241.467	237.110
203	201.623	189.131	182.642	177.497	171.952	168.387	278	279.673	263.738	255.613	249.235	242.412	238.045
204	202.661	190.122	183.610	178.448	172.885	169.309	279	280.715	264.736	256.590	250.196	243.357	238.980
205	203.699	191.113	184.579	179.399	173.818	170.230	280	281.757	265.734	257.567	251.158	244.302	239.915
206	204.738	192.105	185.548	180.350	174.751	171.152	281	282.800	266.732	258.544	252.120	245.247	240.850
207	205.776	193.096	186.516	181.302	175.685	172.074	282	283.842	267.730	259.521	253.081	246.193	241.786
208	206.816	194.088	187.485	182.253	176.619	172.996	283	284.886	268.728	260.498	254.042	247.140	242.722
209	207.855	195.079	188.454	183.205	177.552	173.919	284	285.928	269.726	261.476	255.004	248.085	243.658
210	208.893	196.071	189.423	184.157	178.486	174.842	285	286.971	270.725	262.453	255.966	249.031	244.594
211	209.932	197.063	190.393	185.109	179.421	175.765	286	288.014	271.723	263.431	256.929	249.977	245.530
212	210.972	198.055	191.362	186.062	180.355	176.688	287	289.057	272.721	264.409	257.890	250.923	246.466
213	212.011	199.047	192.331	187.014	181.290	177.612	288	290.099	273.719	265.386	258.853	251.870	247.403
214	213.049	200.039	193.301	187.967	182.225	178.536	289	291.143	274.718	266.364	259.815	252.816	248.339
215	214.089	201.031	194.271	188.920	183.160	179.459	290	292.185	275.716	267.342	260.778	253.763	249.276
216	215.129	202.024	195.241	189.873	184.095	180.383	291	293.228	276.715	268.321	261.740	254.709	250.212
217	216.168	203.017	196.211	190.826	185.031	181.308	292	294.271	277.714	269.298	262.703	255.657	251.150
218	217.207	204.010	197.182	191.779	185.966	182.233	293	295.314	278.713	270.276	263.665	256.604	252.086
219	218.247	205.002	198.152	192.733	186.902	183.157	294	296.357	279.712	271.255	264.629	257.550	253.024
220	219.286	205.995	199.123	193.686	187.838	184.082	295	297.400	280.711	272.233	265.591	258.497	253.961
221	220.326	206.988	200.094	194.640	188.775	185.007	296	298.443	281.710	273.211	266.555	259.444	254.898
222	221.365	207.981	201.064	195.594	189.711	185.933	297	299.486	282.709	274.189	267.517	260.392	255.835
223	222.405	208.974	202.035	196.549	190.647	186.859	298	300.529	283.708	275.168	268.481	261.339	256.774
224													