KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

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DEPARTMENT OF TELECOMMUNICATION ENGINEERING

PERFORMANCE EVALUATION OF A GSM/GPRS CELLULAR NETWORK USING THE CSSR WITH DIRECT TCH ASSIGNMENT FEATURE.

by

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May, 2012

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DECLARATION

I hereby declare that this submission is the result of my own effort towards the MSc. Telecommunication Engineering, and that to the best of my knowledge, this study contains no material previously published by another person nor submitted for the award of any other degree of the Kwame Nkrumah University of Science and Technology, except where acknowledgement has been duly made in the text.

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ABSTRACT

All GSM operators use Key Performance Indicators (KPIs) to judge their network performance and evaluate the Quality of Service (QoS) regarding end user perceived quality. KPIs are becoming increasingly important in the context of network rollouts as well as within mature network optimization cycles. The performance of the mobile network is measured based on several counters describing the most important events over a measurement period. The KPIs are derived with the help of these counters using different formulations. Call Setup Success Rate (CSSR) is one of the most important KPIs used by all mobile operators.

The study made a comparative analysis of measured CSSR and an estimated CSSR which was evaluated using the CSSR formulation presented in [17]. Results obtained from graphical representations showed that the measured CSSR were within acceptable levels though a number of sharp drops were recorded. The estimated CSSR, on the other hand, showed significant improvements in areas where sharp drops in CSSR values were recorded for the measured CSSR. Significantly high R square values of close to 1 representing a high predictive ability from the regression analysis of the estimated CSSR were also recorded. It was concluded that the implementation of the CSSR formulation be extended to CSSR measurements to ensure increased subscriber satisfaction.

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ABBREVIATIONS

3G	Third generation
AGCH	Access Grant CHannel
ARQ	Automatic Repeat Request
AuC	Authentication Center
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BSC	Base Station Controller
BSS	Base Station System
BTS	Base Transceiver Station
CBCH	Cell Broadcast Channel
CCCH	Common Control Channel
CCH	Control Channel
CDMA	Code Division Multiple Access
CDR	Call Drop Rate
CEPT	Confederation of European Posts and Telecommunications
CS	Circuit Switching
CSSR	Call Setup Success Rate
EDGE	Enhanced Data rates for GPRS Evolution
EFR	Enhanced Full Rate
ETSI	European Telecommunications Standards Institute
FACCH	Fast Associated Control Channel
FCCH	Frequency Correction Channel
FDMA	Frequency Division Multiple Access
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GMSC	Gateway Mobile Switching Center
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HLR	Home Location Register

HOSR	HandOver Success Rate
HSCSD	High Speed Circuit Switched Data
HTTP	HyperText Transfer Protocol
ISDN	Integrate Services Digital Network
KPI	Key Performance Indicator
LA	Location Area
MAC	Media Access Control
ME	Mobile Equipment
MO	Mobile Origination
MS	Mobile Station
MSC	Mobile Switching Center
MT	Mobile Terminal
MT	Mobile Termination
NCA	National Communication Authority
NSS	Network and Switching Subsystem
OSI	Open Systems Interconnection
PCH	Paging Channel
PIN	Personal Identity Number
PS	Packet Switching
PSDN	Public Switched Data Network
PSR	Paging Success Rate
PSTN	Public Switched Telephone Network
PUK	PIN Unblocking Key
QoS	Quality of Service
RACH	Random Access Channel
RF	Radio Frequency
RLC	Radio Link Control
SACCH	Slow Associated Control Channel
SCH	Synchronization Channel
SDCCH	Standalone Dedicated Control Channel
SGSN	Serving GPRS Support Node

SIM	Subscriber Identity Module
SMS	Short Message Service
TCH	Traffic Channel
TCH/F	Full rate Traffic Channel
TCH/H	Half rate Traffic Channel
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TRAU	Transcoder/Rate Adapter Unit
TRX	Transceiver
UMTS	Universal Mobile Telecommunications System
VLR	Visitor Location Register

CHAPTER ONE

GENERAL INTRODUCTION

In 1895, Guglielmo Marconi [1] opened the way for modern wireless communications by transmitting the three-dot Morse code for the letter 'S' over a distance of three kilometers using electromagnetic waves. From this beginning, wireless communications has developed into a key element of modern society. From satellite transmission, radio and television broadcasting to the now ubiquitous mobile telephone, wireless communications has revolutionized the way societies function.

In the late 1960s and early 1970s [2], the cellular concept was conceived. This was used to improve system capacity and frequency efficiency. Each cell in a cellular network is equipped with a base station and a number of radio channels assigned according to the transmission power constraints and availability of spectrum (bandwidth).

Currently, wireless communication systems are increasingly serving the demands of voice, data and multimedia users. Previously, these services were considered separate and were optimized for either voice or data services [3]. High bandwidth internet is becoming available through Enhanced Data rates for General packet radio service Evolution (EDGE) and the 3rd generation (3G) mobile systems.

Progression from the first systems to today's Universal Mobile Telecommunications System (UMTS) has resulted in more processing power, more availability and more services due to the continuing growth of customers and availability of newer technology [4].

1.1 Background to the Study

Mobile telephony has become one of the fastest growing and most demanding telecommunications applications. It represents a continuously increasing percentage of all new telephone subscriptions around the world. In Ghana, it has assumed a dominant position in the telecommunications market and become the main driver of growth in the country [5].

New services for mobile phones, like email, web browsing, audio and video streaming demands a lot from the underlying network. If the network does not deliver what these services demand, the performance and the user satisfaction will be unsatisfactory. There are different Key Performance Indicators (KPI) for different services and on different network layers. To identify these will make it easier to optimize the network and applications. Therefore, it is useful for companies who specialize in cellular network optimization or even service providers to have the ability to measure the performance of the network for the purpose of optimizing the network usage and enhancing customer satisfaction [4].

1.2 Objectives of the Study

Specifically the study sought to;

- identify KPIs that affect end user satisfaction in a GSM/GPRS cellular network
- identify an aggregative KPI that evaluates network accessibility and service retainability as perceived by the end user
- perform measurements of these top level KPIs using a Nokia Siemens Network Statistics tool
- perform a comparative analysis of the measured aggregative KPI to that predicted or estimated

1.3 Justification of the Study

Network performance management and optimization is necessary to judge network performance and maintain Quality of Service (QoS) standards. It identifies inconsistencies or limitations in current overall network design and helps to improve processes. Thus, resulting in optimized networks and improved quality of service.

1.4 Organisation of the Study

The final report is put into five main chapters. Chapter one provides an introductory background to the research. Other areas covered include the objectives and justification of the study. Chapter two aims at giving a greater understanding of relevant technologies and summarizes previous related works on GSM/GPRS network performance management and optimization. Chapter three discusses the methodology for the study. Chapter four presents results and analysis. The final chapter, Chapter five presents conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Brief History

In 1982, the first step in creating an European mobile communication standard was taken by the Confederation of European Posts and Telecommunications (CEPT) and the Groupe Spéciale Mobile was born. Their objective was to design an European standard for mobile communication to be used all over Europe. In 1989, the responsibility was shifted over to the European Telecommunications Standards Institute (ETSI) and Global System for Mobile communications (GSM) was accepted as an international mobile digital telephony standard.

The GSM family of technologies has provided the world with mobile communications since 1991. In over twenty years of development, GSM has been continually enhanced to provide platforms that deliver an increasingly broad range of mobile services as demand grows. Starting with plain voice calls, the industry now has a powerful platform capable of supporting mobile broadband and multimedia services. GSM is now used in 219 countries and territories serving more than three billion people and providing travellers with access to mobile services wherever they go [6].

Through the years, the GSM standard has developed when it comes to speech and data, not only bit rates but also codecs, channel utilization, robustness among others. As the standard evolves, the data speeds are increasing, quality is improving and the hardware is getting more efficient [7].

2.2 GSM Overview

GSM is an open digital cellular technology used for transmitting mobile voice and data services. GSM operates in the 900MHz and 1.8GHz bands in Europe and the 1.9GHz and 850MHz bands in the US. The 850MHz band is also used for GSM and 3G in Australia, Canada and many South American countries [6]. Each band is divided into one uplink band and one downlink band with 25 MHz bandwidth each. The uplink and downlink bands are subdivided into 124 frequency channels spaced 200 kHz. These channels are often referred to as carriers or carrier frequencies [8].

By having harmonised spectrum across most of the globe, GSM's international roaming capability allows users to access the same services when travelling abroad as at home. This gives consumers seamless and same number connectivity in more than 218 countries.

GSM networks deliver wireless high quality and secure mobile voice and data through a process called Circuit Switching (CS). Circuit switching is a method of communication that establishes connections on demand through one or more switching nodes and permits exclusive use of those connections until they are released. In this networking method, a connection called a *circuit* is setup between two devices (e.g. mobile phones) which is used for the whole communication. Information about the nature of the circuit is maintained by the network (service provider). The circuit may either be a fixed one that is always present, or it may be a circuit that is created on an as-needed basis. The digital data is sent as a continuous stream of bits allowing the data to be heard from the receiving end whilst it is still being sent [5].

2.3 GSM Architecture

Figure 2.1 illustrates the GSM architecture. In this architecture, a *mobile station* (MS) communicates with a *base station system* (BSS) through the radio interface. The BSS is connected to the *network and switching subsystem* (NSS) by communicating with a *mobile switching center* (MSC) using the A *interface*.

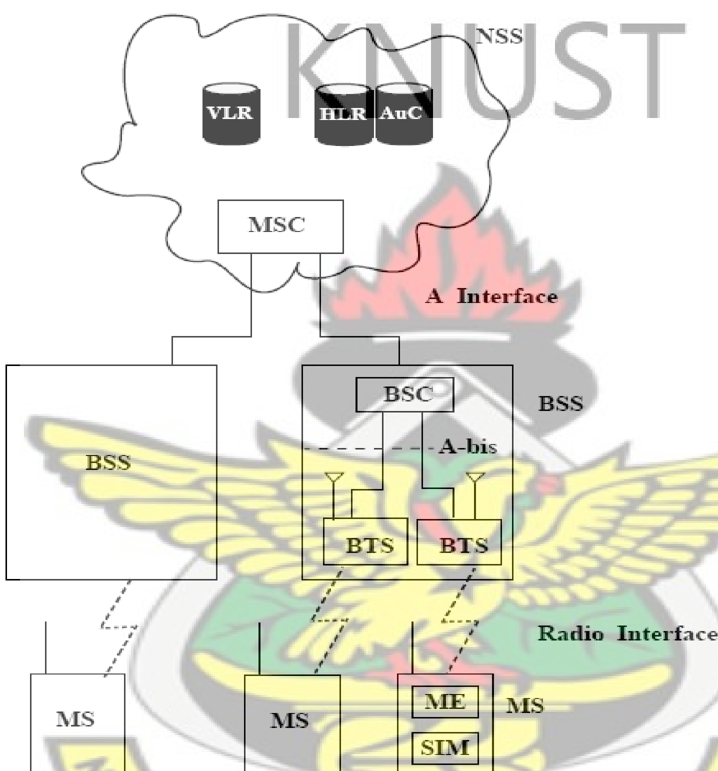

Figure 2.1: GSM Architecture [9]

2.3.1 Mobile Station

The MS consists of two parts: the *subscriber identity module* (SIM) and the *mobile equipment* (ME). In a broader definition, the MS also includes a third part called *terminal equipment* (TE), which can be a PDA or PC connected to the ME. In this case, the first two parts (i.e., ME and SIM) are called the *mobile terminal* (MT).

The SIM although loaned to the subscriber is the property of the service provider. It contains the subscriber-related information including the *personal identity number* (PIN) and PIN *Unblocking Key* (PUK) codes, a list of abbreviated and customized dialing numbers, short messages received when the subscriber is not present, names of preferred networks to provide service and so on.

The ME contains the non-customer-related hardware and software specific to the radio interface. When the SIM is removed from an MS, the remaining ME cannot be used for reaching the service except for emergency calls. SIMs may be attached to MEs with different characteristics. At every new connection between MS (SIM) and the network, the characteristic indication of the ME called *classmark* is given to the network. This SIM-ME design supports portability as well as enhancing security. Usually, the ME is the property of the subscriber [9].

2.3.2 Base Station System

The BSS connects the MS and the NSS. It consists of two parts: the *base transceiver station* (BTS) and the *base station controller* (BSC). The BTS contains transmitter, receiver, and signalling equipment specific to the radio interface in order to contact the MSs. An important part of the BTS is the *transcoder/rate adapter unit* (TRAU) that carries out GSM-specific speech encoding/decoding and rate adaption in data transmission.

The BSC is responsible for the switching functions in the BSS, and is in turn connected to an MSC in the NSS. It supports radio channel allocation/release and handoff management. The BSC may connect to several BTSs and maintain cell configuration data of these BTSs. It also communicates with the BTSs using Integrate Services Digital Network (ISDN) protocols via the A-*bis* interface. In GSM BSS design, a BSC may only connect to one BTS in which case they are likely to be collocated. In this scenario, the BSC and the BTS may be integrated without the A-*bis* interface [9].

2.3.3 Network and Switching Subsystem

The NSS supports the switching functions, subscriber profiles and mobility management. The basic switching function in the NSS is performed by the MSC. This interface follows a signalling protocol used in the telephone network. The MSC also communicates with other network elements external to GSM utilizing the same signalling protocol.

The current location of an MS is usually maintained by the Home Location Register (HLR) and Visitor Location Register (VLR) (as described in Section 2.3.3.1 and 2.3.3.2 respectively). When an MS moves from the home system to a visited system, its location is registered at the VLR of the visited system. The VLR then informs the MS's HLR of its current location.

The *authentication center* (AuC) is used in the security data management for the authentication of subscribers. The AuC may be collocated with the HLR.

An incoming call is routed to an MSC unless the fixed network is able to interrogate the HLR directly. That MSC is called the *gateway* MSC (GMSC). An MSC can function as a GMSC by including appropriate software and HLR interrogation information, and by provisioning interface and the signalling link to the HLR. The GMSC obtains the location information and routes the calls to the visited MSC of the subscribers to receive the calls [9].

2.3.3.1 Home Location Register

This is a database that contains all the administrative information about each subscriber along with their last known location. In this way, the GSM network is able to route calls to the relevant base station for the MS. When a user switches on their phone, the phone registers with the network and from this it is possible to determine which BTS it communicates with so that incoming calls can be routed appropriately. Even when the phone is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position. There is one HLR per network although it may be distributed across various sub-centres for operational reasons [10].

2.3.3.2 Visitor Location Register

This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided. The VLR can be implemented as a separate entity but it is commonly realized as an integral part of the MSC rather than a separate entity. In this way access is made faster and more convenient [10].

2.3.4 Radio Interface

The GSM radio link uses both Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) technologies. The frequency bands for the GSM downlink signal and the uplink signals are 935-960MHz and 890-915MHz respectively. The frequency band is divided into 124 pairs of frequency duplex channels with 200 KHz carrier spacing. Note that for a given distance less power is required to transmit signal over a lower frequency. To save MS power, uplink frequencies in mobile systems are always the lower band of frequencies.

The GSM burst structure is illustrated in Figure 2.2. Every burst contains 148 bits (0.546 msec) followed by 0.031 msec guard time (8.25 bits). The burst begins with 3 head bits and ends with 3 tail bits all of which are logical zeros.

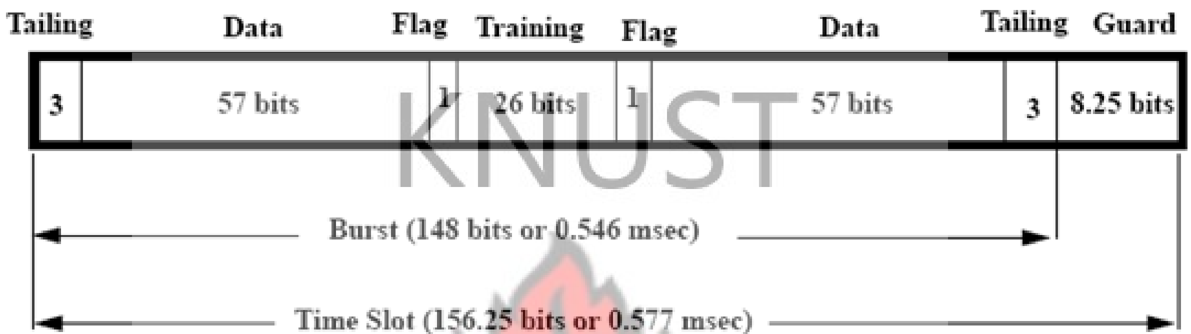

Figure 2.2: GSM Burst Structure [9]

Two groups of data bits are separated by an equalizer training sequence of 26 bits. Each data group consists of 57 information bits and one flag that indicate whether the information bits are for user speech/data or signalling. Depending on the information carried by a time slot, i.e., the information bits in Figure 2.2, two types of *logical channels* are defined: the *traffic channels* (TCHs) and the *control channels* (CCHs).

TCHs are intended to carry user information (speech or data). Two kinds of TCHs are defined:

I. **Full rate TCH** (TCH/F) provides transmission speed of 13 Kb/s for speech or 9.6, 4.8 or 2.4 Kb/s for data. *Enhanced Full Rate* (EFR) speech coders have been implemented to improve the speech quality of a TCH/F.

II. **Half rate TCH** (TCH/H) allows transmission of 5.6 Kb/s speech or 4.8 or 2.4 Kb/s data.

The CCHs are intended to carry signalling information. Three types of CCHs are defined in GSM:

I. **Common control channels** (CCCHs) include the following channel types:

- The *paging channel* (PCH) is used by the network to page the destination MS in call termination.
- The *access grant channel* (AGCH) is used by the network to indicate radio link allocation upon prime access of an MS.
- The *random access channel* (RACH) is used by the MSs for initial access to the network.

Several MSs may access the same RACH potentially resulting in collisions. The slotted Aloha protocol is adopted in GSM to resolve access collision. PCH and AGCH are delivered from the BSS to the MSs by the downlink. RACH utilizes the uplink.

II. **Dedicated control channels** are supported in GSM for dedicated use by a specific MS.

- The *standalone dedicated control channel* (SDCCH) is used only for signalling and for short messages.
- The *slow associated control channel* (SACCH) is associated with either a TCH or an SDCCH. The SACCH is used for non-urgent procedures mainly the transmission of power and time alignment control information over the downlink and measurement reports from the MS over the uplink. A TCH is always allocated with a control channel SACCH to transport both user information and signalling data in parallel.
- The *fast associated control channel* (FACCH) is used for time critical signalling such as call establishing progress, authentication of subscriber, or handoff. The FACCH

- makes use of the TCH during a call. Thus, there is a loss of user data because the FACCH "steals" the bandwidth of the TCH.
- The *cell broadcast channel* (CBCH) only carries the short message service cell broadcast messages which uses the same time slot as the SDCCH.

The CBCH is used in downlink only. SDCCH, SACCH and FACCH are used in both downlink and uplink.

III. **Broadcast channels** (BCHs) are used by the BTS to broadcast information to the MSs in its coverage area.

- The *frequency correction channel* (FCCH) and the *synchronization channel* (SCH) carry information from the BSS to the MS. The information allows the MS to acquire and stay synchronized with the BSS.
- The *broadcast control channel* (BCCH) provides system information such as access information for the selected cell and information related to the surrounding cells to support cell selection and location registration procedures in an MS.

Figure 2.3 shows the radio aspect of *mobile call origination* which describes how the logical channels are involved in the call setup procedure. To initiate the call setup, the MS sends a signalling channel request to the network through RACH. The BSC informs the MS of the allocated signalling channel (SDCCH) through AGCH. Then the MS sends the call origination request via SDCCH. The MSC instructs the BSC to allocate a TCH for this call. Finally, both the MS and the BTS tune to the TCH.

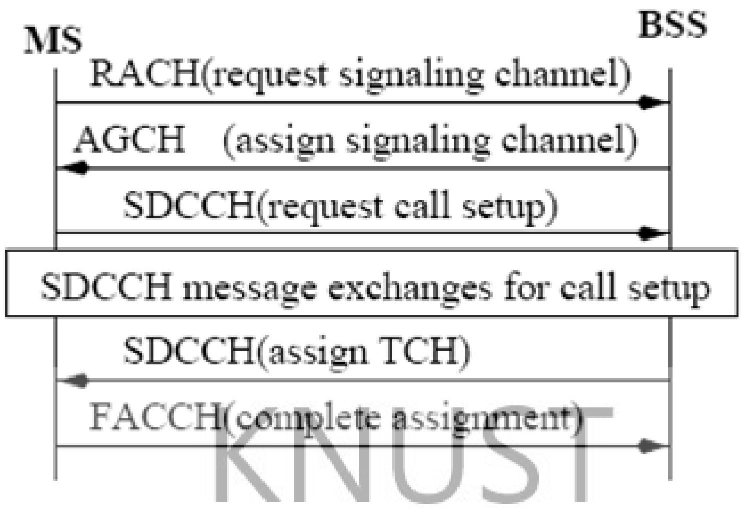

Figure 2.3: GSM Call Origination (Radio Aspect) [9]

Figure 2.4 the radio aspect of *mobile call termination* is shown. In this case the MSC requests the BSS to page the MS. The BSCs instruct the BTSs in the desired Location Area (LA) to page the MS by using PCH. When the destination MS receives the paging message, it requests for a SDCCH. The BTS assigns the SDCCH which is used to setup the call as in the call origination case.

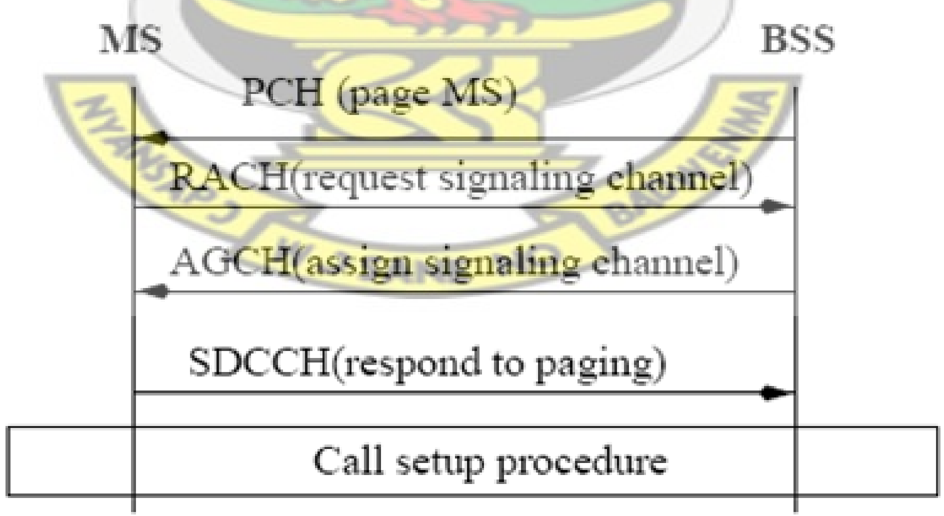

Figure 2.4: GSM Call Termination (Radio Aspect) [9]

2.4 GPRS Overview

GPRS is a packet-based data bearer service for wireless communication services that is delivered as a network overlay for GSM, Code Division Multiple Access (CDMA) and TDMA networks. GPRS applies a packet radio principle to transfer user data packets in an efficient way between GSM mobile stations and external packet data networks. Packet switching is where data is split into packets that are transmitted separately and then reassembled at the receiving end. GPRS is based on GSM communication and complements existing services such as circuit switched cellular phone connections, Short Message Service (SMS) and Bluetooth, a standard for replacing wired connections between devices with wireless radio connections [11].

GPRS and the packet domain transfers packet in an efficient way and optimized the use of network and radio resources. Unlike circuit switched communication, resources are not held when they are not used. To allow the network subsystem to be reused with other radio access technologies, a strict separation between the radio subsystem and the network subsystem is maintained. This allows a common packet domain core network for both GSM and UMTS [4]. Figure 2.5 shows the GPRS network architecture.

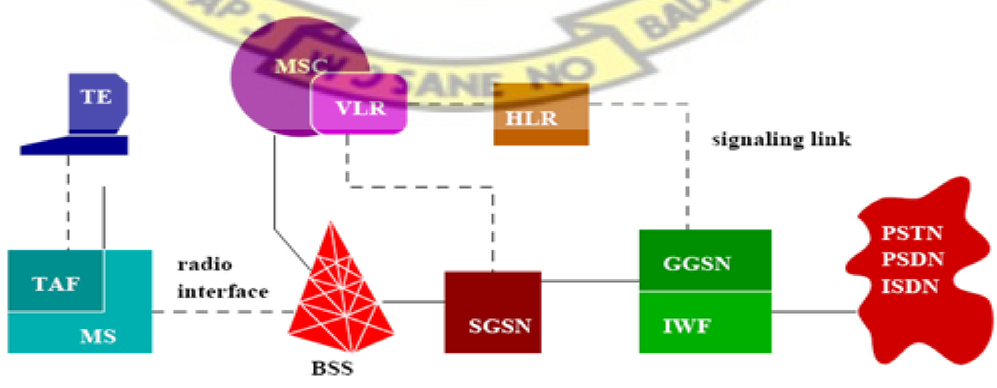

Figure 2.5: GPRS network Architecture [9]

There are two main GPRS nodes in the core network which can be shared with other networks like UMTS, namely, Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN). SGSN receives and transmits packets between the MSs and their counterparts in the public switched data network (PSDN). GGSN interworks with the PSDN using connectionless network protocols such as Internet Protocol and the Open Systems Interconnection (OSI) connectionless network protocol, or connection oriented protocols such as X.25. SGSN and GGSN interact with the GSM location databases including the HLRs and the VLRs to track the location of the MSs. The GPRS data units are routed to the destination MSs based on location information. Both SGSN and GGSN may be equipped with cache memories containing location information to speed up the routing procedure.

Like High Speed Circuit Switched Data (HSCSD), GPRS air interface requires a new radio link protocol to guarantee fast call setup procedure and low bit error rate for data transfer between the MSs and the BSs. Furthermore, GPRS needs to implement a packet radio media access control (MAC) for packet switching [9].

2.5 Performance Management

Performance management involves capturing and analyzing a set of Key Performance Indicators (KPI) that can be quantified by using different sources of performance data. Network operators typically define a set of KPIs and stratified target thresholds in line with marketing and business priorities [12]. The network operator concentrates on many varied performance indicators assigning assumed/theoretical priorities while the subscriber judges the network on the basis of a few basic indicators of performance. It is very important to align the KPI definition according to what quality and performance mean to the subscriber [13]. Figures 2.6 and 2.7 provide a correlation between voice and data KPIs, and the subscriber/end user satisfaction (experience) respectively.

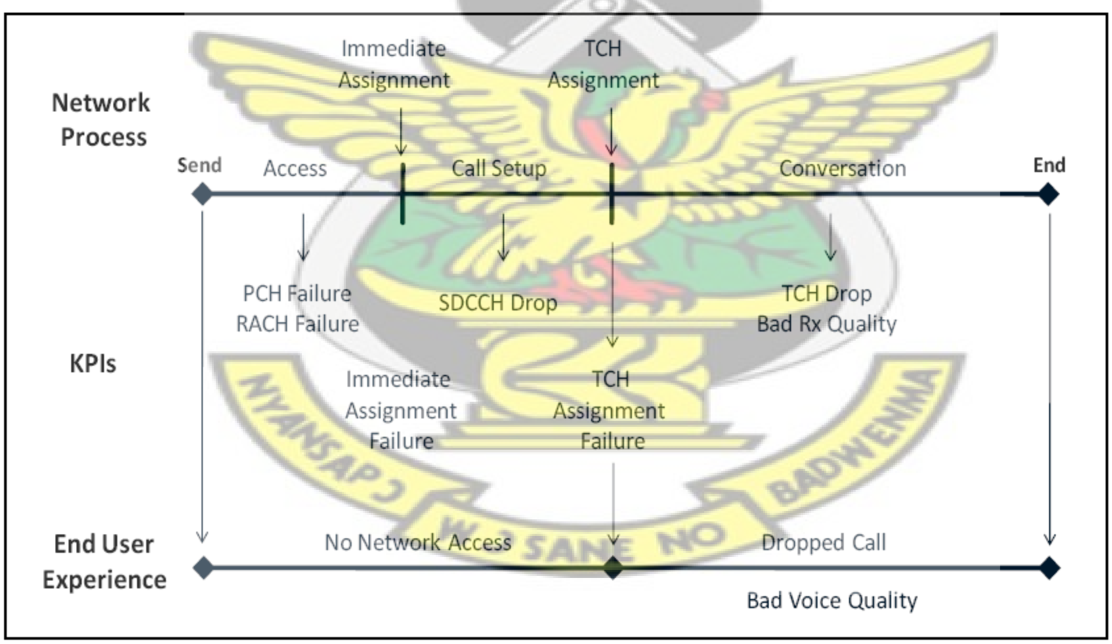

Figure 2.6: Correlation between voice KPIs and end user satisfaction [14]

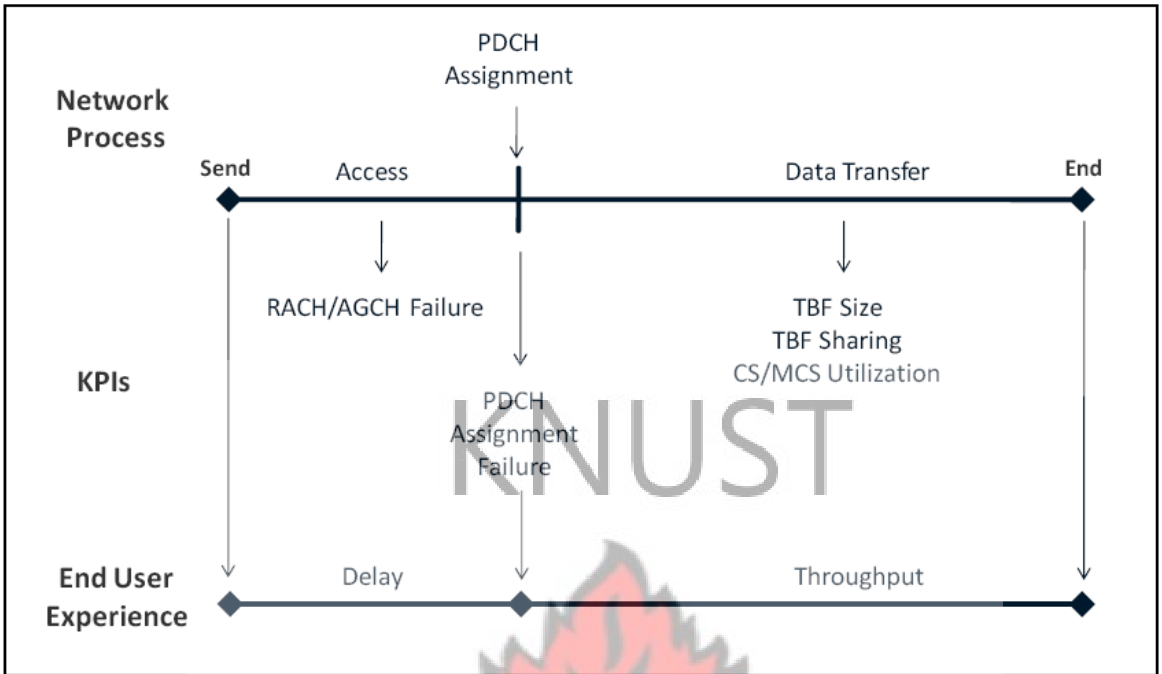

Figure 2.7: Correlation between data KPIs and end user satisfaction [14]

End user satisfaction cannot be represented by a single KPI. A mix of KPIs can be very close to achieving required targets. Table 2.1 shows some suggested user satisfaction oriented KPIs for network performance estimation.

Table 2.1: User oriented KPIs [14]

Service	User Experience	Network KPIs
Voice	Ability to complete call	• Immediate Assignment Success • SDCCH Drop • TCH Normal Assignment Success • TCH Drop
Voice	Acceptable voice quality	• Vocoder Utilization • Bad Rx Quality Samples
Data	Delay	• PDCH Assignment Success
Data	Throughput	• TBF Size • TBF Share • CS/MCS Utilization

Several studies have been conducted on performance evaluation and optimization of cellular networks in the literature [14 – 17].

In [16], a real GSM radio access network was evaluated. A network audit was performed on the radio access part of the GSM network using an audit methodology algorithm or flow chart. The algorithm included many aspects of the network such as performance, neighbor, parameter, frequency and competitive benchmark audits. The audit was mainly a comparative process which required the initial establishment of baseline KPIs. These KPIs were derived from design guidelines, service requirements, customer expectations and market benchmarks. Two assessment parameters (network accessibility and service retainability) for evaluating the performance on the network were employed.

- **Network Accessibility**

  Accessibility is the ability of a service to be obtained within specified tolerances and other given conditions when requested by the user.

$$Accessibility = \frac{Total\_NO\_of\_Successful\_Calls\_Setup}{Total\_Calls\_Accesses\_to\_Network} \tag{2.1}$$

Listed below are the KPIs connected to accessibility.

I. **Paging Success Rate (PSR)**

The paging success rate is a measure of the percentage of how many paging attempts that have been answered either as a result of the first or the second repeated call.

$$PSR = \frac{Time\_of\_Paging\_Responses}{Time\_of\_Paging} \tag{2.2}$$

II. **SDCCH Access Success Rate**

SDCCH access success rate is a percentage of all SDCCH accesses received in the BSC.

III. **SDCCH Drop Rate**

The SDCCH drop rate 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 statistic is intended to give an indication of how good the cell/system is at preserving calls.

$$SDCCH\_Drop\_Rate = \frac{SDCCH\_Drops}{SDCCH\_Seizures} * 100\% \quad (2.3)$$

IV. **Call Setup Success Rate (CSSR)**

This measures successful TCH assignments of total number of TCH assignment attempts.

$$CSSR = (1 - SDCCH\_Congestion\_Rate) * TCH\_Assignment\_Success\_Rate \quad (2.4)$$

$$CSSR = \left(1 - \frac{SDCCH_{Overflows}}{SDCCH_{Call_{Attempts}}}\right) * \left(1 - TCH_{Congestion_{Rate}}\right) *$$

$$(1 - TCH\_Assignment\_failureRate) * 100\% \quad (2.5)$$

V. **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.

$$Call\_Setup\_TCH\_Congestion\_Rate = \frac{No\_of\_TCH\_Blocks(Excluding\_HO)}{No\_of\_TCH\_Attempts} \quad (2.6)$$

- **Service 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:

$$Retainability = \frac{Total\_Calls\_Completed}{Total\_Successful\_calls\_setup} \tag{2.7}$$

Listed below are the KPIs connected to retainability.

I. **Call Drop Rate (CDR)**

This KPI gives the rate of drop calls by percentage of TCH drops after TCH assignment is completed.

$$CDR = \frac{Total\_TCH\_Drops}{TCH\_Normal\_Assignment\_successes + incoming\_DR + Incoming\_HO\_Successes - Outgoing\_HO\_successes} \tag{2.8}$$

DR is directed retry

II. **Handover Success Rate (HOSR)**

The handover success rate shows the percentage of successful handovers of all handover attempts. A handover attempt is when a handover command is sent to the mobile.

$$Handover\_Success\_Rate = \frac{HO\_Outgoing\_Success\_BSC\_or\_MSC\_Controlled}{HO\_Attempt} * 100\% \tag{2.9}$$

Haider *et al* [18], established a real GSM RF network performance evaluation on the basis of four major KPIs i.e., Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Handover Success Rate (HSR) and Radio traffic channel (TCH) congestion rate. These KPIs were summarized as shown in Tables 2.2 to 2.5. The study described simple procedures for cellular network performance estimation. It was analytically proven that optimizing an existing cellular network using different methodologies and fine parameter tuning to offer remarkable QoS to the end users is possible.

Table 2.2: Call Setup Success Rate (CSSR) [18]

Indicator	CSSR
Definition	Rate of call attempts until TCH successful assignment
Formula	$\frac{Number\ of\ successful\ seizures\ of\ SDCCH\ channel}{Total\ number\ of\ requests\ for\ seizure\ of\ SDCCH\ channel}$
Result	$= \left[{(CT01 + CT02)}/{CT03} \right] * 100$
Condition Applied	Where counter CT01 counts SDCCH channels successfully seized for Call termination & CT02 counts SDCCH channels successfully seized for Call origination. CT03 counts SDCCH seizure requests.

Table 2.3: Call Drop Rate (CDR) [18]

Indicator	CDR
Definition	Rate of calls not completed successfully.
Formula	$\frac{Number\ of\ TCH\ drops\ after\ assignment}{Total\ number\ of\ TCH\ assignments}$
Result	$= \left[{(CT04 + CT05)}/{CT06} \right] * 100$
Condition Applied	Where CT04 counts TCH drops due to radio interface problems & CT05 counts TCH drops due to BSS problems. CT06 counts numbers of TCH successfully seized/assigned.

Table 2.4: Handover Success Rate (HSR) [18]

Indicator	**HSR**
Definition	Rate of successful handovers (intercell + intracell).
Formula	$\frac{Number[intercell + intracell]\ Handover\ attempts}{Total\ number\ of\ handover\ requests}$
Result	$= \left[{(CT07 + CT08)}/{(CT09 + CT10)} \right]$*100
Condition Applied	Where CT07 counts number of incoming successful handovers & CT08 counts number of outgoing successful handovers. CT09 counts number of outgoing handover requests while CT10 counts number of incoming handover requests.

Table 2.5: TCH Congestion Rate (TCHCR) [18]

Indicator	**TCHCR**
Definition	Rate of blocked calls due to resource unavailability.
Formula	$\frac{Number\ of\ calls\ blocked\ due\ to\ resource\ unavailability}{Total\ number\ of\ requests}$
Result	$= ({CT11}/{CT12})$*100
Condition Applied	Where CT11 counts number of assignment failures when there is no TCH available & CT12 counts number of normal assignment requests for TCH establishment.

In [19], a summary of measurements and trials that were carried out and evaluations of the performance of GSM and GPRS were presented. Their study revealed that limitations existed in the GSM system with regards to accommodating extreme offered traffic. Also, the GSM system could not predict the rapidly increased traffic in many cases and it could definitely not adapt even by reconfiguring system parameters. In their opinion, GSM was not yet optimized and GPRS, on the other hand was still immature and several issues needed to be considered.

Orstad and Reizer [4], performed practical end-to-end performance tests in cellular networks using an end-to-end test agent, TWSE2E. Their objective was to identify what affects end user performance. Special attention was given to the high latency of the wireless links and the delay introduced with the radio access bearer establishment. They concluded that the 3G cellular network UMTS outperformed EDGE with respect to commonly used services like HTTP/WEB and FTP. It was also discovered that while TCP throughput was good when transferring large files over FTP, the latency of the wireless link made the HTTP performance bad compared to potential TCP throughput.

Meyer in [20] investigated performance issues of TCP when operated over GPRS. Several traces for TCP and RLC were discussed to highlight the characteristics if GPRS is applied as access for bulk data download. Download time measurements showed that GPRS could operate effectively over a wide range of channel conditions. Further results revealed that GPRS provided a sufficiently fast working ARQ mechanism based on the RLC protocol which allowed typically several retransmissions before TCP timed out. He concluded that the RLC ARQ scheme is appropriately designed to ensure that TCP observes just packet delays rather than losses. If additionally these delays could be bounded in such a way that no TCP time-out occurs, TCP would not notice packet errors on the wireless link at all.

Adolfsson [21], by simulation identified possible problems when running TCP in a GPRS environment. Some of these problems he noted were mostly caused by the TBFs which are setup between the MS and the BSC whenever data should be sent. The buffers and the slow link between mobile station and base station may cause other problems which are not fatal but may decrease TCP performance or make TCP less able to respond to loss of data. TCP features that are especially important for good performance were also identified. These features he noted mostly dealt with fast recovery from data loss and how to avoid data loss because of small buffers in the GPRS system. He further suggested some improvements to TCP performance such as responding to medium access requests from the MS quickly, using Explicit Congestion Notification (ECN) to avoid unnecessary drops from the PCU or SGSN queue, implementing new standards for delayed TBF release which would improve connection setup and maybe improve the acknowledgement clustering situation.

In [22], an approximation method is used for evaluating the GPRS performance of single-slot service in the variable radio resource. Voice services are independent of GPRS and because GPRS is mainly designed to transmit intermittent and burst data, the service time of GPRS is rather smaller than that of voice services. As an approximation, the decomposition technique was used to analyze the GPRS performance. The essence of this technique was to use the voice services probability distribution to describe the interaction of voice services to GPRS. Thus, the GPRS performance in the dynamically variable resource was obtained by combining this distribution with the performance in a fixed resource.

By the comparison of numerical results and simulated results, it was shown that the method could be used for evaluating GPRS performance when the average service time of circuit switched services is much longer than that of GPRS. The simulations showed that the interruption probability of GPRS calls due to releasing its channel to the demand of circuit switched services depended on the average message size more strongly than on the traffic load. The multi-slot services caused higher blocking probability and longer delay to the network than the single-slot service. These effects they observed could be reduced by implementing a GPRS resource allocation scheme with flexible multi-slot services. In this scheme, when the available network resource cannot provide a call with its required transmission rate, the network negotiates with the user (GPRS call or circuit switched service) and agrees on a transmission rate which the network can provide.

Kollár [17], gave a definition of a real Call Setup Success Rate (CSSR) and the possibility of its implementation using current GSM technologies. It was concluded that more complex formulation which utilized the Immediate Assignment Success rate, TCH Assignment Success Rate and SDCCH Success rate must be used for measuring CSSR. He further stated that this formulation was the best approach despite a higher effort on the processor part of the equipment where the CSSR is to be calculated. He noted that the formulation did not cover the case when the Direct TCH Assignment feature is enabled.

The aggregative KPI ability that evaluates network accessibility and service retainabilty as perceived by the end user is a Call Setup Success Rate. This consists of three main voice call KPIs [17]:

- Successful Immediate assignment procedure (the result is occupation of SDCCH or FACCH in case of Direct TCH assignment)
- Successful authentication and ciphering on SDCCH or FACCH (these procedures can be excluded in case of Direct TCH assignment)
- Successful TCH assignment

Therefore, equation 2.4:

$$CSSR = (1 - SDCCH\_Congestion\_Rate) * TCH\_Assignment\_Success\_Rate$$

can also be written as;

$$CSSR = \frac{NumTCHAssig}{NumCH\_ReqSpeech} \quad (2.10)$$

where *NumTCHAssig* represents the number of successfully assigned TCH (number of *ASSIGNMENT Complete* messages) and *NumCH_ReqSpeech* represents the number of *CHANNEL REQUEST* messages but related only to request for a mobile originated (MO) or mobile terminated (MT) call. The other procedures, which can be completed with an SDCCH like SMS – MT, SMS – MO, location updating etc. are not counted because they do not represent the request for the speech call. The practical implementation of the equation 2.10 is problematic because up to now it is not possible to distinguish between the requests for the speech call and other calls [17].

One possibility of solving this problem is using the simplified formula given in equation 2.11:

$$CSSR^{*} = \frac{NumTCHAssig}{NumCH\_Req} \quad (2.11)$$

where *NumCH_Req* represents total number of *CHANNEL REQUEST* messages and *NumTCHAssig* represents the number of TCH assignments (number of *ASSIGNMENT Complete* messages). Given that;

$$NumCH\_Req = NumCH\_ReqSpeech + NumCH\_ReqNonSpeech \quad (2.12)$$

where *NumCH_ReqNonSpeech* is the number of *CHANNEL REQUEST* messages not used for MT or MO speech call. Then equation 2.11 can be modified to give equation 2.13:

$$CSSR^{*} = \frac{NumTCHAssig}{NumCH\_ReqSpeech + NumCH\_ReqNonSpeech} \quad (2.13)$$

Under the condition that $\frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech} \leq 20\%$ equation 2.13 can be modified using binomial series as follows:

$$CSSR^* \approx \frac{NumTCHAssig}{NumCH\_ReqSpeech}\left(1 - \frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech}\right) \quad (2.14)$$

The absolute error in measurement of Call Setup Success Rate using equation 2.11 is then evaluated as given in equation 2.15;

$$\Delta = CSSR^* - CSSR = \frac{NumTCHAssig}{NumCH\_ReqSpeech}\left(1 - \frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech}\right) - \frac{NumTCHAssig}{NumCH\_Req} == -CSSR * \frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech} \quad (2.15)$$

In the case that *NumCH_ReqNonSpeech* is equal to zero, equation 2.11 provides exactly the call setup success rate. However, in practice the ratio; $\frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech}$ is within the ranges of tenths of percent which can lead to a big systematic error. Therefore, the mobile operators break away from the use of equation 2.11. In principle equation 2.11 can be used for the calculation of call setup success rate only in regions where the $\frac{NumCH\_ReqNonSpeech}{NumCH\_ReqSpeech} \leq 1\%$

The second possibility is to replace the denominator (*NumCH_ReqSpeech*) in equation 2.10 with *NumTCHAttempt* where *NumTCHAttempt* represents the number of *ASSIGNMENT REQUEST* messages. But in this case the result of the calculation will be TCH Assignment Success rate which is something different from Call Setup Success Rate [17]. Even some of the operators have separate KPIs for Call Setup Success Rate and TCH Assignment Success Rate.

The best approach promises the indirect calculation of *NumCH_ReqSpeech* according to the model given in Figure 2.8.

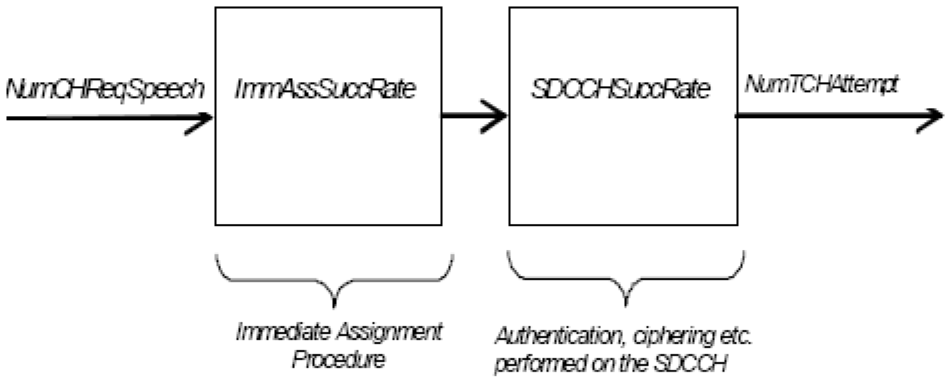

Figure 2.8: Model for calculation of *NumCH_ReqSpeech* [17]

From Figure 2.8, *ImmAssSuccRate* represents Immediate Assignment Success Rate given by the relationship:

$$ImmAssSuccRate = \frac{NumEstInd}{NumCH\_Req} \quad (2.16)$$

where *NumEstInd* represents the number of *ESTABLISH INDICATION* messages. In other words, the Immediate Assignment Success Rate represents the total number of requests for channels that were successful during the immediate assignment procedure.

SDCCHSuccRate represents *SDCCH* Success Rate and is given by:

$$SDCCHSuccRate = 1 - SDCCH\_Drop\_Rate \quad (2.17)$$

where *SDCCH_Drop_Rate* is *SDCCH* Drop rate and provides the total number of SDCCH dropped during the procedures (authentication, ciphering etc.) performed on SDCCH.

From the model in Figure 2.8,

$$NumTCHAttempt = ImmAssSuccRate * SDCCHSuccRate * NumCH\_ReqSpeech \quad (2.18)$$

NumCH_ReqSpeech in equation 2.18 can be written as;

$$NumCH\_ReqSpeech = \frac{NumTCHAttempt}{ImmAssSuccRate * SDCCHSuccRate} \quad (2.19)$$

Substituting equation 2.19 into equation 2.10 gives;

$$CSSR = \frac{NumTCHAssig}{NumTCHAttempt} * ImmAssSuccRate * SDCCHSuccRate \tag{2.20}$$

which can be rewritten as given in equation 2.21;

$$CSSR = TCHAssSuccRate * ImmAssSuccRate * SDCCHSuccRate \tag{2.21}$$

Equation 2.21 is currently the best approach used in measuring the Call Setup Success Rate (CSSR). A disadvantage could be higher effort on BSC or the equipment where the CSSR is to be calculated as three KPIs (or six partial measurements) are used. It provides exactly the CSSR in the case where Direct TCH Assignment feature is disabled [17].

CHAPTER THREE

METHODOLOGY

3.1 Research Statement

The study aims to present an insight into network performance evaluation of a GSM/GPRS cellular network by conducting some measurements. One of the most important KPIs used by all mobile operators is the Call Setup Success Rate (CSSR). The work carries out a comparative analysis of the measured CSSR to that estimated using a CSSR formulation where the direct Traffic Channel (TCH) Assignment feature is disabled.

3.2 Data Collection

The performance measurements were conducted on ONATELs GSM/GPRS cellular network using a Nokia Siemens Network Statistics tool to define top level KPIs which describe the success/failure rates of the most important events such as service blocking, service dropping and handovers at the BTS level.

3.3 Sample size and data processing

The data collection was over a four (4) week period and categorized into the following observation time intervals [23]:

- Hour: Hourly statistics give a detailed picture of the network performance and are useful to help spot temporary problems and identify trends.
- Peak or busy Hour: Peak hour statistics are of great significance because they correspond to the time of heavy utilization of network resources. In a way, they provide the "worst-case" scenario.

- Day: Daily statistics are introduced to provide a way of averaging temporary fluctuations of hourly data. Problems can be identified and corrective actions triggered with more confidence.

Data processing was done using Microsoft Excel (see appendix).

CHAPTER FOUR

RESULTS AND ANALYSIS

In this section results that have come up through the comparison of operational data to that estimated using the CSSR formulation as given in equation 2.21:

$$CSSR = TCHAssSuccRate * ImmAssSuccRate * SDCCHSuccRate$$

is presented.

The logical channels that are primarily used in today's mainly, voice traffic in cellular networks are the Traffic Channel (TCH) and Standalone Dedicated Control Channel (SDCCH) often referred to as "signalling channels". Though many other channels exist, these two (especially the SDCCH) are the most important resources where the system relies on in order to accommodate the subscribers needs [24]. A new call cannot be initiated if SDCCH channels are not available and the same happens when SDCCHs are available but all TCHs are blocked. Thus one can say that blocking of these channels is a main performance indicator for an operational GSM/GPRS cellular network that may lead to severe bottlenecks if the phenomenon persists.

The SDCCH and TCH Success Rates KPIs provide an understanding of when and where congestion appears since these channels are the most vulnerable and directly affects the quality of service offered to the subscribers.

In Figures 4.1 to 4.3 and Tables 4.1 to 4.3, the graphical representation and regression analysis of the measured and estimated CSSR for the various observation time intervals are shown respectively. The top level KPI measurements including the measured CSSR and the computation of the estimated CSSR are shown in appendices A and B respectively. In appendix B the SDCCHdropRate and TCHdropRate are substracted from 100% to obtain the

SDCCHsuccRate and TCHsuccRate respectively. Also, the IMM_ASSGNsuccRate is obtained by subtracting the outcome of equation 4.1 from 100%.

$$\left({IMM\_ASSGN\_SENT}/_{(IMM\_ASSGN\_SENT + IMM\_ASSGN\_REJ)} \right) * 100\% \tag{4.1}$$

4.1 Presentation of Results

4.1.1 Graphical Representation of Measured and Estimated CSSR

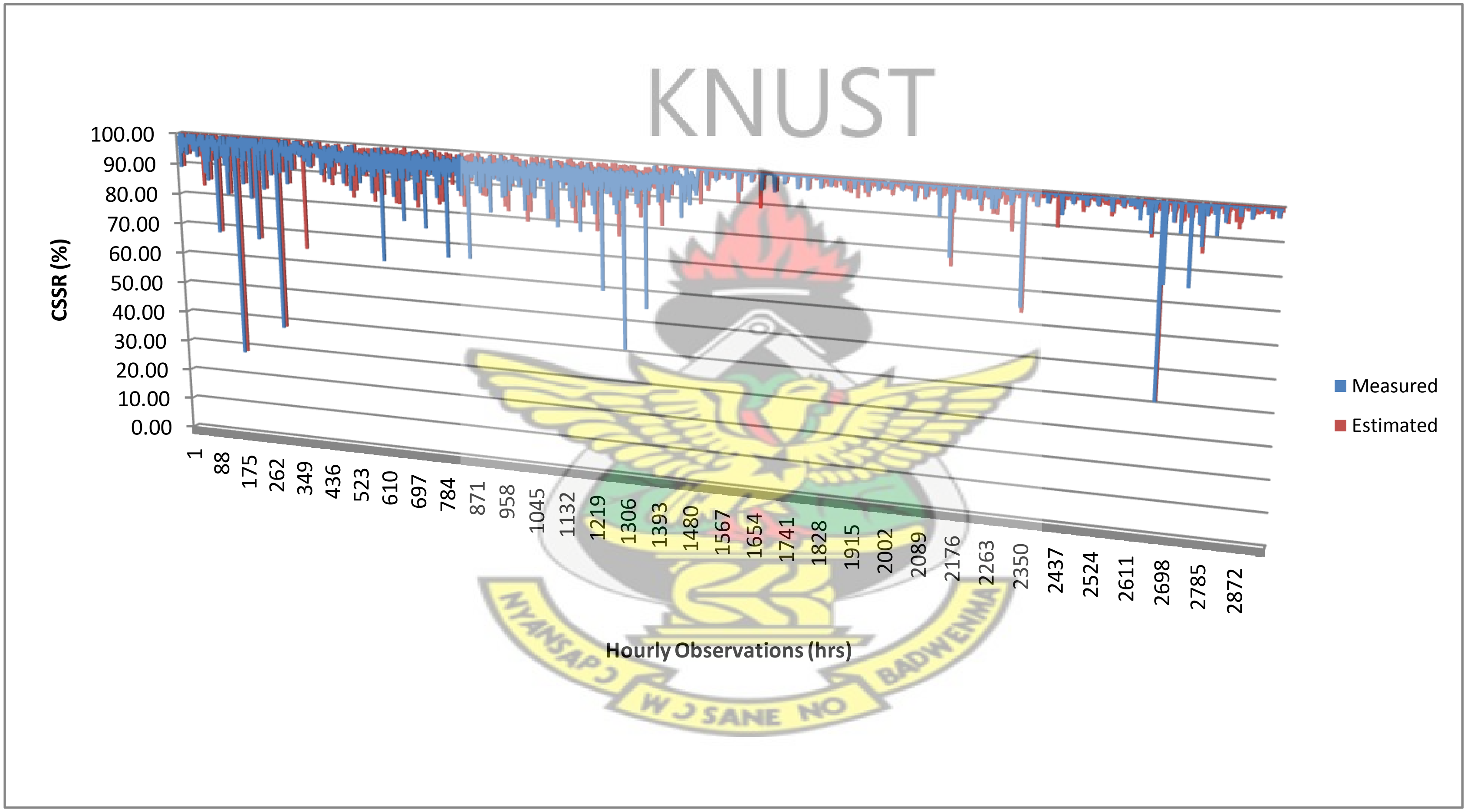

Figure 4.1: Hourly Plot of Measured and Estimated CSSR

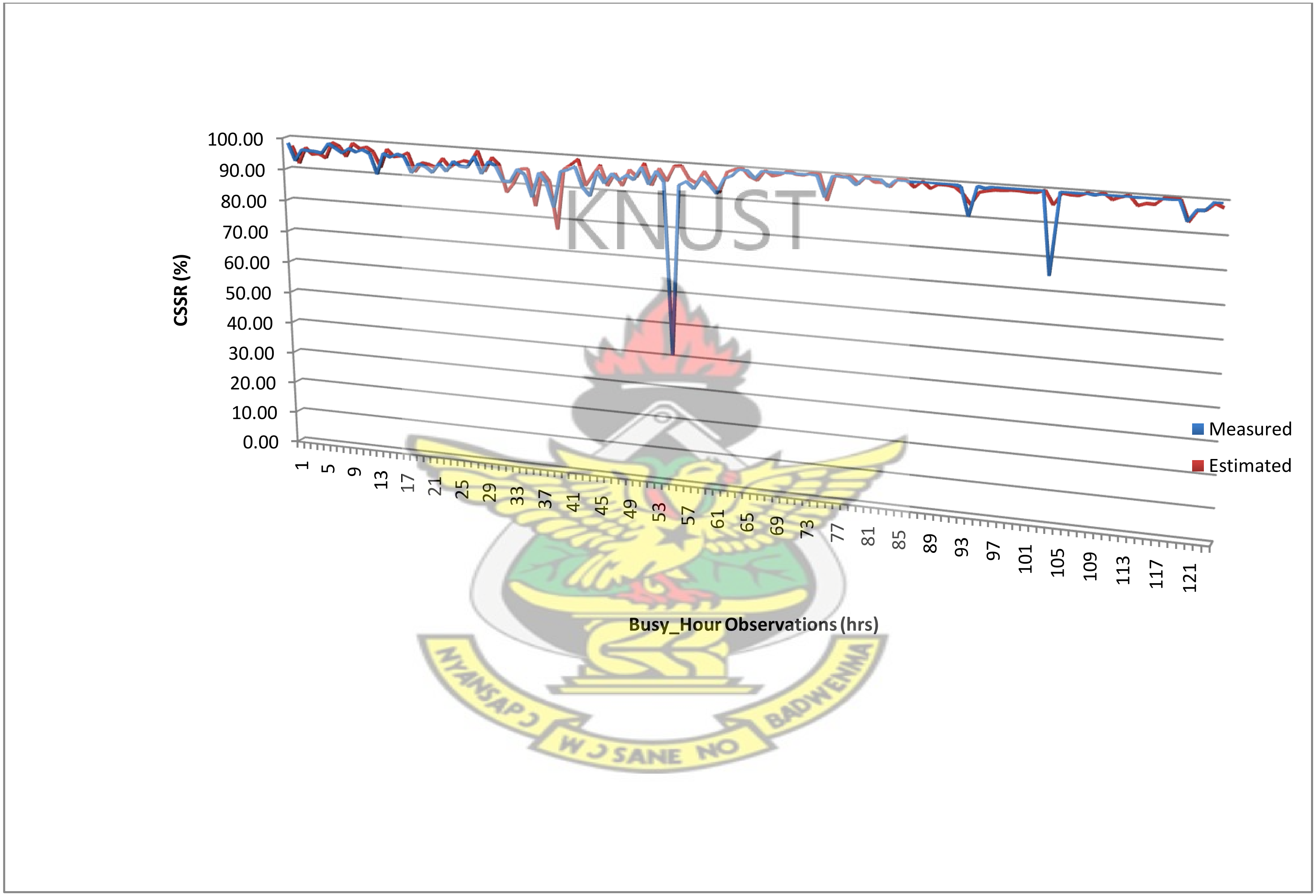

Figure 4.2: Busy_Hour Plot of Measured and Estimated CSSR

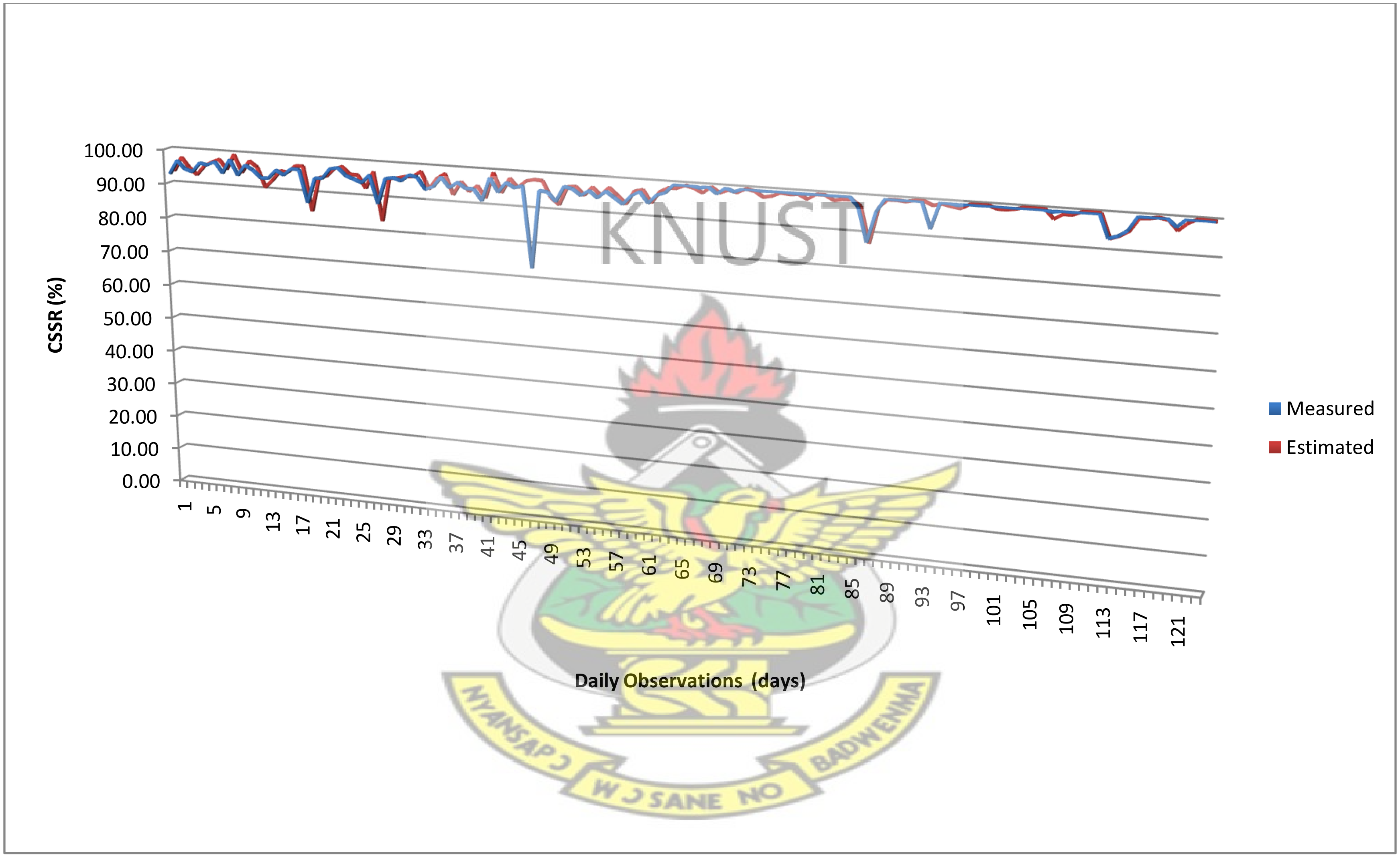

Figure 4.3: Daily Plot of Measured and Estimated CSSR

4.1.2 Regression Analysis of Estimated CSSR

Table 4.1: Regression Analysis of Hourly CSSR Observations

HOURLY SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999856442
R Square	0.999712905
Adjusted R Square	0.999712612
Standard Error	0.066270816
Observations	2943

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	44946.25236	14982.08	3411360	0
Residual	2939	12.90756216	0.004392		
Total	2942	44959.15993			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-192.5234808	0.116536446	-1652.05	0	-192.751982	-192.295	-192.75198	-192.29498
IMM_ASSGN_Success Rate	0.975515392	0.000788655	1236.936	0	0.97396902	0.977062	0.97396902	0.97706176
SDCCH Success Rate	0.990799239	0.000403807	2453.646	0	0.99000747	0.991591	0.99000747	0.99159101
TCH Assignment Success Rate	0.95866157	0.000870567	1101.192	0	0.95695459	0.960369	0.95695459	0.96036855

Table 4.2: Regression Analysis of Busy_Hour CSSR Observations

BUSY_HOUR SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999787297
R Square	0.999574639
Adjusted R Square	0.999563916
Standard Error	0.070670991
Observations	123

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1396.649275	465.5498	93214.56	2.2563E-200
Residual	119	0.594332295	0.004994		
Total	122	1397.243608			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-188.5801282	0.878199492	-214.735	6.2E-156	-190.3190509	-186.841	-190.319051	-186.841206
IMM_ASSGN_Success Rate	0.982417884	0.007158682	137.2345	6.9E-133	0.968242979	0.996593	0.96824298	0.99659279
SDCCH Success Rate	0.978913216	0.002981544	328.3243	7.8E-178	0.973009461	0.984817	0.97300946	0.98481697
TCH Assignment Success Rate	0.923538758	0.006036179	153.0006	1.8E-138	0.911586522	0.935491	0.91158652	0.93549099

Table 4.3: Regression Analysis of Daily CSSR Observations

DAILY SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999921407
R Square	0.999842819
Adjusted R Square	0.999838857
Standard Error	0.037401178
Observations	123

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1058.889104	352.963	252324.1	4.2475E-226
Residual	119	0.166462922	0.001399		
Total	122	1059.055567			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-189.7674752	0.495432383	-383.034	8.6E-186	-190.7484808	-188.786	-190.74848	-188.78647
IMM_ASSGN_Success Rate	0.973002503	0.003155275	308.3733	1.3E-174	0.966754743	0.97925	0.96675474	0.979250263
SDCCH Success Rate	0.983454262	0.001760516	558.6171	2.8E-205	0.979968265	0.98694	0.97996826	0.986940259
TCH Assignment Success Rate	0.940587294	0.004327688	217.3418	1.5E-156	0.932018041	0.949157	0.93201804	0.949156548

4.2 Interpretation of Results

4.2.1 Interpretation of Graphical Representations

Halonen *et al* [25], stated that a well-performing network should have both Call setup success rate and Handover success rate above 95%. Using this as benchmark and referring to the graphical representations in Figures 4.1 to 4.3 for the three observation time intervals, it can be said that averagely, the results of the measured CSSR are within acceptable levels though a number of sharp drops in CSSR recordings exist. The estimated CSSR, on the other hand, shows significant improvements in areas where sharp drops in CSSR values were recorded for the measured CSSR.

A fall in the CSSR below the 95% benchmark were as a result of an increased demand for establishment resources whiles resources were fixed and limited, i.e., blocking increases proportionally to demand. Approaching high congestion situations and maximum handling of traffic, services' requests begin not to be served, thus decreasing TCH Blocking and Handover Failure rates. This results in an increased TCH success rate because the network runs out of call establishment resources (SDCCH mostly). The real call traffic is reduced (as users terminate calls) and TCHs become available. It is worth noting that in cellular networks, TCHs outnumbers SDCCHs in every single Transceiver (TRX) [26].

If conditions worsen more, even deeper beyond the high congestion threshold, then the user cannot even access the network, i.e., Radom Access Channel (RACH) Blocking starts to appear and the user cannot send a Channel Request message at all because the network cannot 'understand' these attempts [22].

A significant observation made from the analysis was the possibility of below standard performance recordings for CSSR being caused by other reasons for which measurements were not available. The most common reasons for such failures are the inadequate radio signal propagation conditions (problems in radio channel in the air interface). The failures in radio channel are usually due to bad signal quality, i.e., the transmitted data includes too many bit errors. Also, the radio signal quality is mostly affected by two components. Firstly, the propagation environment causes attenuation to the transmitted radio signal due to path loss, shadow fading and multipath fading. Secondly, the radio signal may be attenuated by the other radio signals originating from other BTSs having a TRX on the same physical frequency (interference).

4.2.2 Interpretation of Regression Analysis of Estimated CSSR

- Evaluation of R square value

  An important aspect of a statistical procedure that drives a model from empirical data is to indicate or show how well the model predicts results. A widely used measure of the predictive efficacy of a model is its coefficient of determination (R square). If there is a perfect relation between the dependent and independent variables, R square is 1. Where there is no relationship between the dependent and independent variables, R square is 0.

  From Tables 4.1 to 4.3, the regression statistics show an R square value of about 0.9997, 0.9996 and 0.9998 for hourly, busy hour and daily observations respectively. This means that a percentage of about 99.97%, 99.96% and 99.98% (representing hourly, busy hour and daily observations respectively) of the variance in CSSR is expressed in terms of IMM_ASSGN_Success Rate, SDCCH Success Rate and TCH Assignment Success Rate indicating a high predictive ability.

- Test of Statistical Significance (using the p-value approach, $\alpha = 0.05$)

  The p-value shows how likely it is that the coefficient for an independent variable emerged by chance and does not describe a real relationship. For instance, a p-value of 0.05 means that there is a 5% chance that the relationship emerged randomly, and a 95% chance that the relationship is real.

  Condition I: IF $p < \alpha$ THEN reject the null hypothesis.

  Condition II: IF $p > \alpha$ THEN accept the null hypothesis.

  Table 4.4 shows a summary of the p-values drawn from the regression analysis for each independent variable, IMM_ASSGN_Success Rate, SDCCH Success Rate and TCH Assignment Success Rate for the various observation time intervals. P-values of less than α for all three independent variables for the various observation time intervals were recorded. Hence, the null hypothesis is rejected and it can be said that there is a significant relationship between the estimated CSSR and the independent variables. In other words, IMM_ASSGN_Success Rate, SDCCH Success Rate and TCH Assignment Success Rate have a positive and significant effect on the estimated CSSR. P-values of zero (0) as recorded in the case of the hourly observations further lay emphasis on the fact that the independent variables impact significantly on the estimated CSSR.

  Table 4.4: Summary of p-values

	IMM_ASSGN_Success Rate	SDCCH Success Rate	TCH Assignment Success Rate
Hourly	0	0	0
Busy Hour	6.9E-133	7.8E-178	1.8E-138
Daily	1.3E-174	2.8E-205	1.5E-156

- Overall Test of Significance of Regression Parameters (using the F-test)

  F-test shows the significance level for the model as a whole. It measures the likelihood that the model as a whole describes a relationship that emerged at random, rather than a real relationship. The lower the significance F-value, the greater the chance that the relationships in the model are real.

  From Table 4.5, a summary of the significance F-values drawn from the regression analysis is shown. Significantly low F-values were recorded for the three observation time intervals. Therefore, it can be said that there is a very great chance that the relationships in the model are real and the conclusion drawn that the regression parameters are jointly statistically significant.

Table 4.5: Summary of F-test statistic

	significance F-value
Hourly	0
Busy Hour	2.2563E-200
Daily	4.2475E-226

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Operator competency in managing performance and optimizing QoS is not easily taught, it is developed, rather, mainly through trial and error [23]. It is important for mobile network operators to ensure stability and efficiency to deliver a consistent, reliable and high-quality end user (subscriber) satisfaction. For network operators the end user perceived QoS is one of the major forces behind subscriber growth. Thus, it is very important for operators to align their KPI definitions according to what quality and performance means to the subscriber [13-14].

The CSSR is one of the most important KPIs used by all mobile operators. However, there is no standard measurement possible for this parameter [17]. In this study, a CSSR formulation for analyzing GSM network performance in the case where the direct TCH Assignment feature is disabled as presented in [17] was evaluated. Significantly, high R square values of close to 1 were recorded from the regression analysis. This means that knowing the regressors or independent variables (IMM_ASSGN_Success Rate, SDCCH Success Rate and TCH Assignment Success Rate) helps predict the dependent variable (in this case estimated CSSR) very well. It also means that close to 100% of the estimated CSSR around its mean is explained by the regressors. This indeed points to the fact that the CSSR formulation is efficient.

The competitive arena for mobile network operators has changed dramatically over the last few years. It is strongly recommended that the National Communication Authority (NCA) extends the implementation of the CSSR formulation to CSSR measurements. This would guarantee quality in the measurement of CSSR by mobile network operators and ensure higher quality of service delivery to the subscriber.

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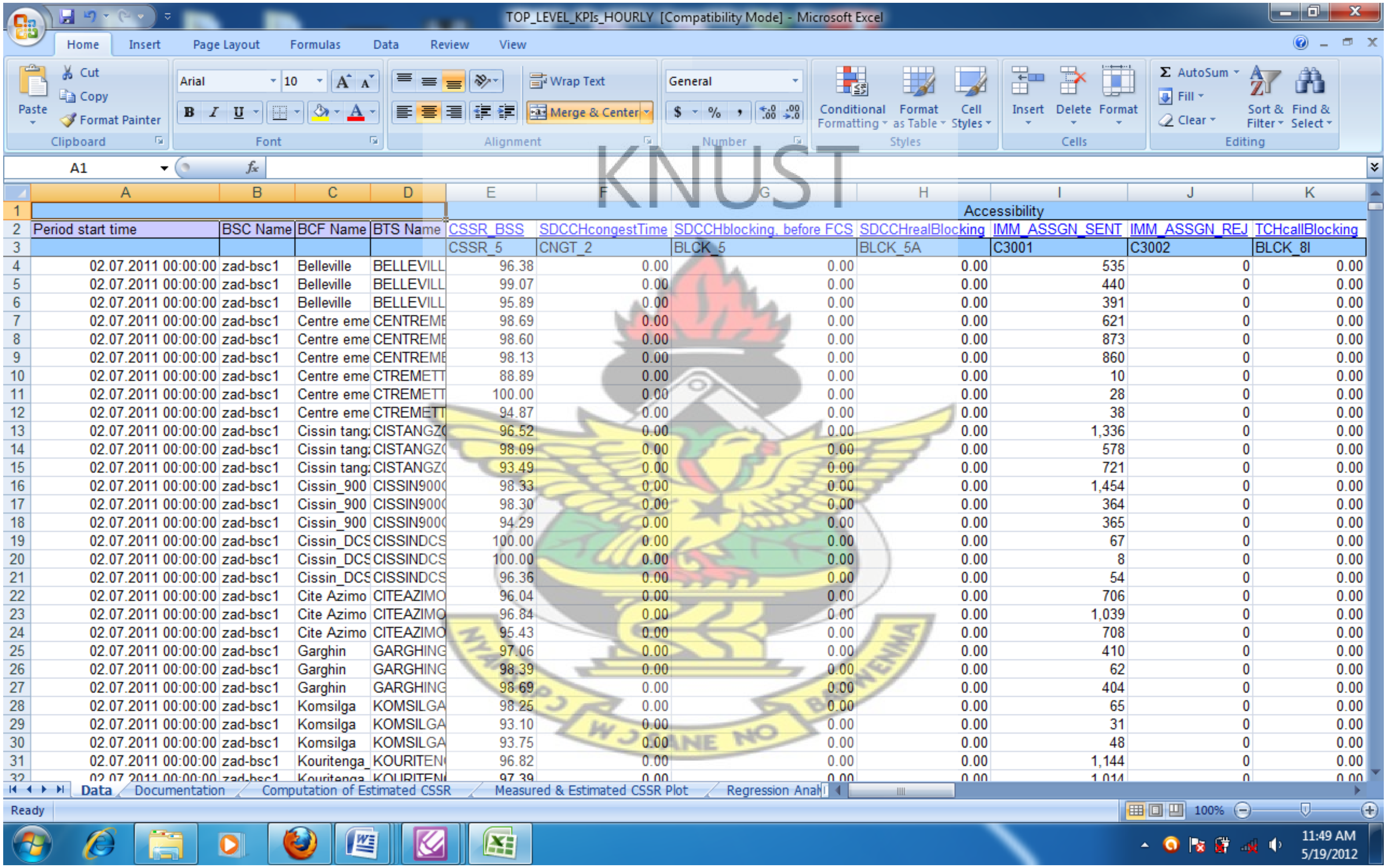
Appendix A: Top Level KPIs



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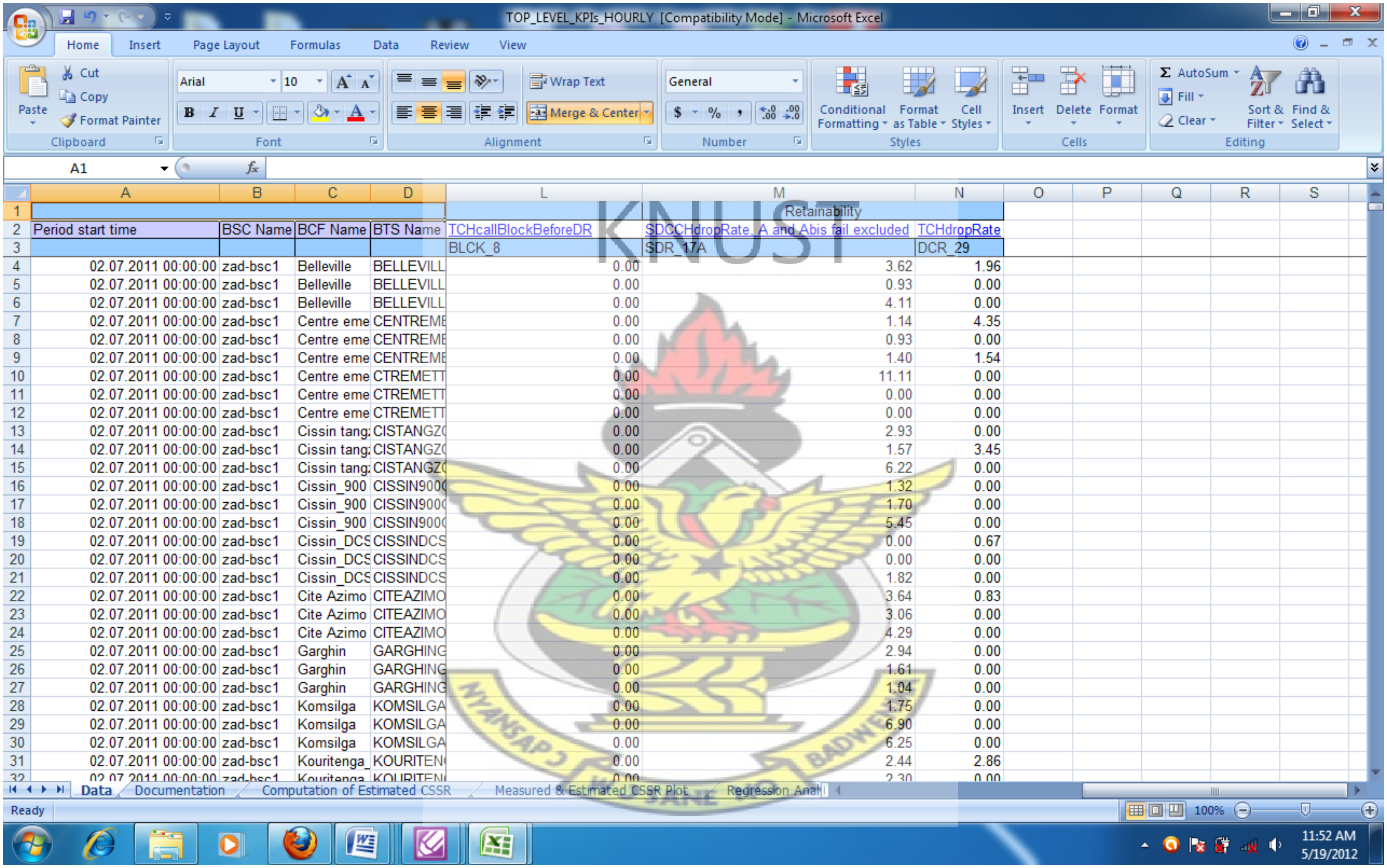
3					CSSR_5	CNGT_2	BLCK_5	BLCK_5A	C3001	C3002	BLCK_8I
4	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILL	96.38	0.00	0.00	0.00	535	0	0.00
5	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILL	99.07	0.00	0.00	0.00	440	0	0.00
6	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILL	95.89	0.00	0.00	0.00	391	0	0.00
7	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	98.69	0.00	0.00	0.00	621	0	0.00
8	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	98.60	0.00	0.00	0.00	873	0	0.00
9	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	98.13	0.00	0.00	0.00	860	0	0.00
10	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	88.89	0.00	0.00	0.00	10	0	0.00
11	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	100.00	0.00	0.00	0.00	28	0	0.00
12	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	94.87	0.00	0.00	0.00	38	0	0.00
13	02.07.2011 00:00:00	zad-bsc1	Cissin tang:	CISTANGZ(	96.52	0.00	0.00	0.00	1,336	0	0.00
14	02.07.2011 00:00:00	zad-bsc1	Cissin tang:	CISTANGZ(	98.09	0.00	0.00	0.00	578	0	0.00
15	02.07.2011 00:00:00	zad-bsc1	Cissin tang:	CISTANGZ(	93.49	0.00	0.00	0.00	721	0	0.00
16	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900(	98.33	0.00	0.00	0.00	1,454	0	0.00
17	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900(	98.30	0.00	0.00	0.00	364	0	0.00
18	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900(	94.29	0.00	0.00	0.00	365	0	0.00
19	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	100.00	0.00	0.00	0.00	67	0	0.00
20	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	100.00	0.00	0.00	0.00	8	0	0.00
21	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	96.36	0.00	0.00	0.00	54	0	0.00
22	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	96.04	0.00	0.00	0.00	706	0	0.00
23	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	96.84	0.00	0.00	0.00	1,039	0	0.00
24	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	95.43	0.00	0.00	0.00	708	0	0.00
25	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	97.06	0.00	0.00	0.00	410	0	0.00
26	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	98.39	0.00	0.00	0.00	62	0	0.00
27	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	98.69	0.00	0.00	0.00	404	0	0.00
28	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	98.25	0.00	0.00	0.00	65	0	0.00
29	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	93.10	0.00	0.00	0.00	31	0	0.00
30	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	93.75	0.00	0.00	0.00	48	0	0.00
31	02.07.2011 00:00:00	zad-bsc1	Kouritenga_	KOURITEN(	96.82	0.00	0.00	0.00	1,144	0	0.00
32	02.07.2011 00:00:00	zad-bsc1	Kouritenga_	KOURITEN(	97.39	0.00	0.00	0.00	1,014	0	0.00



	A	B	C	D	L	M	N
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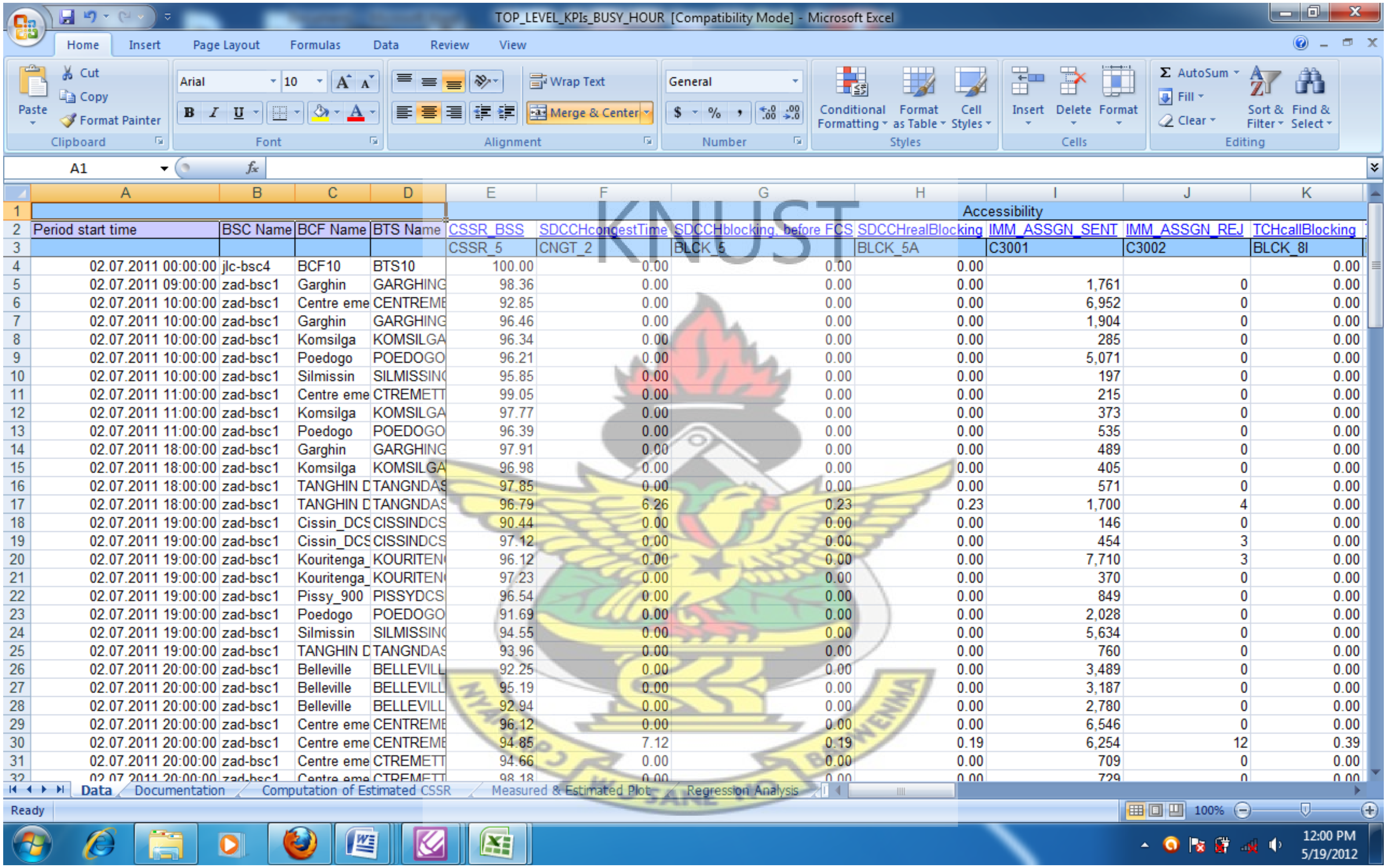
6	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILL	0.00	4.11	0.00
7	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	0.00	1.14	4.35
8	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	0.00	0.93	0.00
9	02.07.2011 00:00:00	zad-bsc1	Centre eme	CENTREME	0.00	1.40	1.54
10	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	11.11	0.00
11	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	0.00	0.00
12	02.07.2011 00:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	0.00	0.00
13	02.07.2011 00:00:00	zad-bsc1	Cissin tang	CISTANGZ	0.00	2.93	0.00
14	02.07.2011 00:00:00	zad-bsc1	Cissin tang	CISTANGZ	0.00	1.57	3.45
15	02.07.2011 00:00:00	zad-bsc1	Cissin tang	CISTANGZ	0.00	6.22	0.00
16	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900	0.00	1.32	0.00
17	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900	0.00	1.70	0.00
18	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900	0.00	5.45	0.00
19	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	0.00	0.67
20	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	0.00	0.00
21	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	1.82	0.00
22	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	3.64	0.83
23	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	3.06	0.00
24	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	4.29	0.00
25	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	0.00	2.94	0.00
26	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	0.00	1.61	0.00
27	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	0.00	1.04	0.00
28	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	1.75	0.00
29	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	6.90	0.00
30	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	6.25	0.00
31	02.07.2011 00:00:00	zad-bsc1	Kouritenga_	KOURITEN	0.00	2.44	2.86
32	02.07.2011 00:00:00	zad-bsc1	Kouritenga	KOURITEN	0.00	2.30	0.00



	A	B	C	D	E	F	G	H	I	J	K
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2	Period start time	BSC Name	BCF Name	BTS Name	CSSR_BSS	SDCCHcongestTime	SDCCHblocking, before FCS	SDCCHrealBlocking	IMM_ASSGN_SENT	IMM_ASSGN_REJ	TCHcallBlocking
3					CSSR_5	CNGT_2	BLCK_5	BLCK_5A	C3001	C3002	BLCK_8I
4	02.07.2011 00:00:00	jlc-bsc4	BCF10	BTS10	100.00	0.00	0.00	0.00			0.00
5	02.07.2011 09:00:00	zad-bsc1	Garghin	GARGHING	98.36	0.00	0.00	0.00	1,761	0	0.00
6	02.07.2011 10:00:00	zad-bsc1	Centre eme	CENTREME	92.85	0.00	0.00	0.00	6,952	0	0.00
7	02.07.2011 10:00:00	zad-bsc1	Garghin	GARGHING	96.46	0.00	0.00	0.00	1,904	0	0.00
8	02.07.2011 10:00:00	zad-bsc1	Komsilga	KOMSILGA	96.34	0.00	0.00	0.00	285	0	0.00
9	02.07.2011 10:00:00	zad-bsc1	Poedogo	POEDOGO	96.21	0.00	0.00	0.00	5,071	0	0.00
10	02.07.2011 10:00:00	zad-bsc1	Silmissin	SILMISSIN	95.85	0.00	0.00	0.00	197	0	0.00
11	02.07.2011 11:00:00	zad-bsc1	Centre eme	CTREMETT	99.05	0.00	0.00	0.00	215	0	0.00
12	02.07.2011 11:00:00	zad-bsc1	Komsilga	KOMSILGA	97.77	0.00	0.00	0.00	373	0	0.00
13	02.07.2011 11:00:00	zad-bsc1	Poedogo	POEDOGO	96.39	0.00	0.00	0.00	535	0	0.00
14	02.07.2011 18:00:00	zad-bsc1	Garghin	GARGHING	97.91	0.00	0.00	0.00	489	0	0.00
15	02.07.2011 18:00:00	zad-bsc1	Komsilga	KOMSILGA	96.98	0.00	0.00	0.00	405	0	0.00
16	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDAS	97.85	0.00	0.00	0.00	571	0	0.00
17	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDAS	96.79	6.26	0.23	0.23	1,700	4	0.00
18	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	90.44	0.00	0.00	0.00	146	0	0.00
19	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	97.12	0.00	0.00	0.00	454	3	0.00
20	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITEN	96.12	0.00	0.00	0.00	7,710	3	0.00
21	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITEN	97.23	0.00	0.00	0.00	370	0	0.00
22	02.07.2011 19:00:00	zad-bsc1	Pissy_900	PISSYDCS	96.54	0.00	0.00	0.00	849	0	0.00
23	02.07.2011 19:00:00	zad-bsc1	Poedogo	POEDOGO	91.69	0.00	0.00	0.00	2,028	0	0.00
24	02.07.2011 19:00:00	zad-bsc1	Silmissin	SILMISSIN	94.55	0.00	0.00	0.00	5,634	0	0.00
25	02.07.2011 19:00:00	zad-bsc1	TANGHIN D	TANGNDAS	93.96	0.00	0.00	0.00	760	0	0.00
26	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	92.25	0.00	0.00	0.00	3,489	0	0.00
27	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	95.19	0.00	0.00	0.00	3,187	0	0.00
28	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	92.94	0.00	0.00	0.00	2,780	0	0.00
29	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREME	96.12	0.00	0.00	0.00	6,546	0	0.00
30	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREME	94.85	7.12	0.19	0.19	6,254	12	0.39
31	02.07.2011 20:00:00	zad-bsc1	Centre eme	CTREMETT	94.66	0.00	0.00	0.00	709	0	0.00
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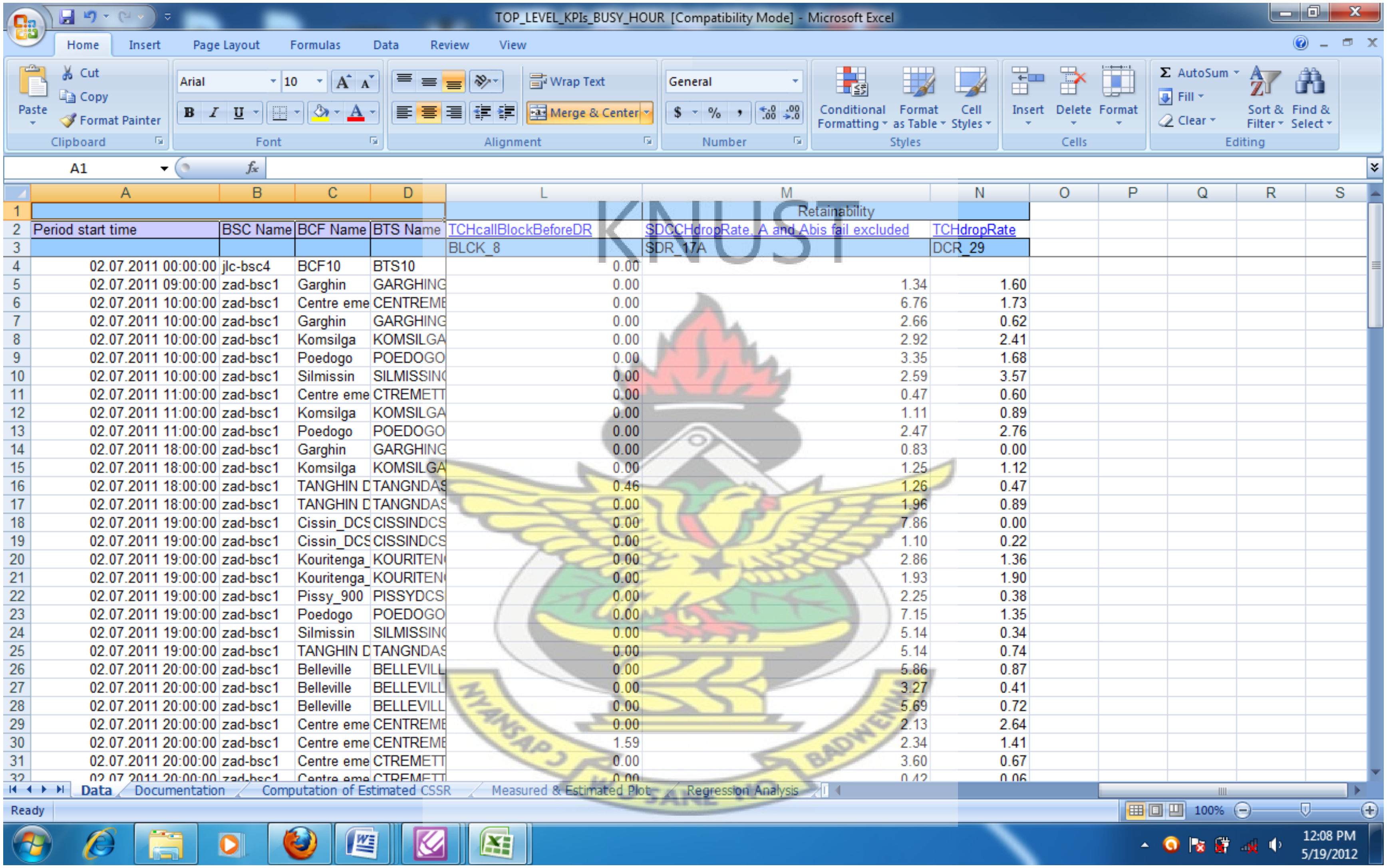

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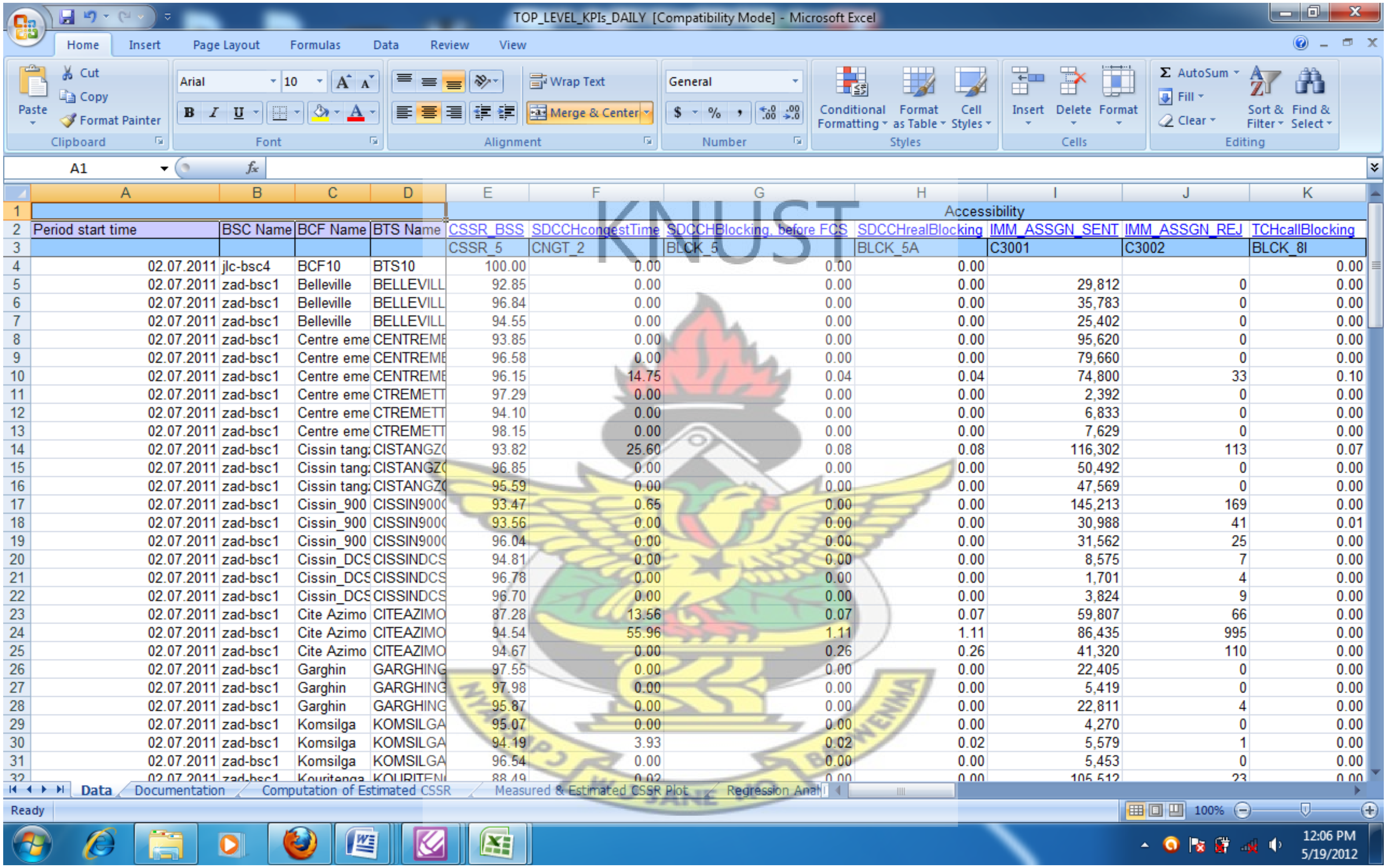
2	Period start time	BSC Name	BCF Name	BTS Name	TCHcallBlockBeforeDR	SDCCHdropRate, A and Abis fail excluded	TCHdropRate
3					BLCK_8	SDR_17A	DCR_29
4	02.07.2011 00:00:00	jlc-bsc4	BCF10	BTS10	0.00		
5	02.07.2011 09:00:00	zad-bsc1	Garghin	GARGHING	0.00	1.34	1.60
6	02.07.2011 10:00:00	zad-bsc1	Centre eme	CENTREME	0.00	6.76	1.73
7	02.07.2011 10:00:00	zad-bsc1	Garghin	GARGHING	0.00	2.66	0.62
8	02.07.2011 10:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	2.92	2.41
9	02.07.2011 10:00:00	zad-bsc1	Poedogo	POEDOGO	0.00	3.35	1.68
10	02.07.2011 10:00:00	zad-bsc1	Silmissin	SILMISSIN	0.00	2.59	3.57
11	02.07.2011 11:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	0.47	0.60
12	02.07.2011 11:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	1.11	0.89
13	02.07.2011 11:00:00	zad-bsc1	Poedogo	POEDOGO	0.00	2.47	2.76
14	02.07.2011 18:00:00	zad-bsc1	Garghin	GARGHING	0.00	0.83	0.00
15	02.07.2011 18:00:00	zad-bsc1	Komsilga	KOMSILGA	0.00	1.25	1.12
16	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDAS	0.46	1.26	0.47
17	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDAS	0.00	1.96	0.89
18	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	7.86	0.00
19	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	1.10	0.22
20	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITEN	0.00	2.86	1.36
21	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITEN	0.00	1.93	1.90
22	02.07.2011 19:00:00	zad-bsc1	Pissy_900	PISSYDCS	0.00	2.25	0.38
23	02.07.2011 19:00:00	zad-bsc1	Poedogo	POEDOGO	0.00	7.15	1.35
24	02.07.2011 19:00:00	zad-bsc1	Silmissin	SILMISSIN	0.00	5.14	0.34
25	02.07.2011 19:00:00	zad-bsc1	TANGHIN D	TANGNDAS	0.00	5.14	0.74
26	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	0.00	5.86	0.87
27	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	0.00	3.27	0.41
28	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILL	0.00	5.69	0.72
29	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREME	0.00	2.13	2.64
30	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREME	1.59	2.34	1.41
31	02.07.2011 20:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	3.60	0.67
32	02.07.2011 20:00:00	zad-bsc1	Centre eme	CTREMETT	0.00	0.42	0.06



	A	B	C	D	E	F	G	H	I	J	K
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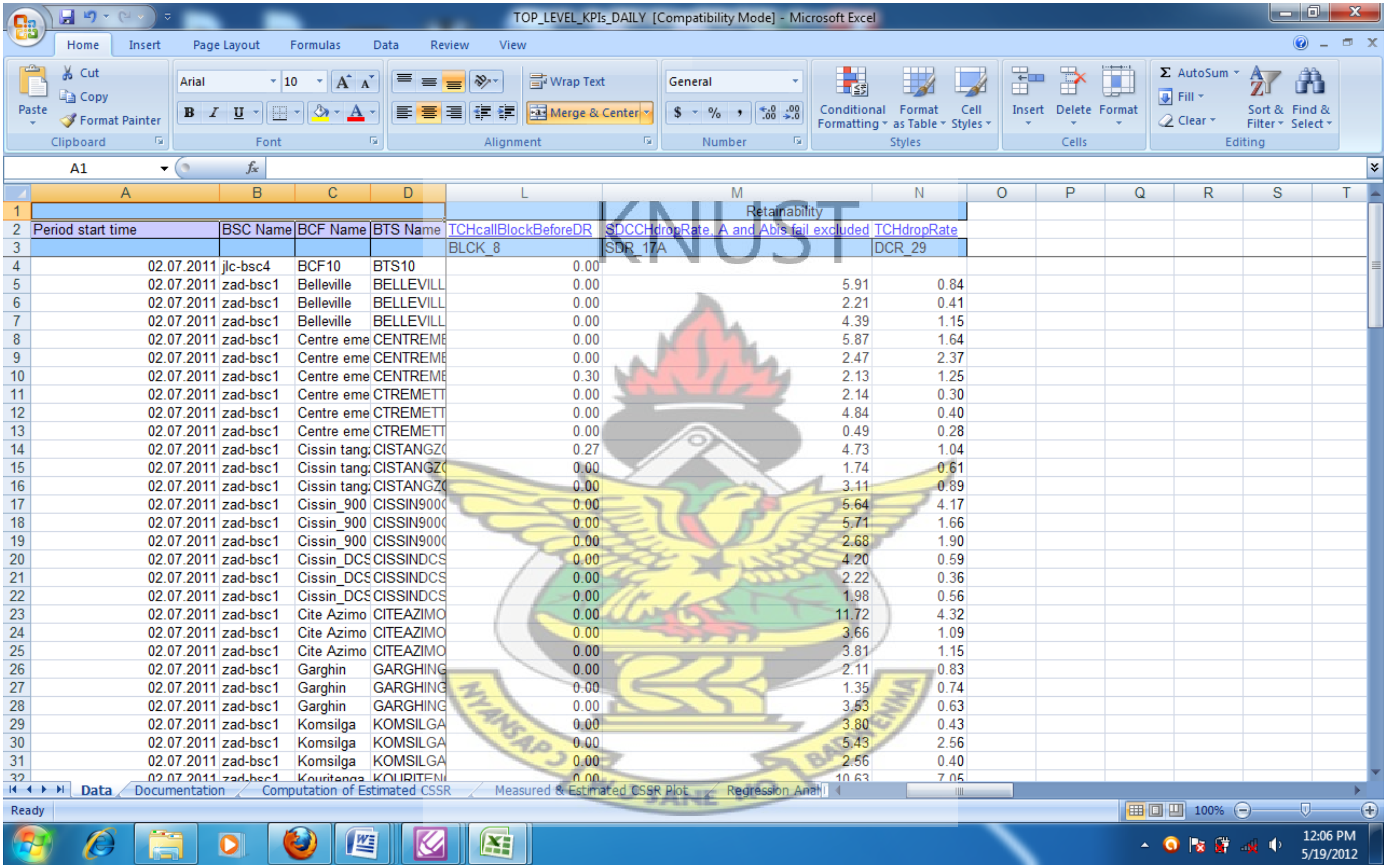
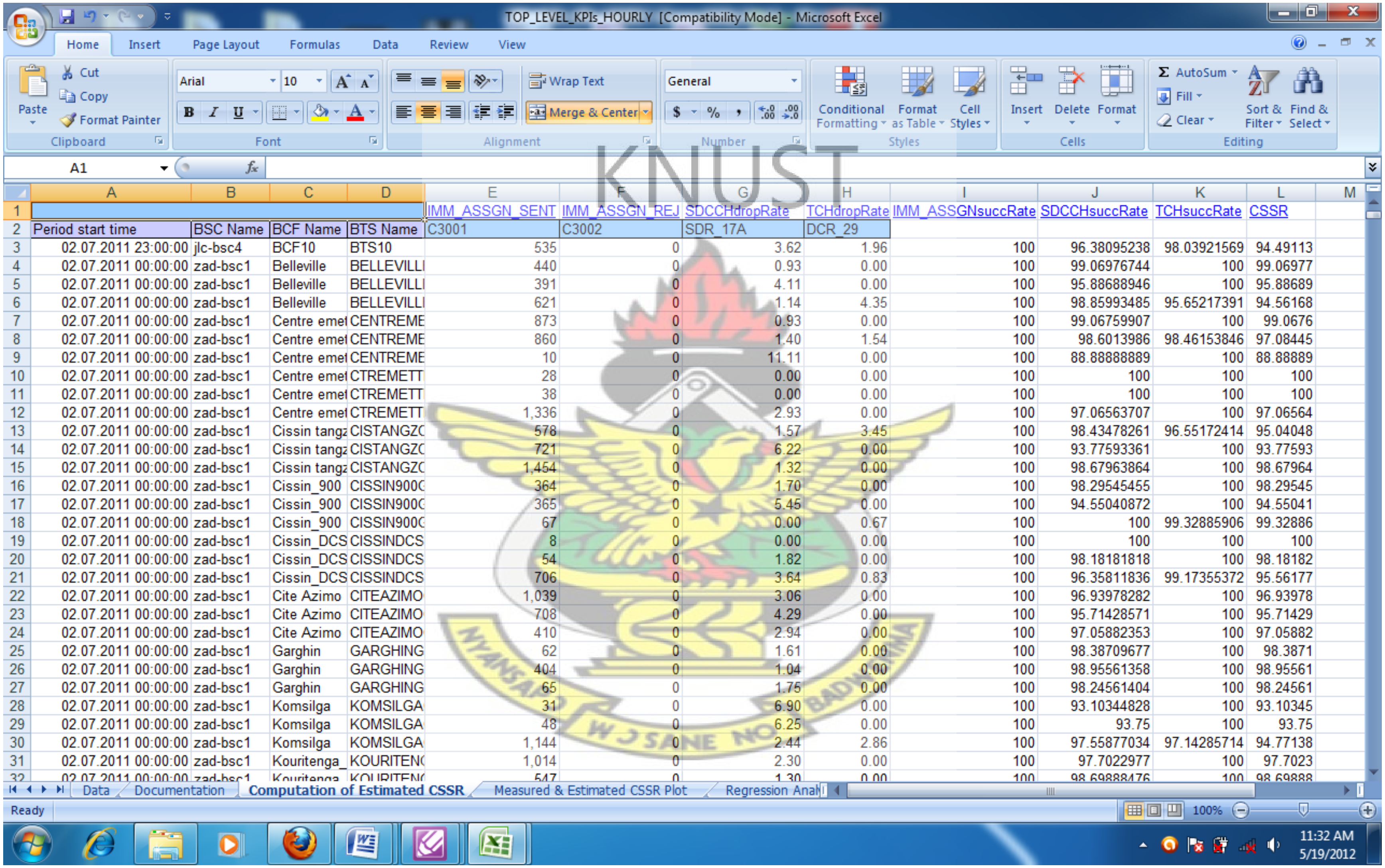
2	Period start time	BSC Name	BCF Name	BTS Name	CSSR_BSS	SDCCHcongestTime	SDCCHBlocking, before FCS	SDCCHrealBlocking	IMM_ASSGN_SENT	IMM_ASSGN_REJ	TCHcallBlocking
3					CSSR_5	CNGT_2	BLCK_5	BLCK_5A	C3001	C3002	BLCK_8I
4	02.07.2011	jlc-bsc4	BCF10	BTS10	100.00	0.00	0.00	0.00			0.00
5	02.07.2011	zad-bsc1	Belleville	BELLEVILL	92.85	0.00	0.00	0.00	29,812	0	0.00
6	02.07.2011	zad-bsc1	Belleville	BELLEVILL	96.84	0.00	0.00	0.00	35,783	0	0.00
7	02.07.2011	zad-bsc1	Belleville	BELLEVILL	94.55	0.00	0.00	0.00	25,402	0	0.00
8	02.07.2011	zad-bsc1	Centre eme	CENTREME	93.85	0.00	0.00	0.00	95,620	0	0.00
9	02.07.2011	zad-bsc1	Centre eme	CENTREME	96.58	0.00	0.00	0.00	79,660	0	0.00
10	02.07.2011	zad-bsc1	Centre eme	CENTREME	96.15	14.75	0.04	0.04	74,800	33	0.10
11	02.07.2011	zad-bsc1	Centre eme	CTREMETT	97.29	0.00	0.00	0.00	2,392	0	0.00
12	02.07.2011	zad-bsc1	Centre eme	CTREMETT	94.10	0.00	0.00	0.00	6,833	0	0.00
13	02.07.2011	zad-bsc1	Centre eme	CTREMETT	98.15	0.00	0.00	0.00	7,629	0	0.00
14	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	93.82	25.60	0.08	0.08	116,302	113	0.07
15	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	96.85	0.00	0.00	0.00	50,492	0	0.00
16	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	95.59	0.00	0.00	0.00	47,569	0	0.00
17	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	93.47	0.65	0.00	0.00	145,213	169	0.00
18	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	93.56	0.00	0.00	0.00	30,988	41	0.01
19	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	96.04	0.00	0.00	0.00	31,562	25	0.00
20	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	94.81	0.00	0.00	0.00	8,575	7	0.00
21	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	96.78	0.00	0.00	0.00	1,701	4	0.00
22	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	96.70	0.00	0.00	0.00	3,824	9	0.00
23	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	87.28	13.56	0.07	0.07	59,807	66	0.00
24	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	94.54	55.96	1.11	1.11	86,435	995	0.00
25	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	94.67	0.00	0.26	0.26	41,320	110	0.00
26	02.07.2011	zad-bsc1	Garghin	GARGHING	97.55	0.00	0.00	0.00	22,405	0	0.00
27	02.07.2011	zad-bsc1	Garghin	GARGHING	97.98	0.00	0.00	0.00	5,419	0	0.00
28	02.07.2011	zad-bsc1	Garghin	GARGHING	95.87	0.00	0.00	0.00	22,811	4	0.00
29	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	95.07	0.00	0.00	0.00	4,270	0	0.00
30	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	94.19	3.93	0.02	0.02	5,579	1	0.00
31	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	96.54	0.00	0.00	0.00	5,453	0	0.00
32	02.07.2011	zad-bsc1	Kouritenga	KOURITEN	88.49	0.02	0.00	0.00	105,512	23	0.00

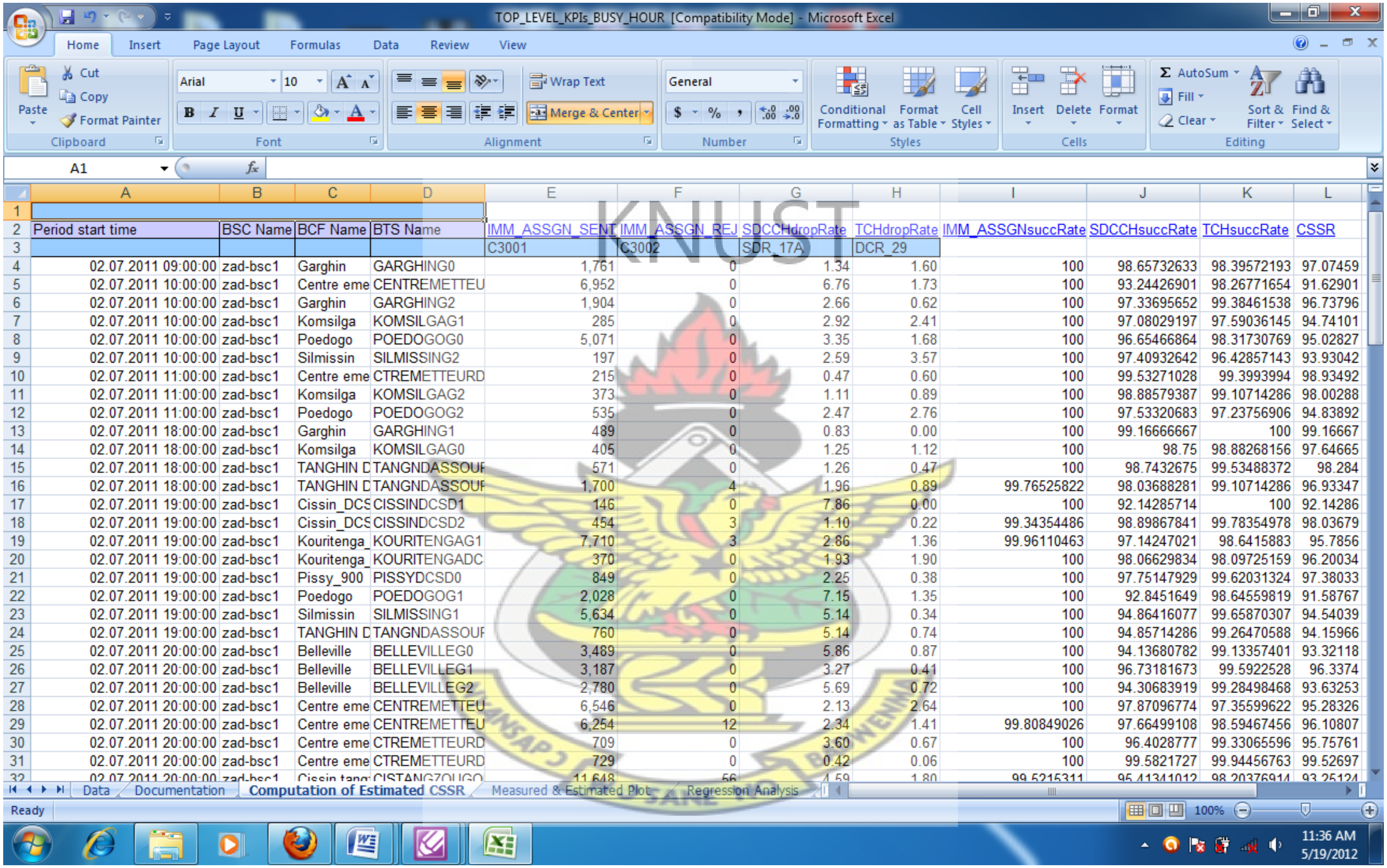


	A	B	C	D	L	M	N
1						Retainability	
2	Period start time	BSC Name	BCF Name	BTS Name	TCHcallBlockBeforeDR	SDCCHdropRate, A and Abis fail excluded	TCHdropRate
3					BLCK_8	SDR_17A	DCR_29
4	02.07.2011	jlc-bsc4	BCF10	BTS10	0.00		
5	02.07.2011	zad-bsc1	Belleville	BELLEVILL	0.00	5.91	0.84
6	02.07.2011	zad-bsc1	Belleville	BELLEVILL	0.00	2.21	0.41
7	02.07.2011	zad-bsc1	Belleville	BELLEVILL	0.00	4.39	1.15
8	02.07.2011	zad-bsc1	Centre eme	CENTREME	0.00	5.87	1.64
9	02.07.2011	zad-bsc1	Centre eme	CENTREME	0.00	2.47	2.37
10	02.07.2011	zad-bsc1	Centre eme	CENTREME	0.30	2.13	1.25
11	02.07.2011	zad-bsc1	Centre eme	CTREMETT	0.00	2.14	0.30
12	02.07.2011	zad-bsc1	Centre eme	CTREMETT	0.00	4.84	0.40
13	02.07.2011	zad-bsc1	Centre eme	CTREMETT	0.00	0.49	0.28
14	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	0.27	4.73	1.04
15	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	0.00	1.74	0.61
16	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZ(	0.00	3.11	0.89
17	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	0.00	5.64	4.17
18	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	0.00	5.71	1.66
19	02.07.2011	zad-bsc1	Cissin_900	CISSIN900(	0.00	2.68	1.90
20	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	4.20	0.59
21	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	2.22	0.36
22	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCS	0.00	1.98	0.56
23	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	11.72	4.32
24	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	3.66	1.09
25	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMO	0.00	3.81	1.15
26	02.07.2011	zad-bsc1	Garghin	GARGHING	0.00	2.11	0.83
27	02.07.2011	zad-bsc1	Garghin	GARGHING	0.00	1.35	0.74
28	02.07.2011	zad-bsc1	Garghin	GARGHING	0.00	3.53	0.63
29	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	0.00	3.80	0.43
30	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	0.00	5.43	2.56
31	02.07.2011	zad-bsc1	Komsilga	KOMSILGA	0.00	2.56	0.40
32	02.07.2011	zad-bsc1	Kouritenga	KOURITENI	0.00	10.63	7.05

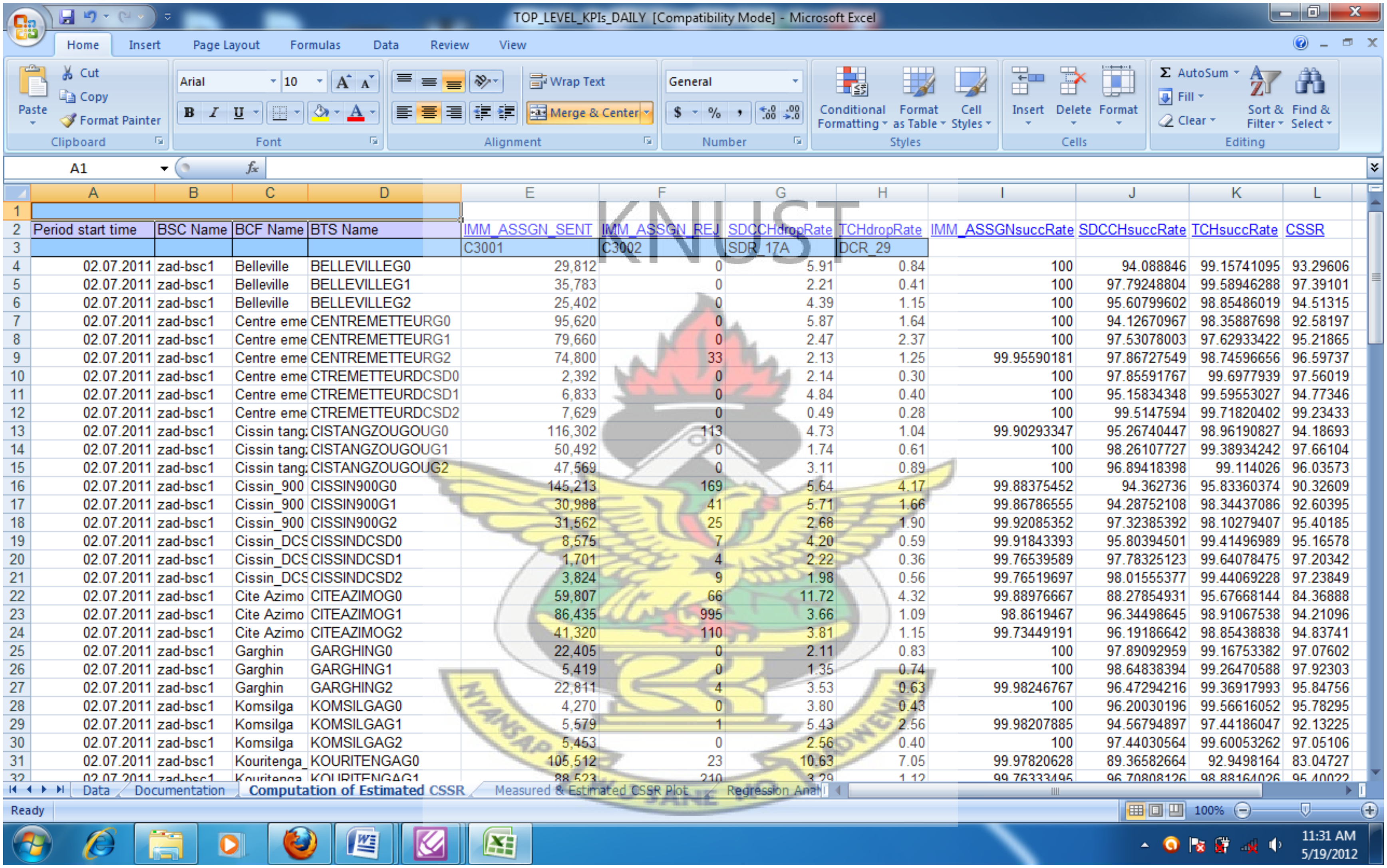
Appendix B: Computation of Estimated CSSR



	Period start time	BSC Name	BCF Name	BTS Name	IMM_ASSGN_SENT	IMM_ASSGN_REJ	SDCCHdropRate	TCHdropRate	IMM_ASSGNsuccRate	SDCCHsuccRate	TCHsuccRate	CSSR
2					C3001	C3002	SDR_17A	DCR_29				
3	02.07.2011 23:00:00	jlc-bsc4	BCF10	BTS10	535	0	3.62	1.96	100	96.38095238	98.03921569	94.49113
4	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILLI	440	0	0.93	0.00	100	99.06976744	100	99.06977
5	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILLI	391	0	4.11	0.00	100	95.88688946	100	95.88689
6	02.07.2011 00:00:00	zad-bsc1	Belleville	BELLEVILLI	621	0	1.14	4.35	100	98.85993485	95.65217391	94.56168
7	02.07.2011 00:00:00	zad-bsc1	Centre emel	CENTREME	873	0	0.93	0.00	100	99.06759907	100	99.0676
8	02.07.2011 00:00:00	zad-bsc1	Centre emel	CENTREME	860	0	1.40	1.54	100	98.6013986	98.46153846	97.08445
9	02.07.2011 00:00:00	zad-bsc1	Centre emel	CENTREME	10	0	11.11	0.00	100	88.88888889	100	88.88889
10	02.07.2011 00:00:00	zad-bsc1	Centre emel	CTREMETT	28	0	0.00	0.00	100	100	100	100
11	02.07.2011 00:00:00	zad-bsc1	Centre emel	CTREMETT	38	0	0.00	0.00	100	100	100	100
12	02.07.2011 00:00:00	zad-bsc1	Centre emel	CTREMETT	1,336	0	2.93	0.00	100	97.06563707	100	97.06564
13	02.07.2011 00:00:00	zad-bsc1	Cissin tangz	CISTANGZC	578	0	1.57	3.45	100	98.43478261	96.55172414	95.04048
14	02.07.2011 00:00:00	zad-bsc1	Cissin tangz	CISTANGZC	721	0	6.22	0.00	100	93.77593361	100	93.77593
15	02.07.2011 00:00:00	zad-bsc1	Cissin tangz	CISTANGZC	1,454	0	1.32	0.00	100	98.67963864	100	98.67964
16	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900C	364	0	1.70	0.00	100	98.29545455	100	98.29545
17	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900C	365	0	5.45	0.00	100	94.55040872	100	94.55041
18	02.07.2011 00:00:00	zad-bsc1	Cissin_900	CISSIN900C	67	0	0.00	0.67	100	100	99.32885906	99.32886
19	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	8	0	0.00	0.00	100	100	100	100
20	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	54	0	1.82	0.00	100	98.18181818	100	98.18182
21	02.07.2011 00:00:00	zad-bsc1	Cissin_DCS	CISSINDCS	706	0	3.64	0.83	100	96.35811836	99.17355372	95.56177
22	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	1,039	0	3.06	0.00	100	96.93978282	100	96.93978
23	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	708	0	4.29	0.00	100	95.71428571	100	95.71429
24	02.07.2011 00:00:00	zad-bsc1	Cite Azimo	CITEAZIMO	410	0	2.94	0.00	100	97.05882353	100	97.05882
25	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	62	0	1.61	0.00	100	98.38709677	100	98.3871
26	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	404	0	1.04	0.00	100	98.95561358	100	98.95561
27	02.07.2011 00:00:00	zad-bsc1	Garghin	GARGHING	65	0	1.75	0.00	100	98.24561404	100	98.24561
28	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	31	0	6.90	0.00	100	93.10344828	100	93.10345
29	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	48	0	6.25	0.00	100	93.75	100	93.75
30	02.07.2011 00:00:00	zad-bsc1	Komsilga	KOMSILGA	1,144	0	2.44	2.86	100	97.55877034	97.14285714	94.77138
31	02.07.2011 00:00:00	zad-bsc1	Kouritenga_	KOURITENC	1,014	0	2.30	0.00	100	97.7022977	100	97.7023
32	02.07.2011 00:00:00	zad-bsc1	Kouritenga	KOURITENC	547	0	1.30	0.00	100	98.69888476	100	98.69888



	A	B	C	D	E	F	G	H	I	J	K	L
1												
2	Period start time	BSC Name	BCF Name	BTS Name	IMM_ASSGN_SENT	IMM_ASSGN_REJ	SDCCHdropRate	TCHdropRate	IMM_ASSGNsuccRate	SDCCHsuccRate	TCHsuccRate	CSSR
3					C3001	C3002	SDR_17A	DCR_29				
4	02.07.2011 09:00:00	zad-bsc1	Garghin	GARGHING0	1,761	0	1.34	1.60	100	98.65732633	98.39572193	97.07459
5	02.07.2011 10:00:00	zad-bsc1	Centre eme	CENTREMETTEU	6,952	0	6.76	1.73	100	93.24426901	98.26771654	91.62901
6	02.07.2011 10:00:00	zad-bsc1	Garghin	GARGHING2	1,904	0	2.66	0.62	100	97.33695652	99.38461538	96.73796
7	02.07.2011 10:00:00	zad-bsc1	Komsilga	KOMSILGAG1	285	0	2.92	2.41	100	97.08029197	97.59036145	94.74101
8	02.07.2011 10:00:00	zad-bsc1	Poedogo	POEDOGOG0	5,071	0	3.35	1.68	100	96.65466864	98.31730769	95.02827
9	02.07.2011 10:00:00	zad-bsc1	Silmissin	SILMISSING2	197	0	2.59	3.57	100	97.40932642	96.42857143	93.93042
10	02.07.2011 11:00:00	zad-bsc1	Centre eme	CTREMETTEURD	215	0	0.47	0.60	100	99.53271028	99.3993994	98.93492
11	02.07.2011 11:00:00	zad-bsc1	Komsilga	KOMSILGAG2	373	0	1.11	0.89	100	98.88579387	99.10714286	98.00288
12	02.07.2011 11:00:00	zad-bsc1	Poedogo	POEDOGOG2	535	0	2.47	2.76	100	97.53320683	97.23756906	94.83892
13	02.07.2011 18:00:00	zad-bsc1	Garghin	GARGHING1	489	0	0.83	0.00	100	99.16666667	100	99.16667
14	02.07.2011 18:00:00	zad-bsc1	Komsilga	KOMSILGAG0	405	0	1.25	1.12	100	98.75	98.88268156	97.64665
15	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDASSOUF	571	0	1.26	0.47	100	98.7432675	99.53488372	98.284
16	02.07.2011 18:00:00	zad-bsc1	TANGHIN D	TANGNDASSOUF	1,700	4	1.96	0.89	99.76525822	98.03688281	99.10714286	96.93347
17	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCSD1	146	0	7.86	0.00	100	92.14285714	100	92.14286
18	02.07.2011 19:00:00	zad-bsc1	Cissin_DCS	CISSINDCSD2	454	3	1.10	0.22	99.34354486	98.89867841	99.78354978	98.03679
19	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITENGAG1	7,710	3	2.86	1.36	99.96110463	97.14247021	98.6415883	95.7856
20	02.07.2011 19:00:00	zad-bsc1	Kouritenga_	KOURITENGADC	370	0	1.93	1.90	100	98.06629834	98.09725159	96.20034
21	02.07.2011 19:00:00	zad-bsc1	Pissy_900	PISSYDCSD0	849	0	2.25	0.38	100	97.75147929	99.62031324	97.38033
22	02.07.2011 19:00:00	zad-bsc1	Poedogo	POEDOGOG1	2,028	0	7.15	1.35	100	92.8451649	98.64559819	91.58767
23	02.07.2011 19:00:00	zad-bsc1	Silmissin	SILMISSING1	5,634	0	5.14	0.34	100	94.86416077	99.65870307	94.54039
24	02.07.2011 19:00:00	zad-bsc1	TANGHIN D	TANGNDASSOUF	760	0	5.14	0.74	100	94.85714286	99.26470588	94.15966
25	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILLEG0	3,489	0	5.86	0.87	100	94.13680782	99.13357401	93.32118
26	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILLEG1	3,187	0	3.27	0.41	100	96.73181673	99.5922528	96.3374
27	02.07.2011 20:00:00	zad-bsc1	Belleville	BELLEVILLEG2	2,780	0	5.69	0.72	100	94.30683919	99.28498468	93.63253
28	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREMETTEU	6,546	0	2.13	2.64	100	97.87096774	97.35599622	95.28326
29	02.07.2011 20:00:00	zad-bsc1	Centre eme	CENTREMETTEU	6,254	12	2.34	1.41	99.80849026	97.66499108	98.59467456	96.10807
30	02.07.2011 20:00:00	zad-bsc1	Centre eme	CTREMETTEURD	709	0	3.60	0.67	100	96.4028777	99.33065596	95.75761
31	02.07.2011 20:00:00	zad-bsc1	Centre eme	CTREMETTEURD	729	0	0.42	0.06	100	99.5821727	99.94456763	99.52697
32	02.07.2011 20:00:00	zad-bsc1	Cissin tang	CISTANGZOUGO	11,648	56	4.59	1.80	99.5215311	95.41341012	98.20376914	93.25124



	Period start time	BSC Name	BCF Name	BTS Name	IMM_ASSGN_SENT	IMM_ASSGN_REJ	SDCCHdropRate	TCHdropRate	IMM_ASSGNsuccRate	SDCCHsuccRate	TCHsuccRate	CSSR
3					C3001	C3002	SDR_17A	DCR_29				
4	02.07.2011	zad-bsc1	Belleville	BELLEVILLEG0	29,812	0	5.91	0.84	100	94.088846	99.15741095	93.29606
5	02.07.2011	zad-bsc1	Belleville	BELLEVILLEG1	35,783	0	2.21	0.41	100	97.79248804	99.58946288	97.39101
6	02.07.2011	zad-bsc1	Belleville	BELLEVILLEG2	25,402	0	4.39	1.15	100	95.60799602	98.85486019	94.51315
7	02.07.2011	zad-bsc1	Centre eme	CENTREMETTEURG0	95,620	0	5.87	1.64	100	94.12670967	98.35887698	92.58197
8	02.07.2011	zad-bsc1	Centre eme	CENTREMETTEURG1	79,660	0	2.47	2.37	100	97.53078003	97.62933422	95.21865
9	02.07.2011	zad-bsc1	Centre eme	CENTREMETTEURG2	74,800	33	2.13	1.25	99.95590181	97.86727549	98.74596656	96.59737
10	02.07.2011	zad-bsc1	Centre eme	CTREMETTEURDCSD0	2,392	0	2.14	0.30	100	97.85591767	99.6977939	97.56019
11	02.07.2011	zad-bsc1	Centre eme	CTREMETTEURDCSD1	6,833	0	4.84	0.40	100	95.15834348	99.59553027	94.77346
12	02.07.2011	zad-bsc1	Centre eme	CTREMETTEURDCSD2	7,629	0	0.49	0.28	100	99.5147594	99.71820402	99.23433
13	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZOUGOUG0	116,302	113	4.73	1.04	99.90293347	95.26740447	98.96190827	94.18693
14	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZOUGOUG1	50,492	0	1.74	0.61	100	98.26107727	99.38934242	97.66104
15	02.07.2011	zad-bsc1	Cissin tang:	CISTANGZOUGOUG2	47,569	0	3.11	0.89	100	96.89418398	99.114026	96.03573
16	02.07.2011	zad-bsc1	Cissin_900	CISSIN900G0	145,213	169	5.64	4.17	99.88375452	94.362736	95.83360374	90.32609
17	02.07.2011	zad-bsc1	Cissin_900	CISSIN900G1	30,988	41	5.71	1.66	99.86786555	94.28752108	98.34437086	92.60395
18	02.07.2011	zad-bsc1	Cissin_900	CISSIN900G2	31,562	25	2.68	1.90	99.92085352	97.32385392	98.10279407	95.40185
19	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCSD0	8,575	7	4.20	0.59	99.91843393	95.80394501	99.41496989	95.16578
20	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCSD1	1,701	4	2.22	0.36	99.76539589	97.78325123	99.64078475	97.20342
21	02.07.2011	zad-bsc1	Cissin_DCS	CISSINDCSD2	3,824	9	1.98	0.56	99.76519697	98.01555377	99.44069228	97.23849
22	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMOG0	59,807	66	11.72	4.32	99.88976667	88.27854931	95.67668144	84.36888
23	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMOG1	86,435	995	3.66	1.09	98.8619467	96.34498645	98.91067538	94.21096
24	02.07.2011	zad-bsc1	Cite Azimo	CITEAZIMOG2	41,320	110	3.81	1.15	99.73449191	96.19186642	98.85438838	94.83741
25	02.07.2011	zad-bsc1	Garghin	GARGHING0	22,405	0	2.11	0.83	100	97.89092959	99.16753382	97.07602
26	02.07.2011	zad-bsc1	Garghin	GARGHING1	5,419	0	1.35	0.74	100	98.64838394	99.26470588	97.92303
27	02.07.2011	zad-bsc1	Garghin	GARGHING2	22,811	4	3.53	0.63	99.98246767	96.47294216	99.36917993	95.84756
28	02.07.2011	zad-bsc1	Komsilga	KOMSILGAG0	4,270	0	3.80	0.43	100	96.20030196	99.56616052	95.78295
29	02.07.2011	zad-bsc1	Komsilga	KOMSILGAG1	5,579	1	5.43	2.56	99.98207885	94.56794897	97.44186047	92.13225
30	02.07.2011	zad-bsc1	Komsilga	KOMSILGAG2	5,453	0	2.56	0.40	100	97.44030564	99.60053262	97.05106
31	02.07.2011	zad-bsc1	Kouritenga_	KOURITENGAG0	105,512	23	10.63	7.05	99.97820628	89.36582664	92.9498164	83.04727
32	02.07.2011	zad-bsc1	Kouritenga_	KOURITENGAG1	88,523	210	3.29	1.12	99.76333495	96.70808126	98.88164026	95.40022