ENHANCING EMERGENCY CALL PROCEDURE IN GSM/W-CDMA NETWORKS TO INCORPORATE PERSONAL SECURITY

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APPROVAL PAGE

This is to certify that this thesis, "Enhancing Emergency Call Handling Procedure in GSM/W-CDMA NetworksTo Incorporate Personal Security " by Sani Balarabe Yusuf with registration number PG/UD/M.ENG/06/044has been supervised and approved by the school of Postgraduate Studies for meeting the regulations governing the award of Master of Engineering (M.Eng.) degree in Electronic Engineering (Communication Specialization) of Electronic Engineering Department, Faculty of Engineering, University of Nigeria, Nsukka, Nigeria.

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CERTIFICATION

This is to certify that, this project titled, " Enhancing Emergency Call Handling Procedure in GSM/W-CDMA Networks To Incorporate Personal Security " has been carried out by me in the UNN-DBI programme in the Department of Electronic Engineering. The information derived from the literatures has been duly acknowleged in the thesis and appropriate list of references provided. However, the work is oiginal and no part of this thesis was previously presented either in part or in whole for the award of any degree or diploma at this or any other institution.

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DEDICATION

This piece of work is dedicated to my late father Alhaji Balarabe Maichitta Galadanchi for his vision and tireless commitment to my success in all facets of lifeduring his lifetime.

May his soul rest in peace.

ACKNOWLEDGMENT

All thanks and glory be to Almighty Allah who preserved me till the completion of this noble work to the benefit of all mankind.

I wish to recognize the enormous moral support by my family and the guidance offered by my supervisor Prof. Cosmas Ani during this project. These are two major drivers to my success and are hereby acknowledged.

ABSTRACT

This project was undertaken with the objective of providing a rather more flexible Emergency Call Handling Procedure (ECHP) for the GSM/WCDMA network which will facilitate call termination to other sourcesof help (Commercial Emergency Service Operators, Vigilante groups etc.) in addition to the Public Safety Answering Point (PSAP) as a possible replacement for the existing procedure that routes all ECs to a PSAP. An alternate Enhanced Emergency Call Handling Procedure (EECHP) was suggested and modeled using call flowchart and mathematical modeling techniques.The Models were then simulated andthe results obtained analyzed. The results analysisshowed significant improvement in call completion success (a measure of QoS) and decreasing Call blocking probability (increased accommodated EC traffic) for those GSM/W-CDMA originated emergency calls processed using the EECHP over those making use of the de-facto call handling procedure for same PSAP condition; thereby suggesting that the EECHP can be effectively used as a replacement for existing ECHP forreducedemergency call drops associated with congested or out of service PSAP(s) and itsattendant adverse effecton peopleǒs lives and property.

ABBREVIATIONS:

BSS	Base Station System
CC	Country Code
CLIP	Calling Line Identity Presentation
CoLP	Connected Line identification Presentation
DP	Detection Point
cOTDI	compressed Originator To Dispatcher Information
CTRLFN	Controller Functional Number
EC	Emergency Call
FNUT	Fixed Network User Terminal
GCRef	Group Call Reference
GMSC	Gateway MSC
GSM	Global System for Mobile Communications
GSM-R	GSM Rail
IC	International Code
IMSI	International Mobile Subscriber Identity
ISDN	Integrated Service Digital Network
HPLMN	Home Public Land Mobile Network
MMI	Man Machine Interface
MOC	Mobile Originating Call
MS	Mobile Subscriber
MSC	Mobile Switching Centre
MSISDN	Mobile Station International ISDN Number
MT	Mobile Termination
MTC	Mobile Terminating Call
NDC	National Destination Code
NPI	Numbering Plan Indicator
OTDI	Originator To Dispatcher Information
PABX	Private Automatic Branch Exchange
QoE	Quality of Experience
QoS	Quality of Service

SIM	Subscriber Identity Module
SM	Short Message
TFN	Train Functional Number
TON	Type Of Number
UUS1	User to User Signalling Service 1
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service
WCDMA	Wideband Code Division Multiple Access
CAMEL	Customized Application for Mobile networks Enhanced Logic
PEC	Personal Emergency Contact
PESOP	Private Emergency Services Operator
PIC	Point in Call
ECHP	Emergency Call Handling Procedure
EECHP	Enhanced Emergency Call Handling Procedure
PSAP	Public Safety Answering Point
RACH	Random Access Channel
ECS	Emergency Communications System
VLR	Visitor Location Register
VPLMN	Visited Public Land Mobile Network

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CHAPTER 1
INTRODUCTION

1.1. Background

Emergenciesarehigh stress situations,often with threat to life, health, property or environment [1]. They are stressful enoughtooverwhelm victims intoforgettingphone numbers of family members, associates or authorities from whom they could seek help.

In an attempt to easecommunication difficulty during emergencies, aglobally accepted Public Safety Emergency Response System (PSERS) was modelled for the Plain Old Telephone System (POTS) and the Cellular networks (GSM, CDMA,W-CDMA) on the basisof the following [2]:

(i) Use of single, easy to remember,emergency number for all emergency needs.
(ii) Publically funded Public Safety Answering Points (PSAP), meant to receive ECs anddispatch help to affected people.
(iii) Priority treatment given to ECs over normal calls by Telecom operators.
(iv) EC calls are made free of chargeon both POTS and Wireless networks

This form of emergency communicationisbeing operated in many countries, includingtheUnited States, Canada United Kingdom, South Africa and Nigeria. However, in Nigeria, it is a common occurrence for PSERS being unable to meet theemergency needs of the peopledue toEC termination failure to a possible source of help. This leads to lower Quality of Experience (QoE) for callers that attempt ECS in Nigeria.Several militating factorsincluding (but not limited to) the Emergency Call Handling Procedure (ECHP) being usedby the GSM and W-CDMA networks are responsible for the callerslow QoE.

1.2. Objective of the study

This project is aimed at mitigatingidentified inadequacies, namely: - call drop and lack of flexibility -with the GSM/WCDMAECHP especiallyduring PSAP congestion.The project analyzed EC handling during PSAP congestions andoffered anEnhanced ECHP (EECHP) that will improve call termination success. This EECHP for the GSM/W-CDMAnetworksremoved the restriction ofEC from being terminated to other sources of help, while maintaining the benefits of emergency call.

1.3. Problem Statement

The GSM/WCDMA ECHP(for networks in Nigeria), implement a procedure that routes all ECs to a tandem switch at a Public Safety Answering Point (PSAP)[3].ECs receive no further processingas soon as they are received at the MSC.They are simply delivered to aconfigured

PSAP as fast as possible for all PSAP conditions ï including congestionperiods.Thus, by default, ECs in GSM/W-CDMA networks are not subjected to any screening (including CAMEL Procedures) [3].

The absence of call processing for ECduring congestion at the PSAPprevents many people fromaccessing alternativesourcesof helpwhile enjoying the benefits ofemergency calls.Such sources of help include:Private Emergency Service Operators (PESOP) and Personal Emergency Contacts(PEC).

During congestion at the PSAP, the call blocking probability (i.e.the chance that an EC arriving at a PSAP would meet no available server)is very high, thereby limitingthe ability of the GSM/W-CDMA network tomatch an originating EC witha source of help within the PSAP.,

Sometimes ECs are routed to alternate distant PSAP,typically,an EC that originated from Lagos could end up at a PSAP in Abuja (a distance of over 600Km apart) and the vice-versa. Personnel at the called PSAP will then began the human process of locating a source of help closer to victims. This process results in a long waiting and eventually help may never get to the victimson time.

Since emergencies are time bound, the ability to reach a source of help closest to victims and as fast as possible is a critical requirement for improving victims QoE. For example,in the event of fire incidence,a dispatch of 10 water tankers arriving at the venue of the incident after the fire had completely razed a building may not be of any help to the victim(s). However, with effective ECS, a single water tanker from the neighborhood could make a lot of difference at the early stage of the fire.The same could be said of a case of kidnapping,where an early response from a local vigilante can foil the exercise and save the victim before the arrival of the police.

It is safe to say that, the ability of an EC to reach alternative destination(s)during PSAP congestion is a critical requirement for improved efficacy of the GSM/ W-CDMA ECS.

In human response to the PSERS inadequacies above, vis-à-vis the urgent need for emergency victims to get help,peopleoften resort to using other ways to seek help - by calling local vigilante group (for Criminal emergencies),personal physician (in case of health issues) andneighbors/ private fire service operators (in case of fire) incidences.

These options often attract fees, but arestill preferred tohaving a callto aPSAP that may be congested or not ready to offer the much desired help. A clear indication of this, can be seen fromthe patronage enjoyed by such private/commercial ventures from the general publici.e:- emergence of private security outfits, private ambulance services and community vigilante groups etc.

The calls to vigilanteô group, Private ambulance, etc; are not recognized as emergency calls by the GSM/W-CDMA network, despite their critical role, rather they are treated as normal calls, hence no preference of any sort is accorded them. Theymay even be denied by the networkfor lack of call credit balance.

It is noteworthy that, a GSM/W-CDMA ECHP as depicted above whereby EC targeted at congested PSAP fail to terminateand alternative sources were not supported, has left much to be desired of an effective ECS.

There is thus the need, to accommodate all these calls into a common and efficient ECS for the utmost satisfaction of emergency victimsin Nigeria and similar countries.

The aim of this project was simplyan adaptation of these new EC realities into the GSM/W-CDMA originating ECHP,through the introduction of an Enhanced ECHP that makes use of GSM operatorφs Customized Application for Mobile networks Enhanced Logic (CAMEL) to offer some flexibility to EC termination.

This alternative originating EECHP will subject ECs to screening and processing at the gsmSSP andthat ECs were not dropped at the MSC or denied Radio Resource by the GSM RR management layer due to congestion, and to ensure that originating ECs are seamlessly terminated to PSAP, PESOP and/or to PEC by callerφs choice (even when PSAP entries are available).

1.4. Scope of work

The scope of work coveredherein was foremergency call situation during congestionat PSAP.Performance was analyzed usingcall flow-chartsfor originated emergency call terminating at a congested PSAPvia a GSM/W-CDMA network for two scenarios: (i) using currentECHP and (ii)using Enhanced ECHP.

The twocall models were examined, mathematicallymodeled, simulated andanalyzed. Simulationresults were then compared to demonstrate benefits offered by EECHP over the existing ECHP.

1.5. Thesis Outline

The thesis is divided into 5 chapters.Chapter 1 covers theöIntroductionö, chapter 2 and Chapters 3coverthe Literature Review andNetwork Modeling respectively; whileChapter 4 coversSimulation and Results Analysis. Finally chapter 5has the Conclusion and Recommendation forfurtherwork.

CHAPTER 2
LITERATURE REVIEW

2.1 GSM Call Process

Before presenting related-work review, it is imperative to take alook at the GSM call process and to explain how GSM/W-CDMA network treats MS originated calls (including emergency calls) with CAMEL subscription.

CAMEL is a network feature that enables the use of Operator Specific Services (OSS) by a subscriber even when roaming outside his HPLMN [13].

The CAMEL Subscription Information (CSI) is provided by the HPLMN operator by administrative means.

Each GSM process is made up of a series of telecommunication events, some of which are service events. At a service event, the IPLMN or VPLMN may suspend the process and make contact with a CSE to ask for instructions or to send a notification. At this time the IPLMN or VPLMN shall send to the CSE the information listed in this GTS. All information sent to the CSE relates to the served CAMEL subscriber unless otherwise stated. The CSE controls subscriber call regardless of his location[14]. The initial service events, and the corresponding CSE identity, which can initiate contact with the CSE is defined in the CAMEL Subscription Information.

The CAMEL feature is applicable in a PLMN if the CSI is received from the HPLMN.

The CSE shall be capable of responding to the CAMEL request with instructions on how to resume the suspended GSM process. It shall be possible for the CSE to instruct the IPLMN or VPLMN to:

- Activate further service events for potential invocation. These events shall remain active only for the life-time of the telecommunication service;
- Alter information relating to the suspended process;
- Alter information relating to the parties involved in the process;
- Indicate which of the possible parts of the process should occur next (e.g. terminate the call).
- CAMEL features shall form an integral part of the following GSM processes:
- MT call;
- MO call (forwarded calls are treated as MO calls).

  As part of an OSS it shall be possible for the CSE to interrogate for information about a particularsubscriber at any time.

CAMEL procedures are applicable to all circuit switched Basic Services without distinction (exceptEmergency calls)[13]

2.1.1 MS Initialization

- Initialization is a random access process performed by the MS. It begins with the MS sending a ñchannel requestò message on Random Access Channel (RACH).
- After receiving this message, BTS notifies BSC, and attaches BTSôs estimation of the transmission delay (TA) from this MS to BTS and the cause for the current access.
- BSC will select an idle and dedicated channel SDCCH to notify BTS to activate it according to the access cause and the current information.
- Access causes mainly include: location updating; response to a paging call; and subscriber service application, such as a call, sending one short message.
- After BTS completes the activation of the designated channel, BSC sends the ñimmediate allocationòmessage on AGCH via BTS, including the description of the SDCCH channel assigned by BSC to MS, TA, the maximum initialization transmission power and the access random reference value.
- When MS correctly receives its initialized allocation, it will, according to channel description, adjust itself to this channel, set up a signaling transmission link, and send the first initialized message on the dedicated channel, including subscriberôs identification number (such as IMSI), cause for the current access, registration, and authentication. If BSC has no idle channels to allocate, BSC will send to MS the ñimmediate allocation rejectedò message.[3]

2.1.2 Originating call establishment

The call control (CC) entity of the MS initiates establishment of a CC connection by requesting the MM sublayer to establish a mobile originating MM connection and entering the "MM connection pending state. There are two kinds of a mobile originating call: basic call and emergency call. The request to establish an MM connection shall contain a parameter to specify whether the call is a basic or an emergency call. This information may lead to specific qualities of services to be provided by the MM sublayers. [13]

Call initiation

Having entered the "MM connection pending" state, upon MM connection establishment, the call controlentity of the mobile station sends a setup message to its peer entity. This setup message is
- a SETUP message, if the call to be established is a basic call, and
- an EMERGENCY SETUP message, if the call to be established is an emergency call.

It then enters the "call initiated" state. This state is supervised by timer T303, which has already beenstarted after entering the "MM connection pending" state.
The setup message shall contain all the information required by the network to process the call. Inparticular, the SETUP message shall contain the called party address information.
When the call control entity of the mobile station is in the "call initiated" state and if it receives:i) a CALL PROCEEDING - signifying call to destination in progressii) an ALERTING message ï

alerting message to caller telling the MS of the call progress eg. Ring back tone, Subscriber busy tone iii) a CONNECT messageiv) a RELEASE COMPLETE ï when call is completely released message it proceeds to act accordingly. See figure 2.1 below.

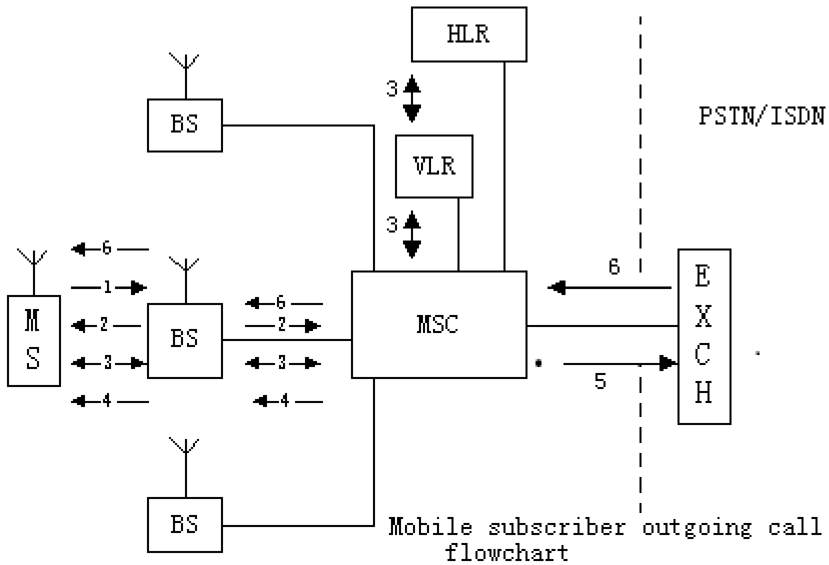

Fig 2.1 Outgoing Call flow from GSM to PSTN [17]

2.1.3 Originating Call with CAMEL subscription

Figure 2.2 below shows signaling activities for an MS originated call with CAMEL subscription. Call starts with CC request and subsequently SETUP message for the basic call. When active originating CAMEL Subscription Information (CSI) is found in the VLR during the call setup, the Visited Service Switching Function (VSSF) sends an InitialDetectionPoint message to the gsmSCF and the VMSC suspends the call processing. The InitialDetectionPoint message always contain the service key, called and calling party numbers, calling partyôs category, location number, bearer capability, event type Basic Call State Model (BCSM), location information and the International Mobile Station Identity (IMSI)[16]. After the service logic processing CAMEL specific handling is initiated from the gsmSCF [16].

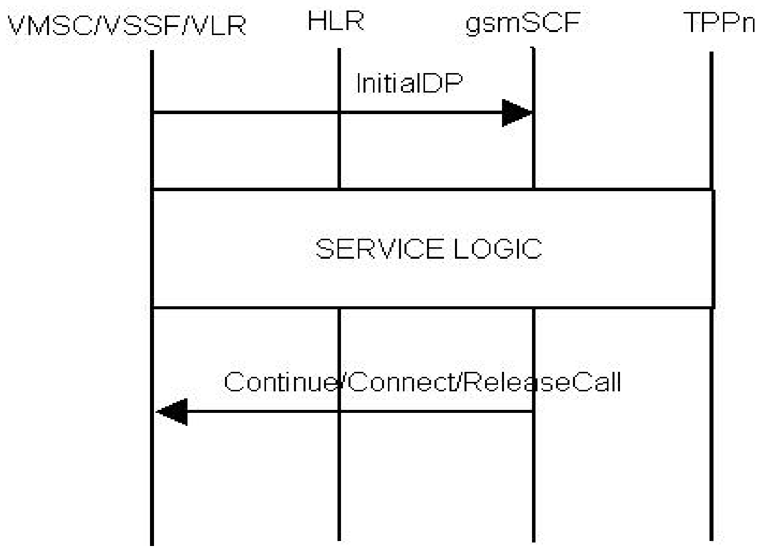

Figure 2.2 Mobile originating call – signaling [15]

2.1.4 Terminating Mobile Calls with CAMEL:

In the case of mobile terminating call, the Gateway MSC (GMSC) in the interrogating PLMN identifies the HLR of the called party with the help of the MSISDN. Then the GMSC sends a RoutingInformation-Request to the HLR. The HLR checks the CSI of the called party and sends the information stored in the subscriber record back to the GMSC.

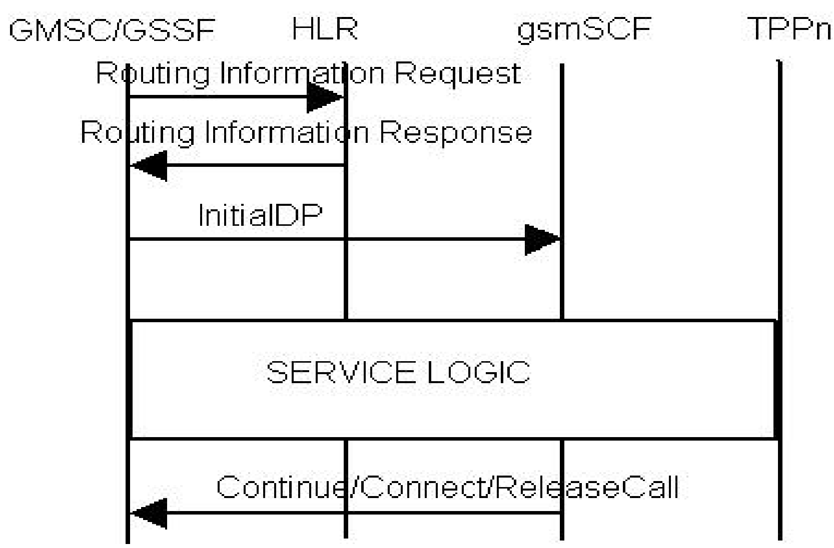

Fig 2.3 Mobile terminating call – signaling [15]

Now, the GMSC acts according to CSI. If the terminating CSI is active the trigger criteria of a Detection Point (DP) is fulfilled and the call processing is suspended. An InitialDP message, which shall always contain the service key, called party number, event type BCSM and the IMSI is sent to the CSE and the service logic execution is started. Thereafter CAMEL specific handling is initiated, see figure 2.3 above.

2.2 CAMEL VERSIONS

The current version of CAMEL is Phase 4, released by 3GPP in the years 2007.The main features of different CAMEL versions are summarizes in table 2.1 to 2.5 below. CAMEL procedures remain a very cost effective way of adding Intelligence to the GSM/W-CDMA networks.

CAMEL phase 1:

Table 2.1 CAMEL phase 1 functionality:

Functionality	Purpose / supports	Restrictions
Triggering on MO, MT and forwarded calls.	• Call screening • Simple VPN • Call Forwarding • Call Redirection • Call Rerouting • Homing of pre-paid calls to HPLMN	• No IN announcements supported • No charging operations • Limited set of detection points, e.g. the hunting services are not possible. • MT calls trigger in the GMSC only. • Not possible to activate Call Forwardings with VPN short codes.
Any Time Interrogation	• The CSE may request HLR to provide subscriber status and/or location information at any time.	• The exact location may not be up-to-date unless the mobile has an active call ongoing. • CS only

CAMEL phase 2:

Table 2.2 CAMEL phase 2 functionality:

Functionality	Purpose / supports	Restrictions
Triggering on MO, MT and forwarded calls.	• Call screening • VPN for calls • Call Forwarding • Call Redirection • Call Rerouting • Follow-on calls • In-band user interaction (DTMF) • Tones and announcements	• MT calls trigger in the GMSC only.
Charging operations	• Pre-paid (MO, MT, CF) • Free-phone • Premium rate • Personal Discount • Location Dependent discount • Reverse Charging	-
CSE provided e-parameters	• MO AoC	-
New detection points (Abandon, Busy, NotReachable, NoAnswer, RouteSelectFailure cases)	• Cleaner termination of relationship. • Better pre-paid service. • Hunting type of services.	-
Triggering criteria	• To reduce CSE & SSP load	-
Any Time Interrogation	• The CSE may request HLR to provide subscriber status and/or location information at any time.	• The exact location may not be up-to-date unless the mobile has an active call ongoing. • No call supervision
USSD communication between MS and CSE	• USSD call-back for pre-paid roaming • Control & enquiry of IN services	

Control of north American carrier information	• Enhances pre-paid • CSE based carrier selection • Selecting correct long distance network for user interaction	
Notification of supplementary service (CCBS, ECT, CD and MPTY) invocation to CSE	• Fraud control	

CAMEL phase 3:

Table 2.3 CAMEL phase 3 functionality:

Functionality	Purpose / supports	Restrictions
Triggering on MO, MT and forwarded calls.	• Call screening • Full VPN • Call Forwarding • Call Redirection • Call Rerouting • Follow-on calls • In-band user interaction (DTMF) • Tones and announcements	
Charging operations	• Pre-paid (MO, MT, CF) • Free-phone • Premium rate • Personal Discount • Location Dependent discount • Reverse Charging	
CSE provided e-parameters		

CAMEL2 new detection points (Abandon, Busy, NotReachable, NoAnswer, RouteSelectFailure cases)	• Cleaner termination of relationship. • Better pre-paid service. • Hunting type of services.	
CAMEL3 new trigger detection points.	• To trigger on demand only, e.g. for hunting services.	
Triggering criteria	• To reduce CSE & SSP load	
Any Time Interrogation. Enhanced with CAMEL3 current location retrieval, and ATI for GMLC.	• The CSE may request HLR to provide subscriber status and/or location information at any time.	• CS only
USSD communication between MS and CSE	• USSD call-back for pre-paid roaming • Control & enquiry of IN services	
Control of north American carrier information	• Enhances pre-paid • CSE based carrier selection • Selecting correct long distance network for	

	user interaction	
Notification of supplementary service (CCBS, ECT, CD and MPTY) invocation to CSE	• Fraud control	
Call Gapping	• To control CSE overload situations within HPLMN	• For CS calls only. Not for SMS or GPRS.
MT call triggering in VMSC-B	• To control MT supplementary services (CW, hold, CF, CD, ECT, MPTY) • Pre-paid for MT air-time charge (1st minute free, e.g. in USA)	
Abandon as an EDP-R	• Improves charging	
Enhanced FreeFormatCharging data (40 octets -> 160 octets)	• Makes the CSE service logic easier	
Reporting of MSRN/FTN to CSE	• Charging control of optimally routed calls	
CSE-HLR interface: ATM/ATSI/NSDC	• Multiple Subscriber Profile phase 2 • CSE can control CF, barring supplementary	

	services. • Off-line subscription control based on VPLMN / time-of-day • Virtual operators	
Subscribed dialled services (D-CSI)	• HPLMN specific service numbers	• No call supervision
Serving Network Dialled services (N-CSI)	• VPLMN specific service numbers	• No call supervision
MO SMS control (CS+PS)	• Enhances pre-paid. • Enhances VPN	• No MT SMS control. • Not content based
Inter-working with GPRS	• GPRS pre-paid	• Not content based
CS Mobility management notifications	• CSE can monitor location / reachability	
Service Interaction Indicators	• CSE can control inter-working with supplementary services (CW, hold, CF, CD, ECT, MPTY). • Multiple subscriber profile phase 2	

CAMEL phase 4:

Table 2.4 CAMEL phase 4 functionality in Release 5:

Functionality	Purpose / supports	Restrictions
Triggering on MO, MT and forwarded calls.	• Call screening • Full VPN • Call Forwarding • Call Redirection • Call Rerouting • Follow-on calls • In-band user interaction (DTMF) • Tones and announcements	
Charging operations	• Pre-paid (MO, MT, CF) • Free-phone • Premium rate • Personal Discount • Location Dependent discount • Reverse Charging	
CSE provided e-parameters	• MO & MT AoC	
CAMEL2 new detection points (Abandon, Busy, NotReachable, NoAnswer, RouteSelectFailure cases)	• · Cleaner termination of relationship. • · Better pre-paid service. • · Hunting type of services.	
CAMEL3 new trigger detection points.	• · To trigger on demand only, e.g. for hunting services.	
Triggering criteria	• · To reduce CSE & SSP load	
Any Time Interrogation. Enhanced with CAMEL3 current location retrieval, and ATI for GMLC. CAMEL4 enhances this to PS domain.	• The CSE may request HLR to provide subscriber status and/or location information at any time. • ATI for GMLC	
USSD communication between MS and CSE	• USSD call-back for pre-paid roaming • Control & enquiry of IN services	
Control of north American carrier information	• Enhances pre-paid· • CSE based carrier selection • Selecting correct long distance network for user interaction	

Notification of supplementary service (CCBS, ECT, CD and MPTY) invocation to CSE	• · Fraud control	
Call Gapping	• · To control CSE overload situations within HPLMN	For CS calls only. Not for SMS or GPRS.
MT call triggering in VMSC-B	• · To control MT supplementary services (CW, hold, CF, CD, ECT, MPTY) • · Pre-paid for MT air-time charge (1st minute free, e.g. in USA)	
Abandon as an EDP-R	• · Improves charging	
Enhanced FreeFormatCharging data (40 octets -> 160 octets)	• · Makes the CSE service logic easier	
Reporting of MSRN/FTN to CSE	• · Charging control of optimally routed calls	
CSE-HLR interface: ATM/ATSI/NSDC	• Multiple Subscriber Profile phase 2 • CSE can control CF, barring supplementary services. • Off-line subscription control based on VPLMN / time-of-day • Virtual operators	
Subscribed dialled services (D-CSI)	• · HPLMN specific service numbers	· No call supervision
Serving Network Dialled services (N-CSI)	• · VPLMN specific service numbers	· No call supervision
SMS control (CS+PS)	• · Enhances pre-paid. • · Enhances VPN	· Not content based
Inter-working with GPRS	• · GPRS pre-paid	· Not content based
CS Mobility management notifications	• · CSE can monitor location / reachability	
Service Interaction Indicators	• · CSE can control inter-working with supplementary services (CW,	

	hold, CF, CD, ECT, MPTY). • · Multiple subscriber profile phase 2	
Interactions with Optimal Routing	• · CSE can control usage of OR	
Call Party Handling	• Wake-up calls • Conference calling • Parallel hunting • Click-to dial • IN based CCBS	
Mid call procedure for MO and MT calls	• Control CPH configuration during call. • Automatic call collect	
CAMEL for IMS	• IMS pre-paid • Convergence to CS and GPRS services	
Inclusion of flexible tone injection	• Enhancements of pre-paid warning tones • Various informative tones	
Provision of location information of called subscriber (Alerting phase)	• The location of B-subscriber at the beginning of the call provided to service logic	
Notification of GPRS mobility management to CSE	• CSE can monitor location / reachability in PS side	
Inclusion of ODB data in the CSE-HLR interface	• Enhancement of MSP ph 2	
Location information during an ongoing call (Handover DP)	• Charging based on current location, for inter-PLMN and/or inter-system handovers	
Transfer of the IMEI (with software version) and MS class mark to the CSE	• allow the gsmSCF to determine information about the capabilities of the ME	
Any Time Interrogation from CSE to MNP-SRF	• Number portability query for prepay calls	
Partial implementation of CAMEL phase 4	• A functional entity (VMSC, GMSC or SGSN) may support the complete	

	CAMEL phase4 functionality or, as a network option, it may support the complete CAMEL phase3 functionality and a partial implementation of CAMEL phase4.	

Table 2.5 CAMEL phase 4 additions in Release 6

Enhancements of Dialled Services	·Full control of Dialled Services	
Full CAMEL4 prepay support for SCUDIF	·The capability to report basic service code changes during ongoing call.	
Change of position procedure armed with criteria	· Technical enhancement to reduce the signalling load	

Applicability of CAMEL Procedure [15]

- The CAMEL feature is applicable to Mobile Originated and Mobile Terminated Call Related Activities. CAMEL procedures are applicable to all circuit switched basic services without distinction (except Emergency calls).
- The CAMEL feature is applicable to Supplementary Services Invocation
- CAMEL procedures are applicable to GPRS sessions and PDP contexts
- CAMEL procedures are applicable to Mobile Originating/Terminating short message service through both circuit switched and packet switched serving network entities
- CAMEL procedures are applicable to IP multimedia services (except Emergency calls) to support legacy services
- CAMEL shall support IPMM sessions which are based on the same charging paradigm as CS/PS calls. This applies most probably to VoIP and Video over IP.
- CAMEL procedures are applicable to IP multimedia sessions addressed by either E.164 numbers or SIP URLs.

2.3 Related Research Work

In broad terms, ECHP in GSM/WCDMA networks can be categorized according to parts where they are implemented, namely: - (i) Network or (ii) Mobile station (MS). Several projects were done in the past to address diverse issues relating to EC origination and termination. Some of these can be categorized as Network based while others are MS based. A review of such works is presented below.

2.3.1 Network Based EC Handling Procedures

2.3.1.1 Private Emergency or Service Specific Call Approach inGSM System[4]

A very noticeable network-based work on Personal/Private emergency services for the ECHP in GSM, was done by Xiaode Xu Freemont, Wenfeng Huang Cupertino and Ian L. Sayers. This work tagged: ñPrivate Emergency or Service Specific call approach in GSM Systemò [4] highlighted a Service Specific Call (SPC) procedure which takes advantage of elements that can be coded into the Radio Resource Management (RR) functional layer, channel request message and/or the Mobility Management (MM) functional call request messages in the GSM communications system. Specifically, an establishment cause field in a RR channel request message and/or a service type field in a MM request message were used to request for specific private Emergency and other service-specific services from the GSM network[4].

They have achieved this by taking the establishment causes and services types which can be defined but not limited to using those codes currently defined as reserved [4]. Thus, these newly added codes do not require any re-programming forthe deployed GSM equipment. The system was modeled using call flow chart in Figures 2.1 and 2.2 below.

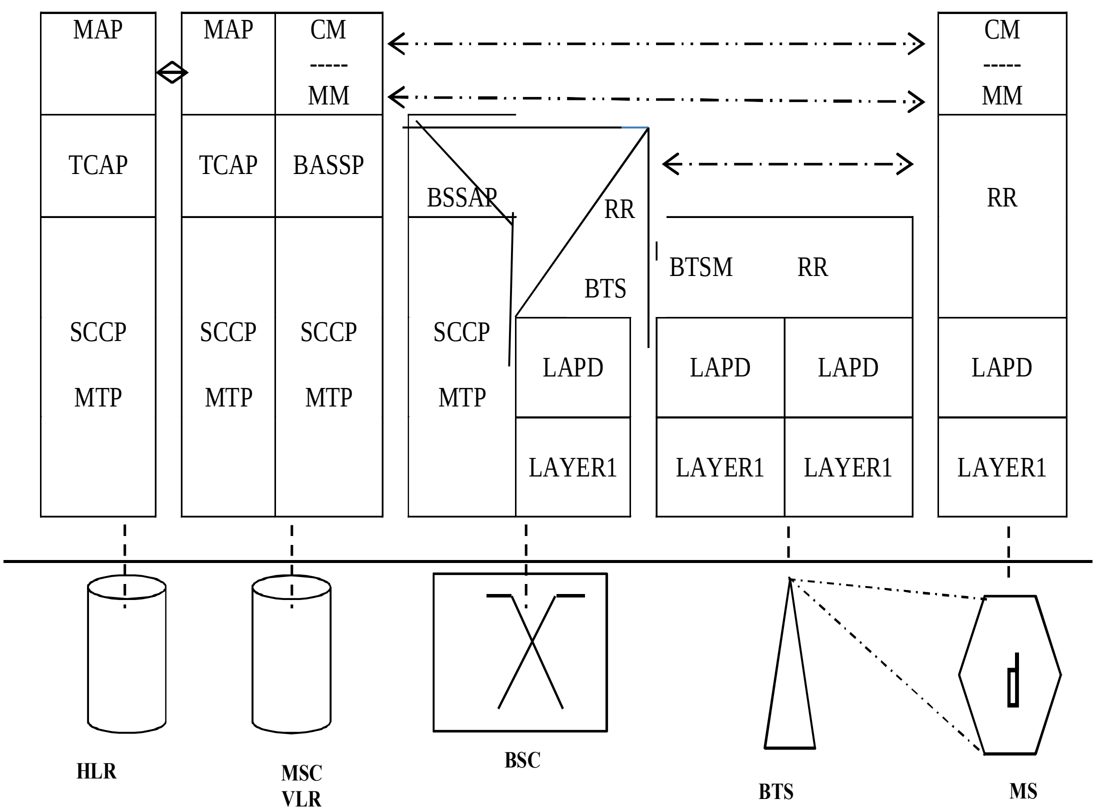

Figure 2.1 Prior act

Figure 2.1 shows the protocols in use during GSM call setup prior to the work by Sayers group. Connection Management layer begins call setup by sending messages which are relayed to the MSC. In the process the MS is assigned SADCH, mobility handed to serving BSC and the call progresses.

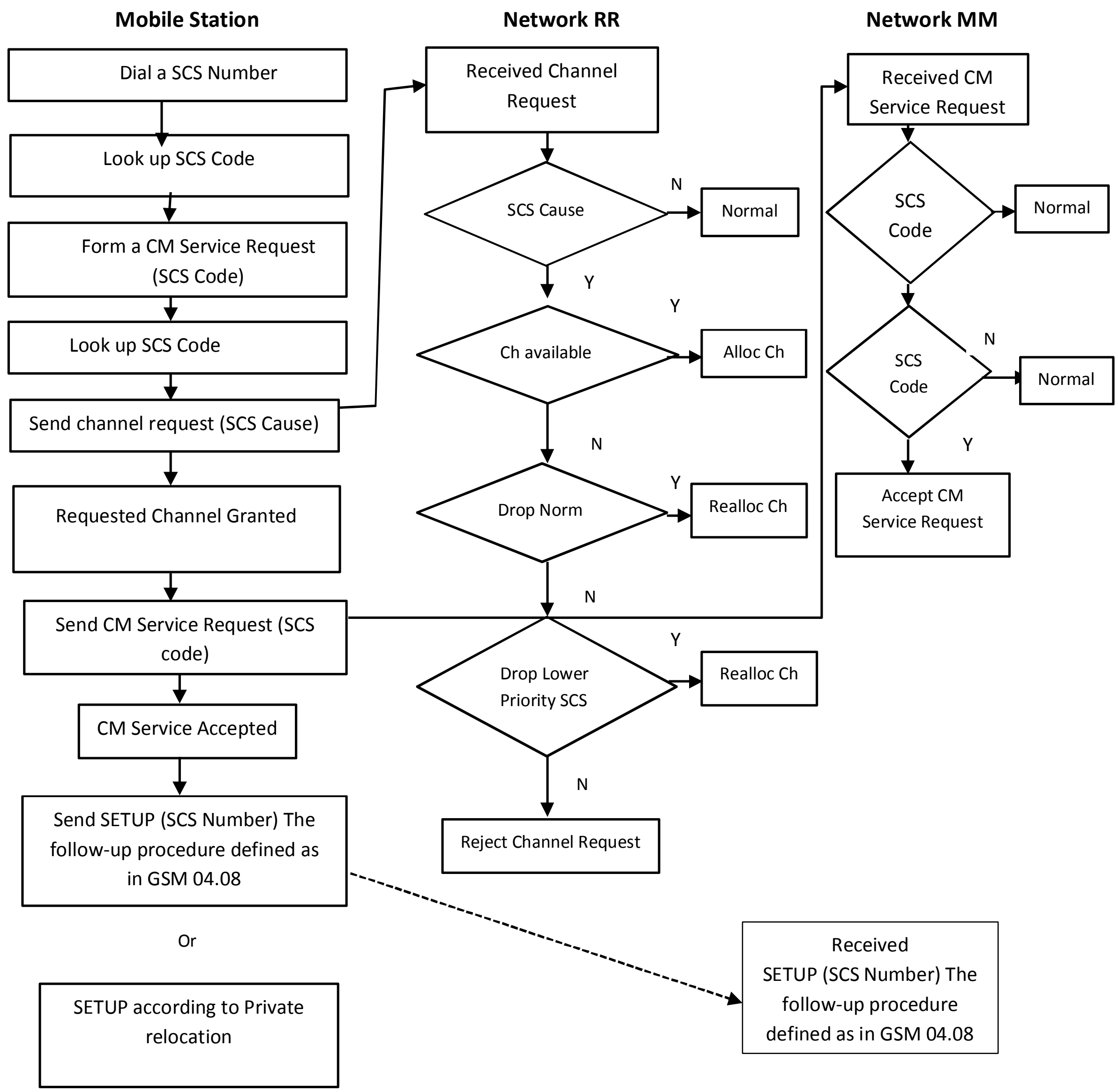

Figure 2.2 GSM Call Flow Chart [3]

Limitations: This option is best suited when GSM network is deployed in a private environment like school campus or factory. It does not accommodate EC needs to call PEC and PESOP.

2.3.1.2 Alternate-Routing Emergency Calls In an Intelligent Network[2]

Another work on alternate routing ECs was done by Edgar Martinez, who established that Emergency calls can be alternate-routed in an intelligent network having at least one Service Control Point (SCP) with access to a routing table, a plurality of Service Switching Points (SSP) equipped with point-in-call triggers and one or more emergency services stations (PSAP). The routing table lists a routing number for each of the emergency services stations. This method comprises the following steps: (i) at a Service Switching Point, presetting a point-in-call trigger to operate at a predetermined point-in-call for emergency services, (ii) subsequently, during processing of an emergency services call, interrupting processing of the call and transmitting to the SCP a query signaling message requesting routing information, (iii) at the SCP, accessing the routing table in dependence on parameters in the query signaling message and obtaining a routing number for a selected emergency services operator station, forming a response signaling message including the routing number and returning such response signaling message to the SSP, (iv) at the SSP, detecting the routing number, and routing the call to the emergency services operator station[4].

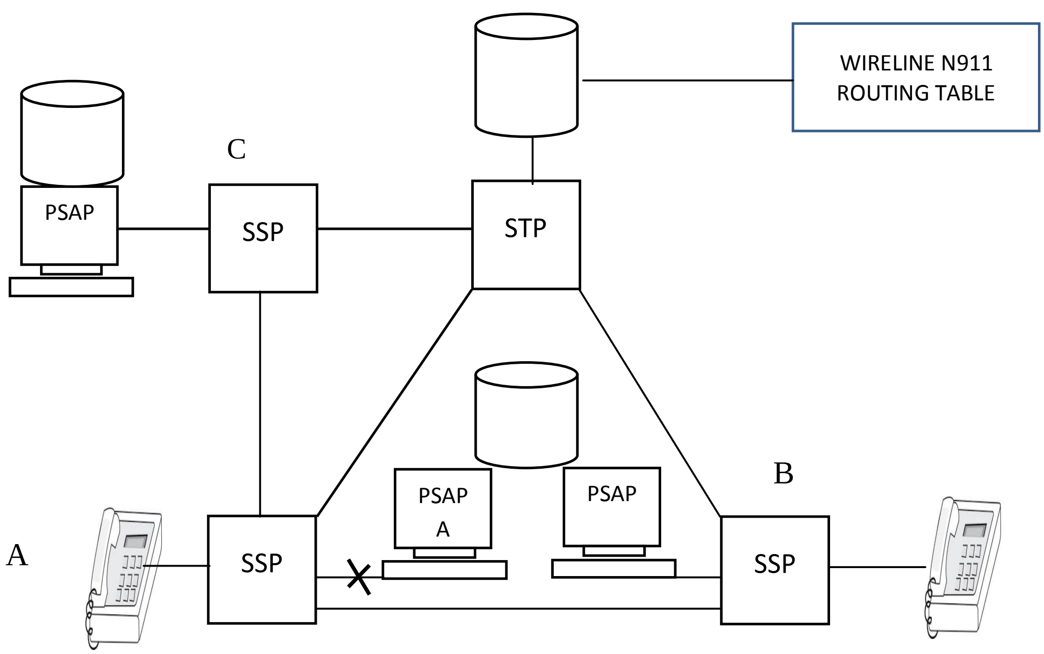

Figure 2.3 Alternate-Routing Emergency call [3]

Figure 2.3 demonstrate how an emergency call destined for PSAPô Aô in the service area of the SSP connected to telephone user óAô can be rerouted if due to link failure PSAP óAô was unavailable, then the EC could be served by other PSAP in B or C service area. Theyôve also provided, a method of translating signaling message parameters from a mobile protocol to an intelligent network protocol, and vice versa, to enable emergency services calls from mobile users to be routed to one or more PSAPs in the network.

Limitations: This option is best suited for GSM deployments having multiple PSAPs. It has the limitation of not accommodating EC needs for PEC, and with no provision for switching between different destinations through IVR, SMS etc.

2.3.1.3 Emergency Call Service with Automatic Third Party Notification And/Or Bridging [5]

This is a system for processing ECs ina telecommunications network in which at first an EC call is received at a node (A) of the telecommunications network from a calling party that originated the first call; detecting that the received first call is an emergency call; establishing a conference bridge in response to the detected emergency call; connecting the emergency call over the conference bridge to a designated facility (B) that handles emergency calls; and, automatically originating at least one second call from the node (A)to at least one predetermined third party that is different than the calling party and the facility (B).

Limitations: Option quite suitable but lacks support for SMS &PEC communication.

2.3.2 MS BASED EC HANDLING PROCEDURE

2.3.2.1 Short Code Dialing

This is very common implementation available in most GSM/WCDMA MS.

In the short code dialing, MS is used to dial stored(in its memory) emergency numbers without necessarily having to dial the complete digits; rather by just dialing a short code from the keypad. The MS performs the necessary translation before sending the actual stored destination number (B) to the network. Such can be used during emergency to reference an already stored contact for personal emergency call.

Limitations: This option has very limited application.

i. It cannot accommodate EC to PESOP which changes automatically as the MS moves from one location to another.

ii. PECs need to be re-configured for every new MS.

iii. The behavior of the EC is completely determined by the GSM network and not by the MS.

2.3.2.2 Mobile Emergency Number Recognition

The GSM system identifies the numbers "911" and "112" as standard Emergency numbers. The MS was therefore made to allow access to these numbers even when the handset is locked or out-of-coverage of your registered network. Upon dialing these numbers, the MS will identify the numbers and attempt to setup emergency call via any available GSM network it founds. However, the behavior of these calls is still completely subject to the GSM network as outlined earlier. In most cases (in Nigeria) such calls are not even accepted by the GSM networks.

Observed Limitations:

This option has very limited application because:

i. It cannot provide EC setup to PESOP, PEC if not supported by the network.

ii. The behavior of the EC is completely determined by the GSM network and not by the MS.

2.3.3 Summary of Observed Limitations with Current EC Handling Procedures

None of the reviewed work on EC handling procedure above has addressed the deficiency of the ECHP to accommodate the followings:-

i. Delivery of EC to nearby non PSAP destinations in the event of congestion at PSAP

ii. Personal Emergency Communications (PEC) where needed; especially the need for emergency victims to reach destination other than PSERS (for help) while maintaining the benefits of EC from the GSM network perspective (as described in chapter 1)

iii. Emergency victim's freedom of choice as to how or where to request for help (as a form of service), ie from PESOP,PEC or PSAP.

iv. The opportunity to deliver pre-stored messages – SMS, email to some intended recipients in the event of emergency.

CHAPTER 3

NETWORK MODELING

3.1 Enhanced ECHP Architecture

EECHP is a logical service procedure built on top of the existing GSM /WCDMA components consisting of MS, BSS, NSS and OSS CSEequipped with CAMEL2 or later functions andhaving one or more form of connectivity to a PSAP and PSTN as (depicted in figure 3.1 below).

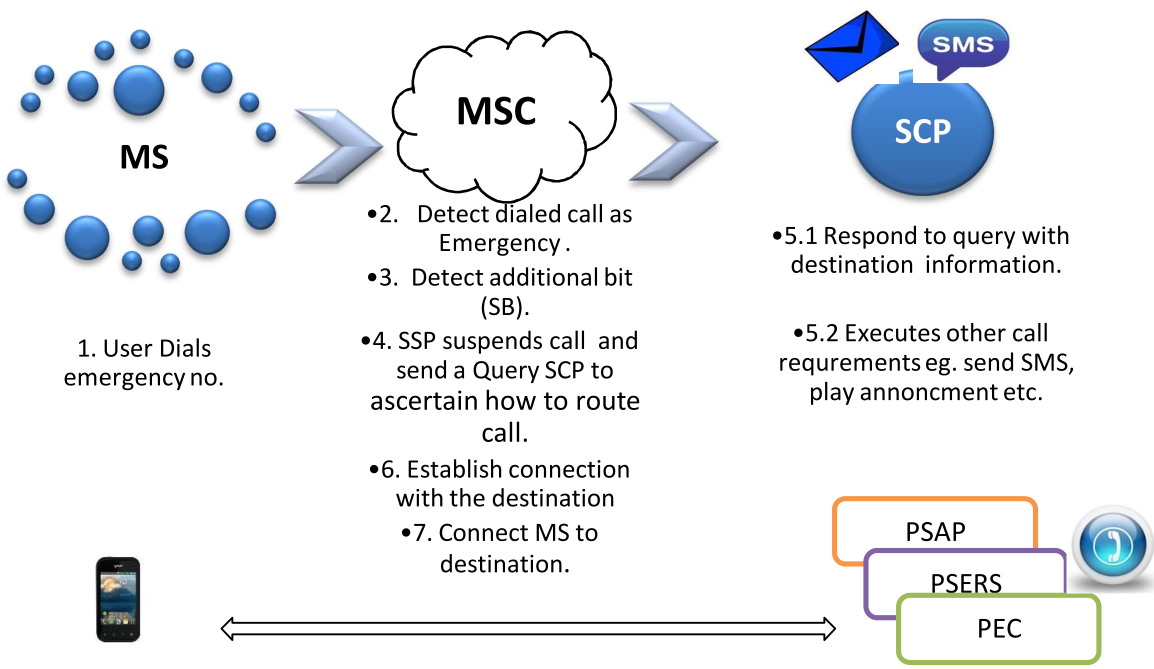

Figure 3.1 EECHP Architecture

EECHPoperation is hinged ona four digits emergency number ó112Xö instead of the 3 digits number 112 currently being used. Thisproposed number would represent originating EC number for the entire GSM network. The forth digit - referred to here as Service-bit (when present) - is used to define the kind of emergency service being sought from the GSM/W-CDMA network. It isto be used as a trigger for additional services. It shall be detected (when present), and consequently used to invokenecessary service control logic to support the EC. Depending on value of X, CAMEL procedure may be invoked, which may include SCP lookups. Typical support may be the routing of the EC to PEC or to PESOP instead of PSAP.

Unlike the existing call handling model where all ECs are routed to a configured PSAP, EC routing in EECHP is strictly determined by the value of the forth digit in every instance.

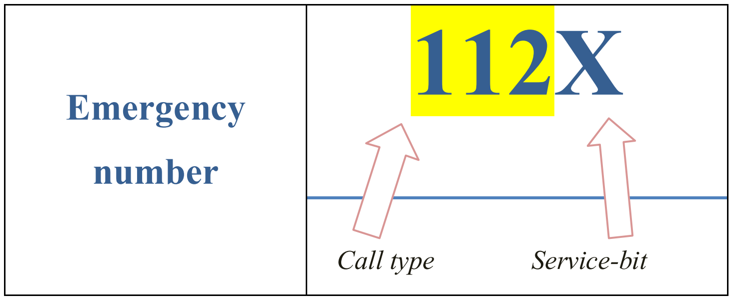

Fig 3.2EECHP Emergency Number made of four digits ABCX of two components

ABC ï Call Type description (1-9) cannot be null,
X ï Service-bit description (0-9) can be null.

The first component is a three digit number óABCô used to define the call being made as an óemergency callô, it could be configured as ó112ô or any other number. It is used by the RR component of the GSM network to accord priority and other considerations offered ECs to this call during SETUP; and the second component a single digit number X, which defines the kind of emergency service being sought by the caller. This number if left blankwould defaults to ó0ô and points to PSAP.

A typical emergency system for example, could use the following configuration:

Emergency number 112X,Where: X could be: 0 = PSAP, 1 = PESOP, 2 = PEC

The CAMEL feature as explained in chapter 2 allows for the separation of service logic from the MSC. Thus for instance, when an MS originates an EC by dialing 1121, the number 112 is detected as an emergency call and the last digitó1ô is detected to mean a call to PESOP (ofcourse with a fall back to PSAP).

Successful EC termination involves seamless call flow from MS up to the PSAP and/or alternative termination point(s) as depicted in Figure 3.1 above.

3.1.1 EECHP Operation

Consider a scenario where the number 1121 was dialed by an MS, then, for an EECHP compliant network, it will treat the call as an emergency call up to the gsmSSP provided at the Visited Service Switching point (VSSP). At this point, instead of routing the call to a PSAP, the call processing begins right from the first MSC. The last digit (in this case ó1ô) is detected by a PIC DP at the VSSP which sends an InitialDetectionPoint message to the gsmSCF (a functional entity which contain the CAMEL service logic). Depending on the configuration provided for the fourth digit in dialed number ó1121ô, the gsmSCF will process and return call destination (B number) to the VSSF which in this caseis an entry for a PESOP contact nearest the caller, or in its absence, other options are played to the caller and the call returned to the PSAP. The CAMEL procedure also provides the opportunity to send pre-stored SMS messages to a PSAP and/or other destinations.

Assuming four peoplesdialedan emergency number, each,seekingcall terminationto a source of helpbythe GSM/W-CDMA network. Then, forEECHP compliant network it is possible for each of these calls - depending on callerpreferenceï to havedifferent network behavior / response in realization of the call objective.

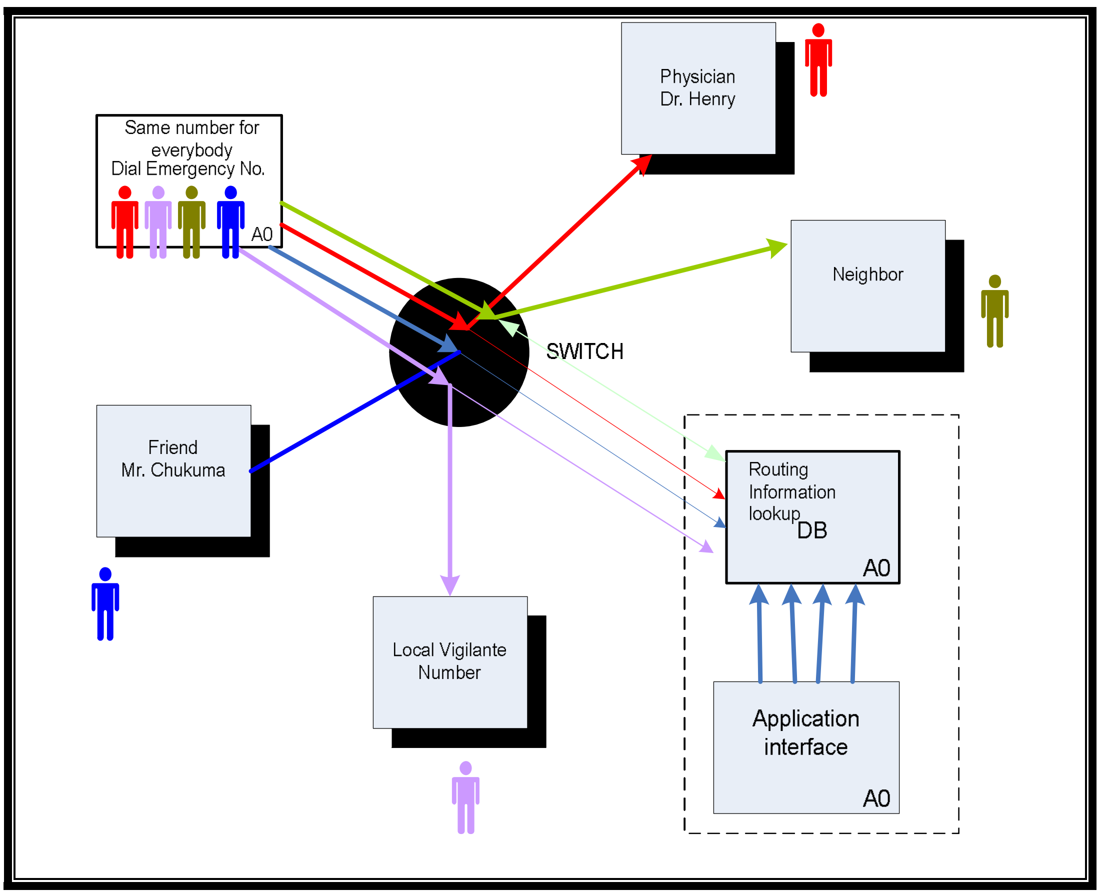

Figure 3.3EECHP Network Operation

For example,Mr. Sulaiman Jacobdialed the common number ó1123ô for Health emergency as being used by a typical GSM/WCDMA system, then it is now possible for the GSM network to do a database lookup, to know that for Mr. Jacob, such calls should be routed to his physician on +234-806-4068383 and hence instruct the MSC to do exactly that.However, when the same number was dialed by Amina Okechuku (a female house wife), the call could be routed to her local maternity home on +234-9-4137676 and a text message notification sent to her husband on +234-804-4103722.

Similarly, consider another scenario where emergency number ó1124ô is used to denote an EC involving armed robbery, assault, rape etc., then upon calling ó1124ô by typically Mr. Jacob, the call couldbe routed to the phone number of his local vigilante group or to the private security company guarding his house, whereas the same number when dialed by Mrs. Okechuku, the call is to be routed to the local police station and a text message sent to her husband Mr. Okechuku.With this kind of network in place, emergency victims would have more flexibility in what they do with their EC before it happens.

EECHP compliant networkare assumedto have a unified emergency number for all emergencies (for the country in consideration) eg 911 in North America,and installed CAMEL2 or later version of CAMEL Service Environment (CSE) containing a Service Control Function (SCF) and Service Management Function (SMF).

3.2 Call Flowchart

3.2.1 GSM/WCDMA network with existing ECHP

Call flowchart for emergency call through GSM/W-CDMA network using existing call handling procedureis as shown in Figures 3.4 below.

From the chart: (i) ECs are dropped if call setup to PSAP fails(for all network conditions -congestion or not) and (ii) There is no alternative termination point other than PSAP. Call setup to PSAP begins as soon as subscriber dialed the emergency number and MM component of the MSC receives EMERGENCY SETUP message from MS MM unit. If the call setup attempt was successful, MS is connected to the available PSAP server channel.The call objective is thus achieved and the system moves to CONNECTED MS status (the desired status).However, if the call setup fails, the MSC will play óCall failure announcementô and disconnect the MS(this is not a desiredstate for an EC).

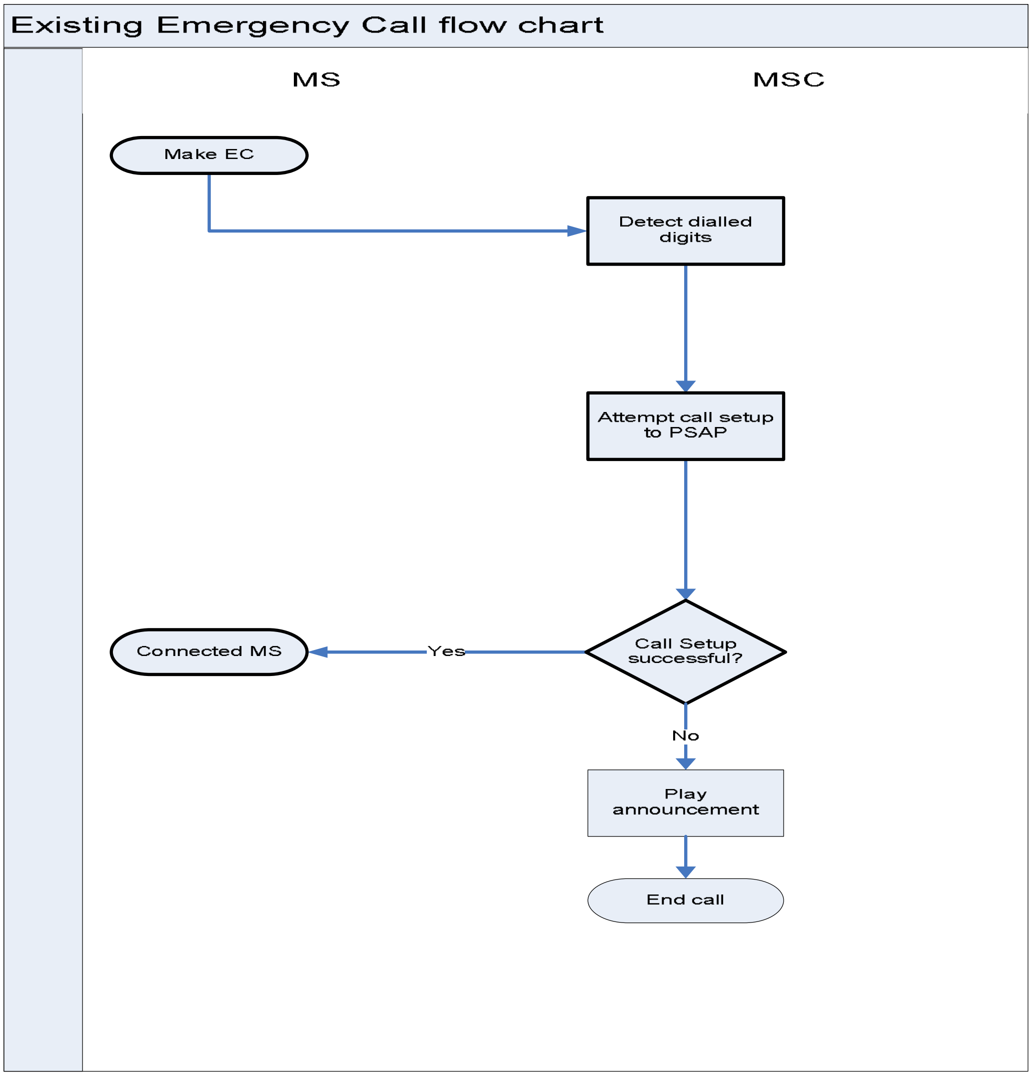

Figure 3.4 Existing GSM/WCDMA Emergency call flow

- EC detected by the MSC
- Call are SETUP with PSAP
- Call is dropped in the event of call SETUP failure

3.2.2 Call Flowchart for GSM/WCDMA network with Enhanced ECHP

Figures 3.5 below is the call flowchart for EC through a GSM/W-CDMA network using the proposed EECHP. This procedure wa is aimed at improving ECtermination success.

When EMERGENCY SETUP MESSAGE is received by the MSC, the dialed (Bnumber) is analyzed. The behavior of the call will be based on the value of the forth Service bit (SBt) as follows:

- If SB is null,an Event Detection Point-Notification (EDP-N) will notify gsmSCP that SB=0. The call setupwould proceed with its first call setup attemptto an available PSAP. If connection to PSAP failed for some reason, the service logic will play announcement to the MS, and ask óif MS would like to terminate the call to other available non PSAP locations?ô Options are then relayed to the MS.The MS makesa selection, and the EMERGENCYSETUP continues to the new destination. If the call setup succeeds between MSC and the new destination,the EC is then connected to the new destination. We now have a Connected MS (desired condition).
- If SB is aninteger other than ó0ô, an Event Detection-Trigger (EDP-T)is activated. This will suspend call and executes a CAMEL procedure to determine routing information.The SCP responds with destination (B number) and call SETUPwould begin to the destination. If MSC was able to establish connection to destination MS is connected. Else, announcement is played to MS, and other options are relayed for the MS to choose from. The MS makes a selection and the CAMEL procedure is executed again (Figure 3.5).

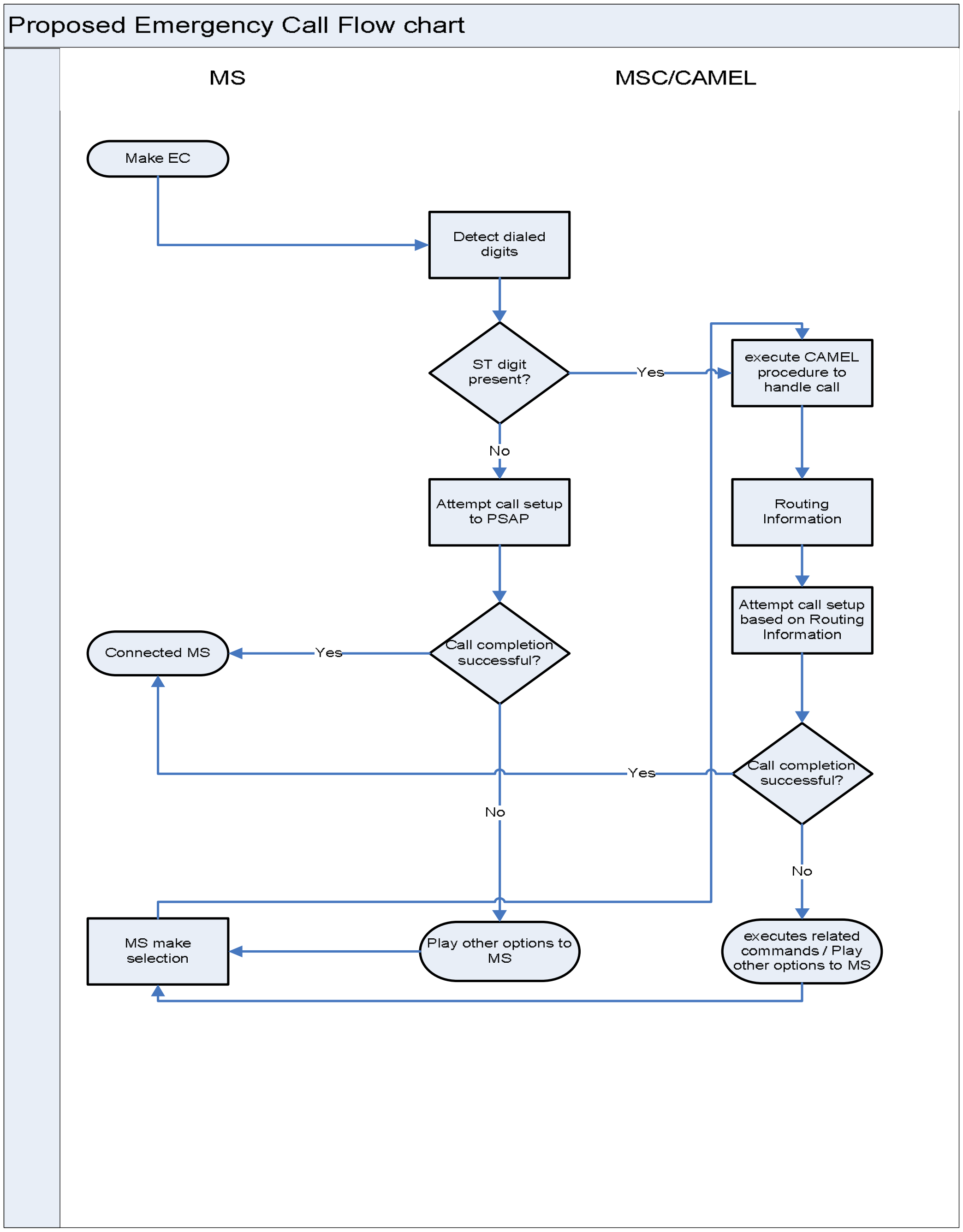

Figure 3.5 Proposed EC call flow for EECHP

Note:

From the flowchart above it can be seen that with EECHP,an EC can be re-routed to other destinations when PSAP is unavailable for termination.

For the purpose of this project,ECduring congestion period are studied and analyzed.

All call arrivals at the PSAP areassumed to be from infinite sources and randomly distributed.i.e.Poisson arrival process. [12]

3.3 Mathematical Model 1-ExistingECHP.

Considerthe diagram shown belowwhere an incoming EC traffic from a GSM/WCDMA network arrivePSAP at the rate of lamda /s, with an average call holding time □(s).Then depending on the call arrival time, lets say□ calls were answered by the PSAP, while □ are simply rejected due to congestion as shown in Figure 3.4 below.

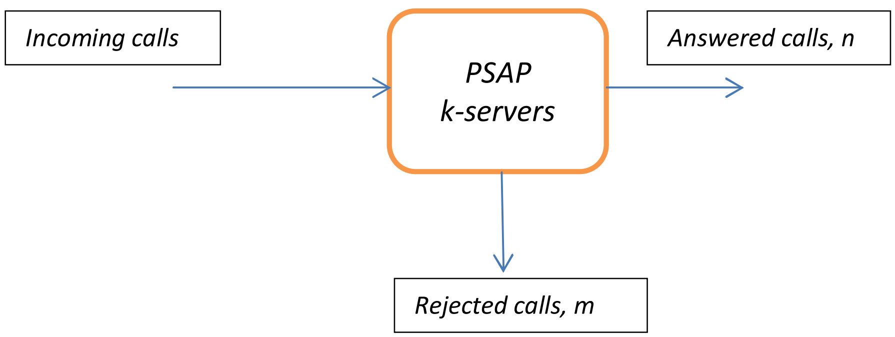

Figure 3.4 Congested EC arrivals at PSAP with ECHP

Then, giventhe above scenario,a performanceappraisalof this systemcan be easily done byquantitatively establishing the relationship between (i) Call Blocking Probability, Incoming traffic &System capacity and(ii) Quality of Servicevs. offered traffic.

These relationships were mathematicallydetermined as follows:
EC traffic intensity at the PSAP is given by:

$$\square = \square\square\square\ \square\square\square * \square erlang \qquad 3.1$$

Given that the arrival process is markovian, the probability that an EC is dropped due to congestion at the PSAP is given by the Erlang B loss formula [5]**:**

$$\square_{\square} = \square(\square, \square) = \frac{\frac{\square^{\square}}{\square!}}{\sum_{\square\square}^{\square} \frac{\square^{\square}}{\square}} \qquad 3.2$$

Where A = offered traffic in erlangs and k=number of servers at the PSAP. Equation 3.2 represents the quantitative relationship between Call blocking probability, PSAP capacity and EC Traffic. Since QoS is the probability for a successful call termination, it can easily be derived from P_b,

$$QoS = 1 - P_b \qquad 3.3$$

To obtain the carried traffic given a certain blocking probability P_b, the carried traffic is equal to the mean number of busy servers.The, blocked and terminated traffic 'm' and 'n' are given by equation 3.4 and 3.5 respectively; ie.

$$\text{Blocked traffic } m = A.P_b \qquad 3.4$$

$$\text{Terminated traffic } n = A.QoS = A(1 - P_b) \qquad 3.5$$

3.4 Mathematical Model 2 –GSM/WCDMA Network with Proposed EECHP

Consider another scenario wherePSAP blocked traffic (the overflow traffic)m ,from the congestion process in fig 3.4 above, was not dropped, rather itwas fed to an alternative server group with $k2$ number of servers as shown in Fig 3.5 below. From this traffic$m$, some $n2$ calls are terminated while m 2 was finally blocked due to congestion of k2 servers. See figure 3.5 below.

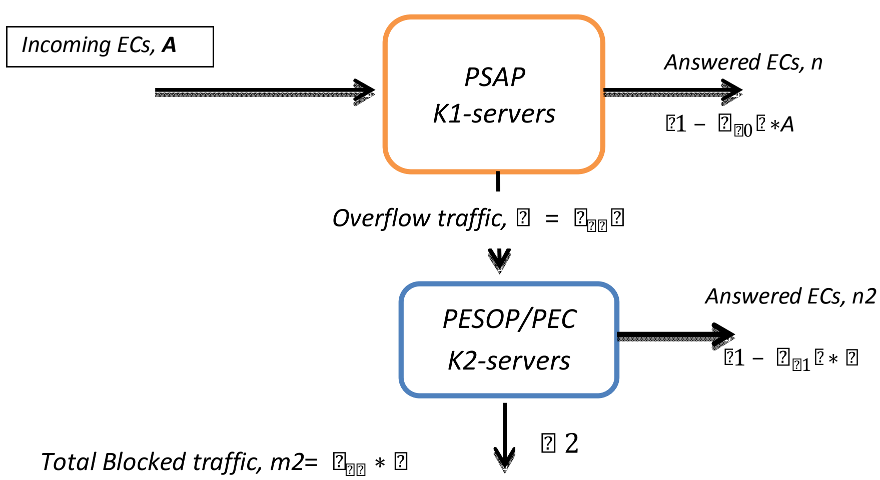

Fig 3.5 Congestion EC traffic in a GSM/WCDMA network with EECHP

The traffic that was allowed to overflow to $k2$ server group (PESOP, PEC) is not Poisson in distribution;rather it is bustierthan a Poisson process. In other words, the variance of the number of arrivals in an interval ishigher than the mean number of arrivals in that interval[6].

It is therefore important to characterize such overflow traffic by its variance and its mean.

In particular, let's consider a $M/M/k/k$ queuing system with offered traffic 'A' Erlangs, and let ρ [Erlangs] be the overflow traffic from this k-server system. From equation 3.3 we knewthat

$$\rho = A E_k(A)$$

Where A is the EC offered traffic to PSAP,

$E_k(A)$ is the erlangb value for A traffic and k servers.

If the number of serversin the primary and secondary groupsare given as: k1 and k2, respectively, then the blockingprobability of the secondary server group is obtained by using the Multi-server Loss M/M/k/k systemequation for non-Poisson inputgiven below [5]:

$$B_{k2}(k_1, k_2, A) = \frac{E_{k1+k2}(A)}{E_{k1}(A)} \quad 3.6$$

Where $k1$ and $k2$ are the number of servers in PSAP and overflow System respectively.

The total blockedtraffic as seen by the EECHP is thus:

$$T2 = \rho * B_{k2} \quad 3.7$$

But $\rho = E_k * A$, thereforeequation 3.7 can be re-written as

$$T2 = B_{k2} . E_k . A$$

Substituting B_{k2} and E_k with equations 3.6 and 3.2 respectively we have

$$T2 = \frac{E_{k1+k2}(A)}{E_{k1}(A)} . E_{k1}(A) A$$

which upon elimination of $E_{k1}(A)$ reduces to

Total blocked traffic $T2 = A . E_{k1+k2}(A) \quad 3.8$

Where: A is the EECHP system offered traffic,

$E_{k1+k2}(A)$ is the Erlang B value for servers 'k1+k2', with 'A' traffic

System Blocking Probability

The total blocking probability as seen by the system isgiven by:

$$\square_{\square\square} = \frac{\square\square\square\square\square\square\square\square\square\square\ \square\square\square\square\square\square\square}{\square\square\square\square\square\square\square\square\square\square\square\square\ \square\square\square\square\square\square\square}$$

Form 3.8 $\square_{\square\square} = \frac{\square\,2}{\square}$

$$\square_{\square\square} = \square . \frac{\square_{\square 1 + \square 2}\square\square\square}{\square}$$

Which is reduced s to: $\square_{\square\square} = \square_{\square\square\square\,\square\square}\square\square\square$ 3.9

Thus,the total blocking probability, as seen by the EECHP is equal to the Erlang B value of the sum of servers in PSAP and secondary servergroup for any offered traffic during the congestion.

Equations 3.2 and 3.9quantitatively define the relationship between blocking probability, offered traffic and number of servers in PSAP only and PSAP with an overflow system.

3.4.1 Mathematical Models highlight:

Table 3.4 below compares EC blocking probability, blocked traffic and call success (QoS) as seen by an ECS using ECHP and EECHP for any given offered traffic óAʹduring congestion.

Table 3.4Mathematical model key parameters

Network: GSM/WCDMA	**ECHP (Current)**	**EECHP**
Offered Traffic (Erlangs)	A	A
Blocking Probability (Pb)	$\frac{\frac{\square^{\square}}{\square!}}{\sum_{\square\square\square}^{\square}\frac{\square^{\square}}{\square!}}$	$\frac{\frac{\square^{\square\square\square\,\square\square}}{(\square\square\square\,\square\square)!}}{\sum_{\square\square\square}^{\square\square\square\,\square\square}\frac{\square^{\square}}{\square!}}$
Total Blocked traffic	$\square\square_{\square}\square\square\square$	$\square\square_{\square 1+\square 2}\square\square\square$
QoS	$1 - \square_{\square}\square\square\square$	$1 - \square_{\square\square\square\,\square\square}\square\square\square$
Total allowed traffic	$\square(1 - \square_{\square}\square\square\square)$	$\square(1 - \square_{\square\square\square\,\square\square}\square\square\square)$

CHAPTER 4

MODEL SIMULATION AND RESULTS

4.1 SIMULATION: Emergency call simulationswere carried out using Matlab (in the absence of live GSM network) to quantitatively compare the two emergency call handling procedures against each other. The efficacy of the proposed EECHPwas compared to the existing ECHP using Call Blocking Probability (P_b) and Quality of Service (QoS) performance indicatorsderived fromthe previous chapter 3.

4.1.1 Simulation 1: GSM/W-CDMA Network with current ECHP

Figure 3.1 shows a MS making an emergency call to a GSM network. The GSM network attempts to terminate the call to a PSAP equipped with 30 active servers.

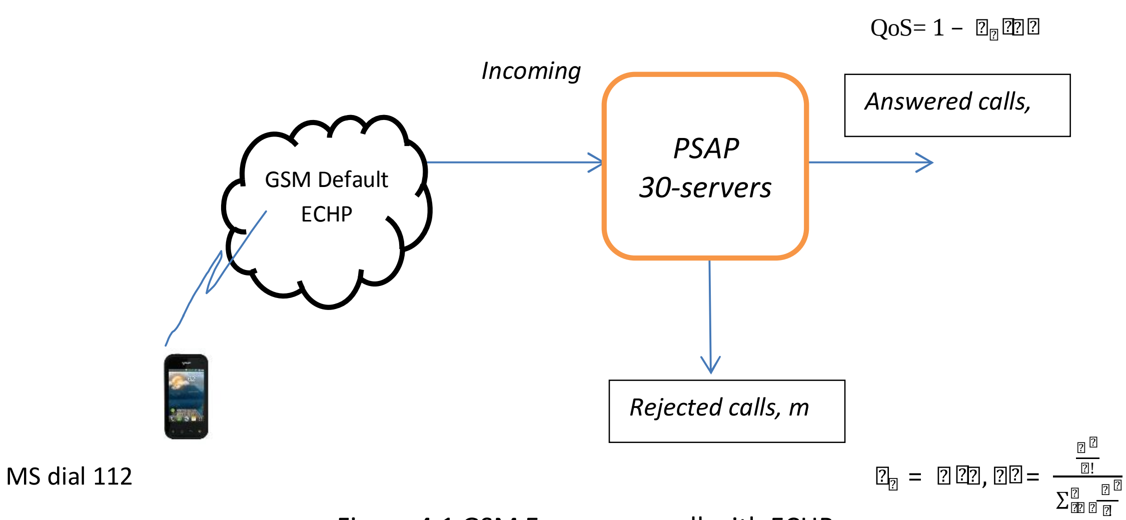

Figure 4.1 GSM Emergency call with ECHP

4.1.1.1 Simulation features:

(i) A PSAP is connected to a GSM/WCDMA network via at least 1 no E1 circuit (30ch). All ECs are routed to PSAP only for possible termination.

(ii) Number of available servers at PSAP=30

(iii) Emergency calls arrival at PSAP is randomand from infinite sources.

(iv) Call blocking probability was computed for varying offered EC traffic 'A' before congestion and after congestion based on equation 3.2 above i.e. $P_b = B(k, A) = \frac{\frac{A^k}{k!}}{\sum_{i=0}^{k} \frac{A^i}{i!}}$.

(v) Quality of Service given as QoS= (1-Pb) was also computed and values obtained were plotted against the Offered Traffic.

4.1.2 Simulation II:GSM/W-CDMA Network with EECHP

Shown in figure 4.1 below are components of the EECHP simulation process, comprisinga random source of emergency callsseeking for calls termination at a congested PSAP with 30 servers. Calls that could not be terminated at PSAP are diverted to a secondary server group with *k2* servers.Where k2 is a variable quantity.

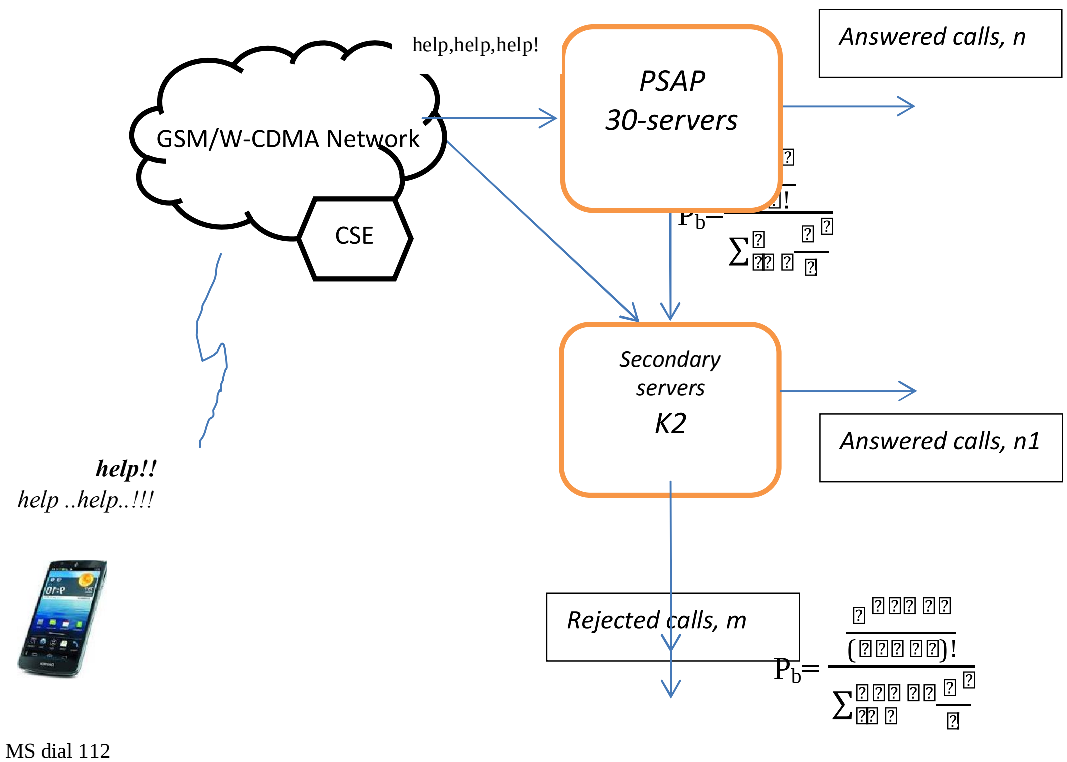

Figure 4.2 EECHP simulation flow diagram k1=30 PSAP and k2 Secondary Servers

4.1.2.1 Simulation features:

(i) A PSAP connected to a GSM/WCDMA networkvia at least E1 circuit (30ch)capable of supporting 30 concurrent calls

(ii) Number of available servers at PSAP=30

(iii) Overflow trafficfrom PSAP is fed to a server group with ók2ô servers representing the system capacity of alternate termination point as inEECHP model in Fig 3.5.

(iv) All ECs arrivedPSAP randomly and from infinite sources.

Callblocking probability was computed for different offered traffic conditions,with varying number of secondary servers K2 ie. k2=0, 5,10 and 15, while k1 was maintained at 30

4.2 Results and Analysis

Results were obtained from the network simulation carried out on the two emergency call handling models, namely: - (i) GSM/W-CDMA network terminating ECsusing default ECHPto a PSAP with 30 servers and (ii) GSM/W-CDMA network terminating ECsusing EECHP to a PSAP with 30 servers and to other destinations in the event of PSAP congestion.

The first set of simulation results are for GSM/WCDMA system using existing ECHP while the subsequent ones are for the network with EECHP.

Obtained simulations results are presentedand analyzed below.

4.2.1 ECHP Simulation Results:

4.2.1.1 Call Blocking Probability

Figure 5.1shows result of simulated emergency call scenario using existing GSM/CDMA ECHP to terminate all incoming ECs to a PSAP equipped with 30 servers.
Call blocking probability and QoS values were captured and plotted as shown in Fig 5.1 below with call blocking probability on Y axis and Offered EC traffic on the X- axis.

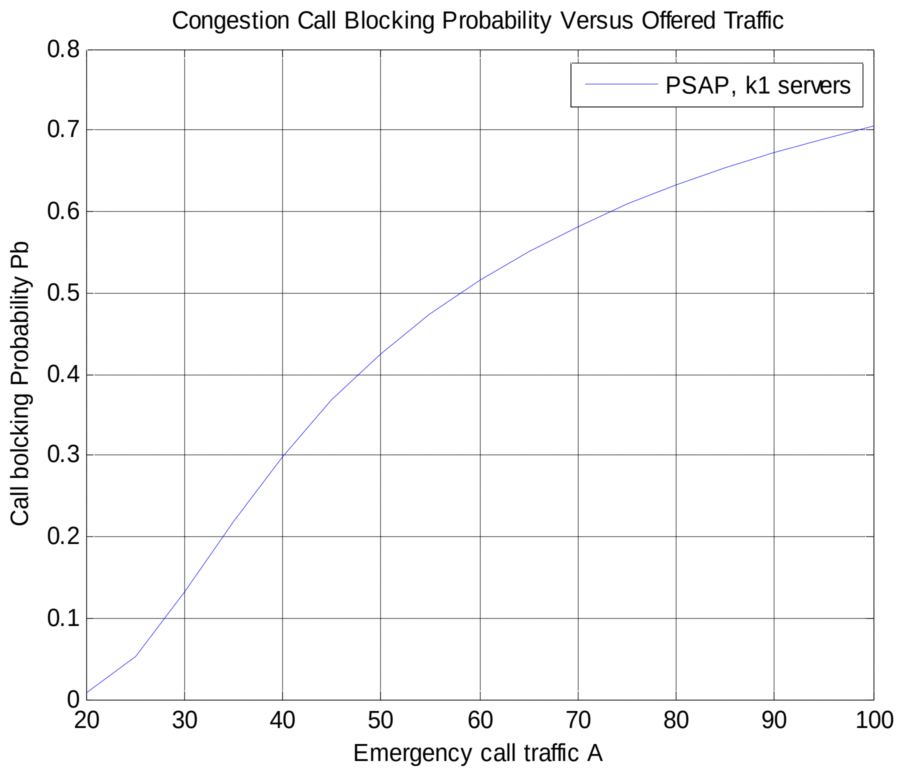

Figure 4.3 Call Blocking Probability against Offered Traffic for K1=30

From the graph in figure 4.3, it can be seen that blocking probability (P_b) grew exponentially with increase in offered EC traffic before and during congestion period. For instance, from the graph it can be seen that 50% of EC traffic cannot be terminated when the offered traffic reached 58.11 Erlang. Similarly, the 5% maximum call drop tolerable blocking probability for mobile network dimensioning corresponded toan offered emergency traffic of 24.798 Erlangs. Thus the threshold of 24.798erlang is the best performance maximum traffic for this system of 30 servers without call drop in excess of 5%.

4.2.1.2 Quality of Service (QoS)

QoS values obtained from simulation process were also plotted,QoS on Y axis and offered traffic on X- axis,as shown in Fig 5.2 below.

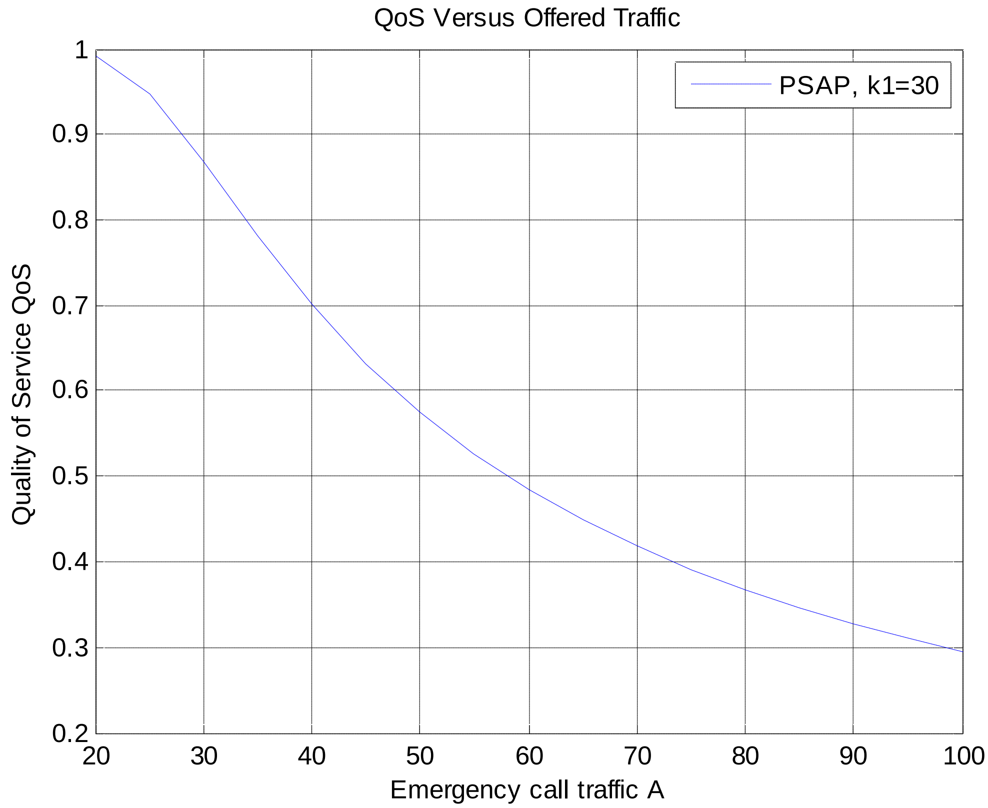

Fig 4.4 QoS against Offered EC Traffic for K1=30

Again, it was observed that Fig 4.4 obtainedis an exponential decaying graph, signifying deteriorating QoS with increased EC traffic for a system with PSAP as only termination point. The tolerableQoS limit (95% for mobile networks) occurred at an offered EC traffic value of 24.798Erlang in agreement with earlier value obtained using blocking probability from Fig 4.3.

4.2.2 Enhanced ECHP Simulation Results

Figures4.5 and 4.6 shows simulated. Blocking probability (P_b) and QoS valuesobtained by simulation of an EECHP compliant GSM/W-CDMA network terminating ECs to a 30 servers PSAP with call overflow to other k2 servers during congestion. The Blocking probability (P_b) and QoS values were plotted against offered EC traffic respectively for varying k1,k2 values.

4.2.2.1 Call Blocking Probability

The graph in figure 5.3 is a plot of simulated blocking probability value against offered EC traffic for k1=30 and varying k2=0, 5,10 & 15.

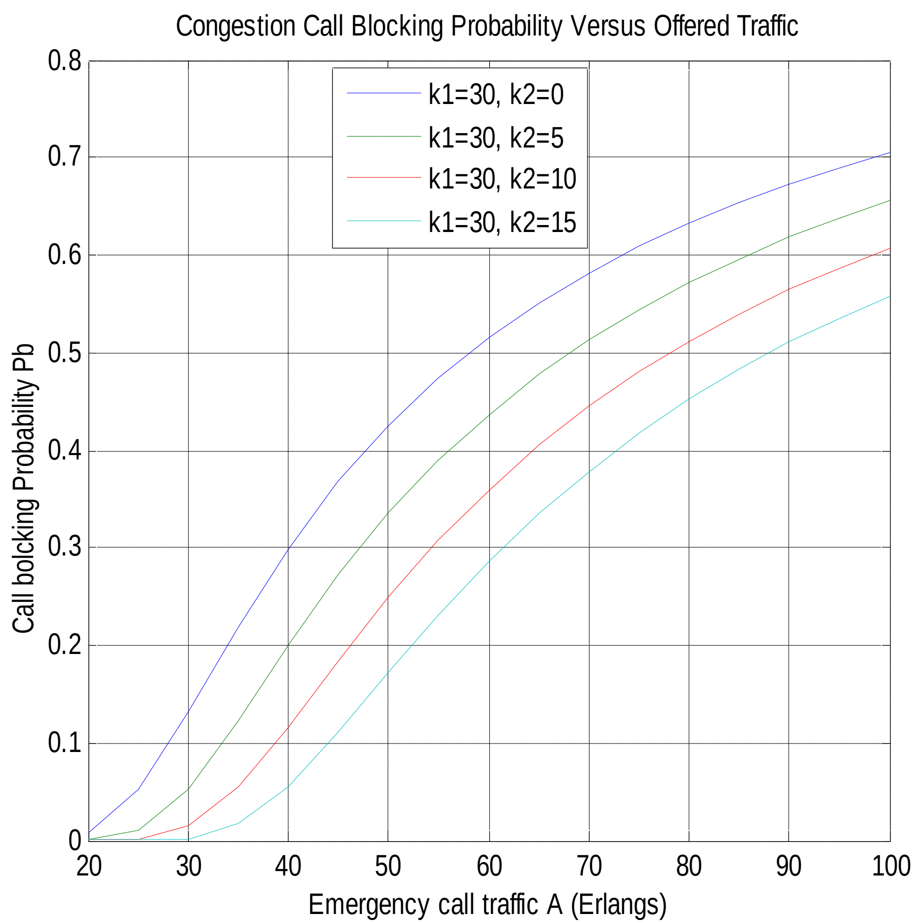

Figure4.5 Call blocking probability against offered traffic –EECHP

Again Figure4.5 shows an exponential growth of call blocking probability for increased offered EC traffic on each plot condition. It can also be seen that for any given EC traffic (A), the system experiences comparatively lower blocking probability with increasing number of secondary servers (k2).

Thus the call blocking probability decreases with increasing value of k2 secondary servers.

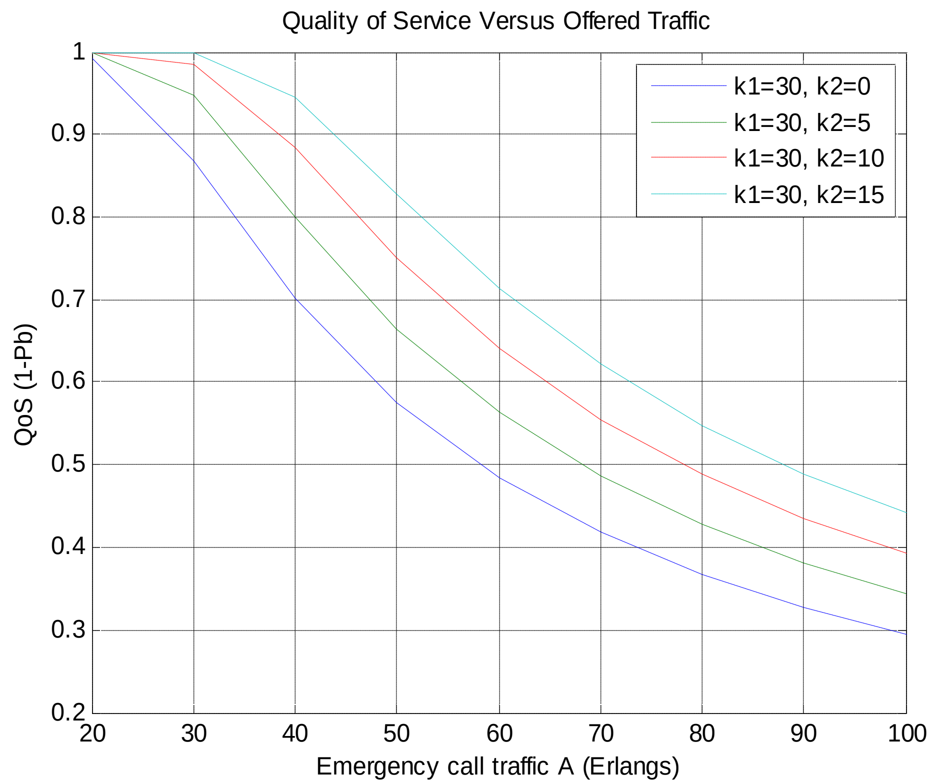

Figure 4.6 QoS against offered EC traffic for EECHP

4.2.3 Summary of Result Analysis:

From figures 4.3, 4.4, 4.5 and4.6above, the following were deduced:

i. For any given number of PSAP servers, N, the blocking probability is lower for lower EC traffic and itincreases exponentially withan increase in EC traffic.

ii. For any given offered EC traffic, a relatively higher QoS is obtained for increased number of available servers for termination. Eg QoS (25 servers,30 erlang traffic) = 0.7547 < QoS (30,30) =0.8675 < QoS (35,30) =0.9462 (Figure 5.2)

iii. The proposed EECHP model effectively increasedthetotal number of available servers for EC termination during congestion from ó*k*1′(for ECHP) to ó□1 + □2′ where *k2*= number of secondary servers.

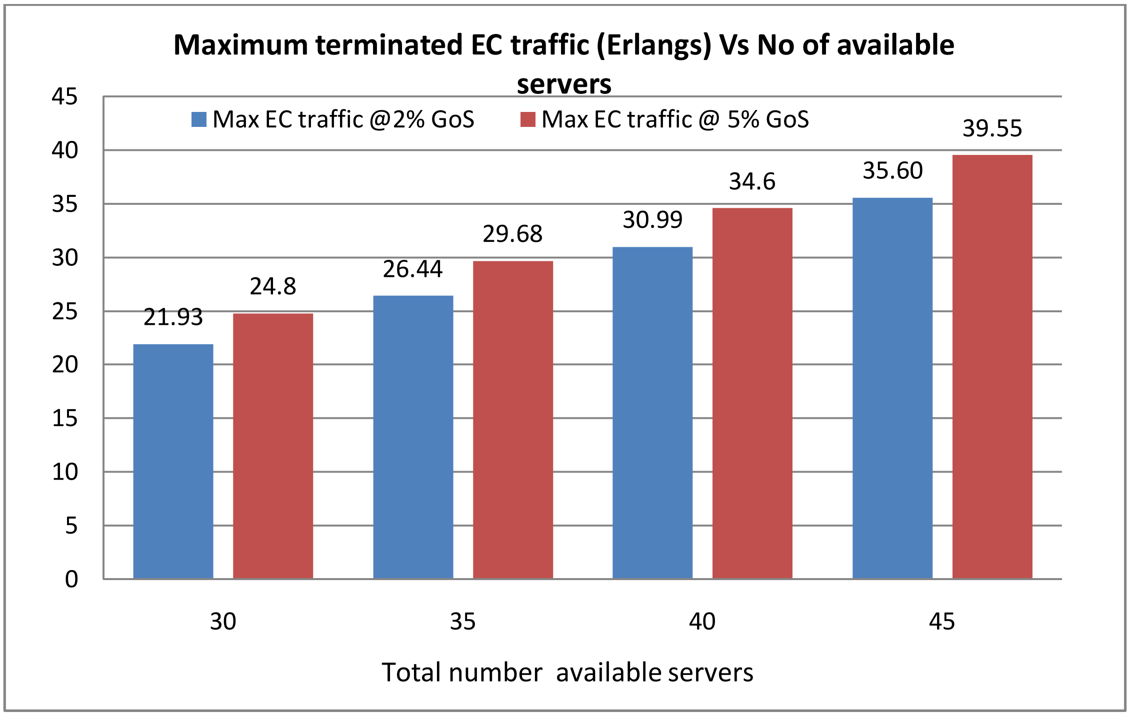

Figure 4.7 Maximum supported EC traffic

iv. From the QoS values in Fig 4.7 above, it can be seen that the 2% and 5% Grade of Service (GoS) for emergency calls using EECHP tend to shift by accommodating about 4.5 Erlangs additional EC traffic for every 5 added *k2*servers. Thus signifying the usage of EECHP brings about improved GoS.

v. That for any given number of servers N, QoS drops exponentially with increase in EC traffic.

vi. Higher EC traffic will require a higher number of servers to maintain same QoS

CHAPTER 5

CONCLUSION AND FURTHER WORK

The user perception ofan emergencycommunication service is usually quite different from the quality thatisdeterminedby the service providers, though closely related.The Quality of Experience (QoE) metric is whatis used to describe service usability strictlyfrom the end-userôs point of view. [15]However, for practical purpose it can be said that the Quality of Service (QoS) influences, to a large extent, the user QoE.

Thegrowing need for more flexibility in GSM/W-CDMA emergency call handling procedure,fromthe userôs viewpoint,wasclearly establishedbythepersistent callinghabit of people in emergencies,calling from one source of help to the other with the same message- help!é help!!é help!!!; and from any source they seek communication thatcan save the situation.

Consequently,there is a need for an all-encompassing EC handling procedure for the GSM/WCDMA network to carter for the identified sources of help other than PSAP, especially duringcongestion at the PSAP. Suchdesirefor commercial and personal emergency communications is growing in areas prone to security challenges,since thehighly reliable emergency communicationsystem,as required by public safety and disaster reliefagencies is being challenged by severalmilitating factors,an improvementof the current call handling modelwould thus improve the overall user QoE.

The work presented in this thesis, proffered a way of improving theexisting GSM/W-CDMA emergency call handling procedure which was hinged on fast routing all ECs to PSAP without scrutiny - with an implementation which is referred to as ôEnhanced Emergency Call Handling Procedureô (EECHP) for the GSM/W-CDMA. This EECHPimplementation modifies the GSM originating call handling procedure to incorporate the use of Customized Application for Mobile Network Enhanced Logic (CAMEL) to perform intelligent routing of ECs while enabling call termination to other sources. The procedure has shown an improved call termination success during PSAP congestion.

Simulated performance evaluation of atypical modeled ECS using EECHP vis-à-vis existing call handling procedure as carried out, indicated an increase in the number of available servers for EC termination, from $k_1$for current ECHP to (k_1 + k_2),where *k1* is the number of servers atthe PSAP and *K2* represent the number of availablesecondary servers.

Making additional servers availableby EECHP directly translates into more likelihood of EC termination.

On the overall, the efficacy of GSM/W-CDMAECS as simulated using EECHPhave shownimproved Grade of Service (GoS) or call success rate over a similar GSM/W-CDMAECS thatutilizesexisting emergency call handling procedure for the same network conditions.

5.1 Costs

The cost of this project was estimated at N500,000.00 only. However, the cost of implementing this solution in real life could run into millions of Naira. The cost elements include, but not limited to, the cost of setting up PESOP call centers for private emergency service operators, staff costand logistics. Other cost elements are those already procured GSM/W-CDMA systems (eg the CAMEL platform, SCP etc.). The rest are configurations that could be implemented at the MSCs and CSE.

5.2 Opportunities

This project when implemented will open new socio-economic activities in the country where it is implemented.Improved communication leads to improved security of lives and property of the people, as seen with the activities of civilian JTF in the fight against insurgency in theNorth-East,of Nigeria.

Business opportunities are also made available for Privateemergency service operators (PESOP) who would invest in resources to support emergency victims and charge money for services rendered. Different models can be explored the details of which are beyond the scope of this project.

A rather more encompassing approach to security involving government and the people will provide employment opportunities for youths.Other benefits include, licensing of commercial emergency service operators for a fee and setupof regulatory agency by government to coordinate activities of the private operators.

5.3 Limitations / Challenges

EECHP model is meant to offer a convergence point for all emergency call needsï Public, Private or Personal. The procedure ensures that ECs,whatever their nature, are not denied or miss prioritized during and after call setup due to mis-classification or rigid routing by the GSM/WCDMA networks; and they are delivered to some destination.

The success of this model (as with all other emergency response systems)however, is hinged on the assumption that the GSM/W-CDMAnetwork is not overwhelmed by a large number of concurrent EC requests ï similar to what happened during the September 11 attack in the United States of America, USA ï as this will render the platform useless due to prolonged service time among others.

The EECHP within above limits would offer significant caller QoE improvement over the existing way of handling emergency callsby the GSM/W-CDMA networks in Nigeria.

5.4 Suggestion for Further Work

The scope of this project was limited to modeling and evaluation of EECHP in a congested PSAP situation.There is room for further investigation into applicable call handling model for emergency calls in non-congested PSAP condition using EECHP.

Further studies can also be focused on the new LTE network being built by operators with completely packet-switched core and SIP protocol.

5.5 Definite Contribution to Knowledge

It is on record that the contribution of civilian JTF in the fight against the Boko Haram terrorists in the North-East, of Nigeria,was quite significant [16]. So are the contribution of vigilantegroups in taming theactivities of robbers and kidnappers in different parts of the country. These groups, though voluntary or private in nature, requirean effective medium of communication through which they can be reached as the need arise; i.e. during emergencies.

This project work brought to the limelight (for the first time) the need to broaden Public Safety Emergency Response System (PSERS), from a strictly government affair, to that which will involve Private, Commercial, Vigilante and/or other voluntary stakeholders. The success of such a collaboration begins with the Emergency Communication System (ECS), which currently is 90-95% being handled by GSM/W-CDMA networks(the most deployed cellular technology) in Nigeriaandhence the most used media for reporting emergencies.

Reforming the emergency call handling procedure (ECHP) in GSM/W-CDMA networks to accommodate the new identified stakeholders was the primeobjective achieved by the Enhanced ECHP provided in this work,which will translate intoimproved stakeholder collaboration amongst PSERS operators.

So effectively it can be said that the introduction of EECHP is helping the fight against insecurity and improving collaboration between government and the general public for the betterment of the society.

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