Signaling on the Most Critical Interfaces in GSM

Zorica Bungurova-Kaziovska [1] and Toni Janevski [2]

Abstract - **In this paper, the analytic model for prediction of signaling on the interfaces, referred as most critical and very often as bottleneck in the core mobile network, and design of signaling network, are given. Gb specific interfaces is out of the scope of this paper.**

Keyword – **Signaling, A-interface, C/D interface**,

I. Introduction

GSM (Global System for Mobile Communication) is most popular standard for public mobile network, which is designed to provide mobility to the end users of cellular phones and Internet. Common channel signaling system Number 7 is a key element in supporting a large number of applications in telecommunication networks.

Addressing and control information from an origin to destination point in a communication network is referred to as signaling, and is used in selecting a path, providing information on the status of the users and resources, or performing the necessary network supervision and charging function.

II. Signaling

The A-interface lies between the MSC (Mobile Switching Center) and the BSS (Base Station Subsystem). The A-interface consists of both user plane (PCM links) and control plane (signaling).

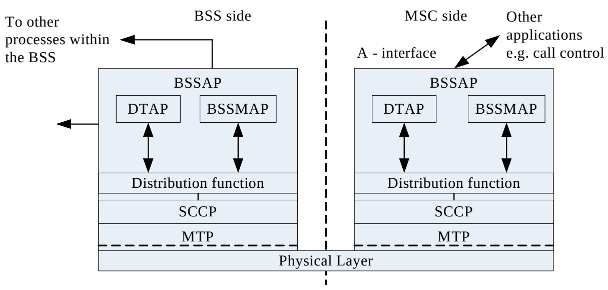

Fig. 1 SS7 stack for BSS Application Part

[1] Zorica Bungurova-Kaziovska, is with Faculty of Electrical Engineering, Dept of Telecommunication, Karpos 2 bb 1 000 Skopje, Macedonia
Zorica.BungurovaKaziovska@t-mobile.com.mk
[2] Toni Janevski, is with Faculty of Electrical Engineering, Dept of Telecommunication, Karpos 2 bb 1 000 Skopje, Macedonia
tonij@etf.ukim.edu.mk

The SS7 stack is composed of an SCCP (Signaling Connection Control Part) layer on top of the three MTP (Message Transfer Part) layers, MTP3, MTP2 and MTP1.

The signaling part of the A-interface is used to carry information concerning: BSS management, call handling and mobility management. BSSAP [1] (Base Station System Application Part) is application (upper), which sits on an SS7 stack, as it shown in Fig. 1

TCAP is not used for BSSAP. BSSAP is an SCCP user (usually SSN=254 for ETSI) and it often uses the logical connection function in SCCP (Signaling Connection Control Part) in order to identify the MS for signaling messages that follow the initial message. The BSSAP requires both SCCP service: CO and the CL. The CO transfers many or long signaling messages between two nodes. The CL transfers short messages, including routing information, to their destination. The BSSAP application layer is divided into two parts: DTAP (Direct Transfer messages) and BSSMAP (Base Station System Management Application Part). Generally, the CM – Connection Management and MM – Mobility Management layers consist of DTAP messages while the RR – Radio Resource Management and FM – Facilities Management layers consist of BSSMAP messages. Discrimination parameter is used for distribution function.

DTAP (Location Updating, Identity, Authentication, CM service) messages are call control or mobility management between the MSC and the MS, pass through the BSS transparently. Initial MS (DTAP) messages are associated with call control and mobility management and they pass through BSS unchanged, but part of them is analyzed by BSS (Paging, CM Service request). They are encapsulated within the Information Element "Layer 3 Information" in the BSSMAP Complete Layer 3 Information. BSSMAP messages are used for resource management (Assignment, Clear), Ciphering, Handover control as CL and Paging, Circuit management as CO.

C-interface between HLR and GMSC is used for interrogation procedure during Call Setup and a Forward Short Message. D-interface between HLR and VLR is used for management of Subscriber and during Location procedure. The MSC/VLR, HLR, and GMSC communicate via the MAP, using only the CL mode for Location Management, Handling of call and subscriber services, Handover and Transfer of security/authentication data.

To support GSM requirements is especially designed Mobile Application Part – MAP [2]. MAP is a TCAP [3] (Transaction Capabilities Application Part) user and also uses the SCCP [4] and MTP [5] for transmission of information.

Only the MTP network has access to the physical link, for example, cable. It provides the common platform between the different user parts and functional elements. The combination of the MTP and the SCCP is called the Network Service Part (NSP).

In a node, a signaling message can be originated, terminated, or transferred. The signaling method uses an address called a Signaling Point (SP), which is identified by the Network Indicator (NI) and the Signaling Point Code (SPC). Each node in a network must know all its potential receivers (cooperating SP). The NI distinguishes between the different networks, national and international. To generate an originating labeled message, the node uses the SPC of the OWNSP as the Originating Point Code (OPC), and the SPC of the cooperating SP as the Destination Point Code (DPC). Whether terminating or transferring a message, a node always compares the DPC of the incoming message to its OWNSP. If they are not equal, the node must transfer the message. This requires a routing function called MTP routing. The MTP routing ties a DEST to a Link Set (LS). Group of Signaling Links (SL) that directly interconnects two SP is called LS. Each SL in LS receives an individual number called a Signaling Link Code (SLC). SL is one time slot (64kbit/s) within PCM (2Mbit/s). The Signaling Terminal (ST) is connected to the LS via the SLC. Routing is always based on addresses: Calling address (identifies call origination) and Called address (identifies call destination). SCCP addressing is very flexible and makes use of three separate elements: Destination Point Code (DPC), Global Title (GT) and Sub-System Numbers (SSN). SSN and DPC are used for routing if the nodes are directly connected. Usually, SSN and GT are used for routing across mediate nodes. Each node must have its individual calling address, used in national and international transmission. It has the same structure (defined by E.164) as an MSISDN. The structure is CC+NDC+SN.

In AXE (A Switching System for mobile and fixed telephone networks), a specific MAP operation is typically handled by one function block, which is referred to as Application System Elements (ASE). An ASE can only communicate with a compatible peer ASE. A set of Application Service Elements (operations) is called an Application Context. MAP and TCAP belong to the layer 7 in the OSI model. Application Context version 1, 2 and 3 belongs to the Presentation layer (layer 6). Please see Fig. 2.

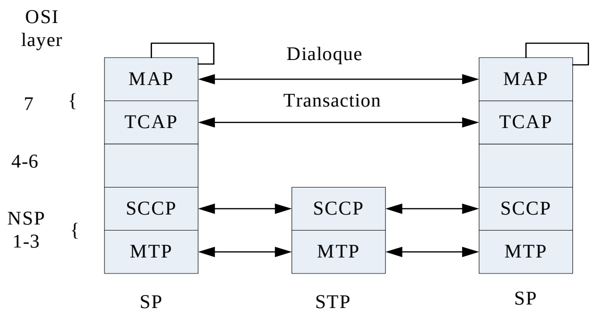

Fig. 2 Functional view of SS7 system

The main purpose of TCAP is support for interactive applications (TC-user) in a distributed environment (across many nodes). TCAP allows TC-users to have several conversations running concurrently. In order to set up and support the dialogue between two TC-users, TCAP provides an association between the local and remote ends called a Transaction. A TCAP message is composed of three portions: transaction, component and dialog. The Transaction portion consists of an originating and/or destination transaction identifier that is used by both TCAP ends to identify the connection. The component portion encapsulates the information sent to and received from TC-users in the form of components. For example, MAP messages to and from TC-users in GSM are encapsulated as components. One or multiple components (MAP messages) can be sent at the same time. The dialogue portion of a TCAP message allows two TC-users to negotiate the terms of a transaction. For example, the dialogue portion is used by MAP TC-users in order to negotiate which MAP version is to be used for a particular transaction. The dialogue portion is optional within TCAP and if used is only present in the first two TCAP messages within a transaction. Components which are used to perform Operation are exchanged within the Structured dialogue (begin, continue and end message). All components within an operation have the same Invoke ID. Dialogue must be terminated or aborted. The MAP protocol only makes use of structured dialogues. TCAP receives data from the TC-users, encapsulates it and hands it over to NSP.

III. RESULTS

The transmission rate for signaling link is 64kbit/s or 8000 octet/s in both directions. The recommended traffic load per SL under normal condition is 0.3 E or 2400 octet/s. Table 1 shows the capacity of the link set. If number of SL in the LS is divisible by 2, the load of the links within the LS is balanced. For redundancy, minimum two links are required towards one destination. Maximum 16 SL can be established towards one destination.

Table 1 Signaling capacity

Number of signaling links	Signaling capacity
1	19,2 kbit/s
2	38,4 kbit/s
3	51,2 kbit/s
4, 5	76,8 kbit/s
6, 7	102,4 kbit/s
8, 9, 10, 11, 12, 13, 14, 15	153,6 kbit/s
16	307,2 kbit/s

Table 2 Measuring report for traffic event

Normal LU	MO	MT	SMS-MO	SMS-MT	HO
0.16	0.15	0.11	0.01	0.03	0.01

Table 2 shows the average value of event/s per subscriber for observed traffic cases, because observed BTS have different busy hour per different service. For sampling was used 15 minutes resolution. Measurements are done within period of 1 year and for all cells within the BSC. SS and HO produce insignificant signaling load. From the measuring report for traffic event, we can see that bigger part of the signaling load is from LU. All results lead to the same conclusion: 50.7% of load is originated from calls; 1.8% - from handover; 1.65% - from SS; 37% - from LU; 5.3% - from SMS and 2.8% - from internal traffic.

IV. Analytic Model

Procedure for calculation of signaling traffic on the common C and D interface

Incoming and outgoing octets per sec., in both directions (query and response) for each traffic event are calculated. Fig. 3 shows the results.

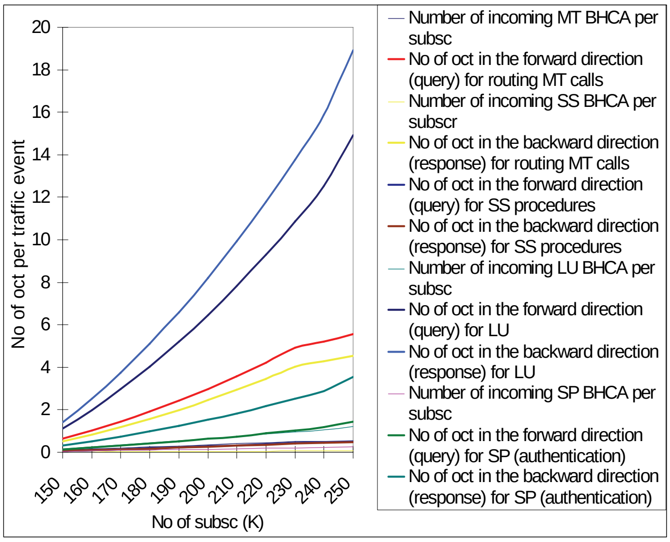

Fig. 3 Estimated no of octet per traffic event on the C/D interface

Table 3 Length of message units on the C/D interface

Direction	Type of event	Length of MSU
forward	MT call	128
forward	LU	179
forward	SS	130
forward	SP	67
backward	MT call	105
backward	LU	227
backward	SS	120
backward	SP	164

Table 3 shows the used length of message signaling unit for observed events on the C/D interface in both directions.

Equations (1) and (2) are used to calculate max number of octets transmitted per second in each direction, and equation (3) - to estimate required number of SL between MSC/VLR and HLR.

$$O_T^I = \left(O_{MT}^I + O_{LU}^I + O_{SS}^I + O_{SP}^I\right) * k \quad (1)$$

$$O_T^O = \left(O_{MT}^O + O_{LU}^O + O_{SS}^O + O_{SP}^O\right) * k \quad (2)$$

Factor k = 1.1 is for SMS and USSD notification.

$$O_T = \max\left(O_T^I, O_T^O\right) = 0.085 * N \quad (3)$$

Fig. 4 shows estimated and measured signaling load on the C/D interface in the six observed measure periods.

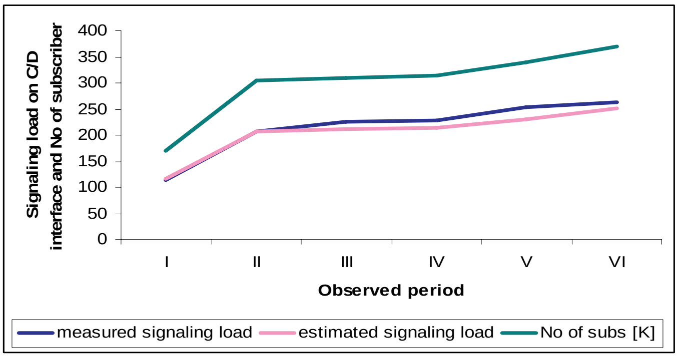

Fig. 4 Estimated signaling load as compared with measured signaling load on the C/D interface

Procedure for calculation of signaling traffic on the A interface

Incoming and outgoing octets per sec., in both directions (query and response) for each traffic event are calculated. Fig. 5 shows the results.

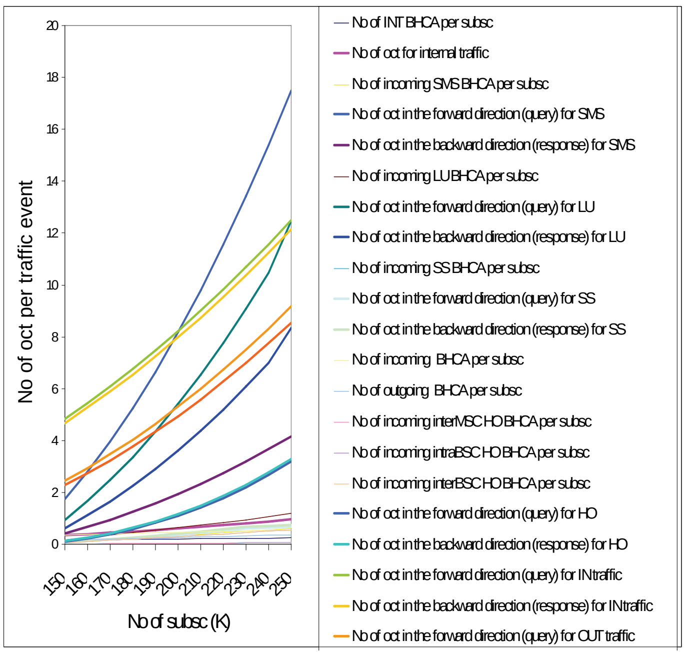

Fig 5 Estimated no of octet per traffic event on the A interface

Table 4 shows the used length of message signaling unit for observed events on the A interface in both directions.

Table 4 Length of message units on the A interface

Direction	Type of event	Length of MSU
forward	call	268
forward	SMS	420
forward	LU	130
forward	SS	165
forward	call/LU/SS	306
forward	inter-MSC HO	82
forward	inter-BSC HO	82
forward	Internal traffic	55
backward	call	260
backward	SMS	100
backward	LU	87
backward	SS	182
backward	call/LU/SS	285
backward	inter-MSC HO	70
backward	inter-BSC HO	90
backward	intra-BSC HO	31

Equations (4) and (5) are used to calculate max number of octets transmitted per second in each direction, and equation (6) - to estimate required number of SL between MSC/VLR and BSC.

$$O^I = O^O_{IN} + O^O_{OUT} + O^O_{HO} + O^O_{SS} + O^O_{LU} + O^O_{SMS} \quad (4)$$

$$O^O = O^I_{IN} + O^I_{OUT} + O^I_{HO} + O^I_{SS} + O^I_{LU} + O^I_{SMS} + O_{INT} \quad (5)$$

$$O_T = \max\left(O^I, O^O\right) = 0.13306 * N \quad (6)$$

Fig. 6 shows estimated and measured signaling load on the A interface in the six observed measure periods.

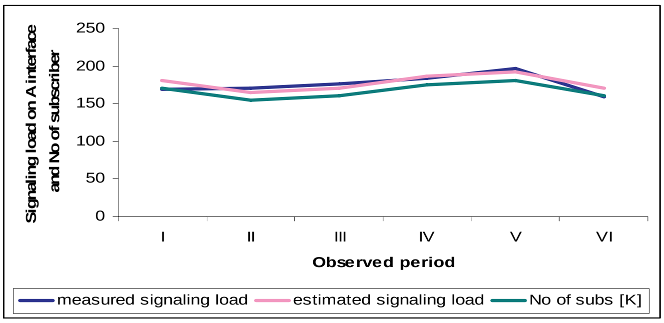

Fig. 6 Estimated signaling load as compared with measured signaling load on the A interface

VI. Discussion

The service area of the observed BSC covers mountain region and valley, and must be define a lot of neighbour relation between cells. Subscribers are very mobile and it was registered high fluctuation of subscribers to the neighbour BSC that cover the major city in the country. Also, in this MSC service area is registered high fluctuation during summer and religious vacations. For this reason is used very high number of attempt per LU (e.g. for normal type of LU - 0.18 event per subscriber in busy hour, instead of measured 0.16. Also, for call was used four time bigger value because of a high number of registered calls without B-answer (snakes). To adjust the real conditions in the model for C/D interface was added factor of 10% for SMS and USSD notification. For Call dependent SS was added a factor of 10% on the C/D interface and 15% on the A-interface, where they have bigger impact on the signaling volume. If Authentication is not performed in the network (during the call, SMS, SS or LAI changing), signaling load will be decreased for 0.5kbit/s on the A and C/D interfaces. LU and call related procedures take the most part of the produced signaling load. The A and C/D interfaces are most critical, because on the other interfaces under the same environment was registered insignificant signaling load.

V. Conclusion

The signaling load is highly dependent on the configuration of terrain and radio design. Bad relation between cells, unbalanced power of the cell, interference, SDCCH configuration in the cell, LAPD concentration factor in the cell and other radio factors can produce a bigger load on the A and also on the C/D interface (e.g. config=4 is set for cell which serves high traffic). A use of different services increases the signaling load (e.g. SMS, USSD notification). Also the signaling load is dependent on the subscriber behavior and the tariff model. This analytic model can be used just for prediction of the signaling load in the normal terms, because signaling in the network has a burst and unpredicted grow under abnormal terms (e.g. accident). Those two observed interfaces can be bottleneck in the network. Signaling load will be rapidly increased with increasing of traffic intensity, number of subscribers, and number of the offered services and applications to the customers. High speed signaling links (bigger capacity of medium and bigger speed) must be used to support needed signaling volume on these interfaces, beside careful and optimal design of the serving area. Special attention is needed for area that covers the major city.

References

[1] Digital cellular telecommunications system (Phase 2+); Signalling transport mechanism specification for the Base Station System - Mobile-services Switching Centre (BSS - MSC) interface (GSM 08.06)

[1] Digital cellular telecommunications system (Phase 2+); Application of the Base Station System Application Part (BSSAP) on the E-interface (GSM 09.08)

[2] Digital cellular telecommunications system (Phase 2+); Mobile Application Part (MAP) specification, GSM 09.02 series

[3]Digital cellular telecommunications system; Guidelines for the modification of the Mobile Application Part (MAP) in phase 2+ (GSM 10.02)

[4] ITU-T recommendation Q.711, Q.712, Q.713, Q.714, Q.716

[5] ITU-T recommendation Q.701, Q.702, Q.703, Q.704, Q.705, Q.706, Q.707