EVALUATION OF REAL CALL SET UP SUCCESS RATE IN GSM

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ABSTRACT

The Call Set up Success Rate is one of the most important Key performance Indicators (KPIs) used by all mobile operators. However there is no standard measurement possible for this parameter. Therefore the different operators can measure it differently.

In this paper, a definition of a real Call Set up Success Rate, possibility of its implementation using the current technologies in GSM and difference between the real and implemented Call Set up Success rate is provided. The "real" in this case means that Call Set up Success Rate is calculated as ratio of the assigned TCHs to the channel requests. The error in measurement of real Call Set up Success Rate with activated Direct TCH Assignment feature is evaluated as well. The proposed error modeling can be used in order to guarantee a quality in measurement of Call Set up Success Rate.

Keywords: *GSM, Call Set up Success Rate, Error, TCH Assignment, Direct TCH Assignment*

1. BASIC STRUCTURE OF GSM NETWORK

A part of GSM network is shown in Fig. 1. The Base Transceiver Station, or BTS, contains the equipment for transmitting and receiving of radio signals (transceivers), antennas, and equipment for encrypting and decrypting communications with the Base Station Controller (BSC). Typically a BTS will have several transceivers (TRXs) which allow it to serve several different frequencies and different sectors of the cell [1, 4].

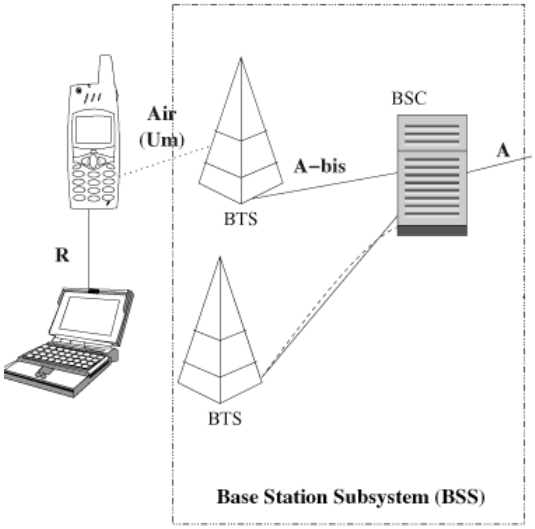

Fig. 1 Structure of GSM network

The Base Station Controller (BSC) provides, classically, the intelligence behind the BTSs. The BSC handles allocation of radio channels, receives measurements from the mobile phones, controls handovers from BTS to BTS (except in the case of an inter-BSC handover in which case control is in part the responsibility of the Anchor MSC). A key function of the BSC is to act as a concentrator where many different low capacity connections to BTSs (with relatively low utilisation) become reduced to a smaller number of connections towards the Mobile Switching Center (MSC) via A interface [1 - 6].

2. CALL SET UP IN GSM

The successful call set up consists of two procedures. The simplified description of these procedures is provided in the next text in such a way that the focus is only on the parts necessary to understand the philosophy of Call Set up Success Rate calculation correctly.

First procedure is Immediate Assignment procedure which is used to create a signaling connection between the Mobile station (MS) and the network. It can be initiated only by the MS sending a CHANNEL REQUEST message on the Random Access channel (RACH) to the BTS that it requires a signaling channel (SDCCH). This message contains the information field „establishment cause and random reference". The „establishment cause" gives the reason why the MS is requesting a SDCCH [2]. Possible reasons are:

- emergency call
- call re-establishment
- answer to paging
- originating speech call
- originating data call
- location updating
- other procedures, which can be completed with an SDCCH.

Then it comes next signalization between the MS and network in order to activate the signaling channel, recognize the service being requested by the MS, etc. The successful seizure of SDCCH is acknowledged by sending the Establish Indication message from MS to BTS and then to BSC. Further coordination procedure (authentication, ciphering etc.) are now performed on the SDCCH [2, 5, 6].

Second procedure is Assignment procedure which is used to occupy a radio resource (speech channel). The MSC is initiator of this procedure. The MSC sends an ASSIGNMENT REQUEST message to the BSC requesting the assignment of a radio resource (RR). Then it comes next signalization between BTS and BSC in order to allocate and activate a suitable RR (Traffic channel - TCH). If the TCH is successfully seizured by

MS, the BSC sends the ASSIGNMENT COMPLETE message [2, 5, 6].

Fig. 2 summarizes the above described procedures.

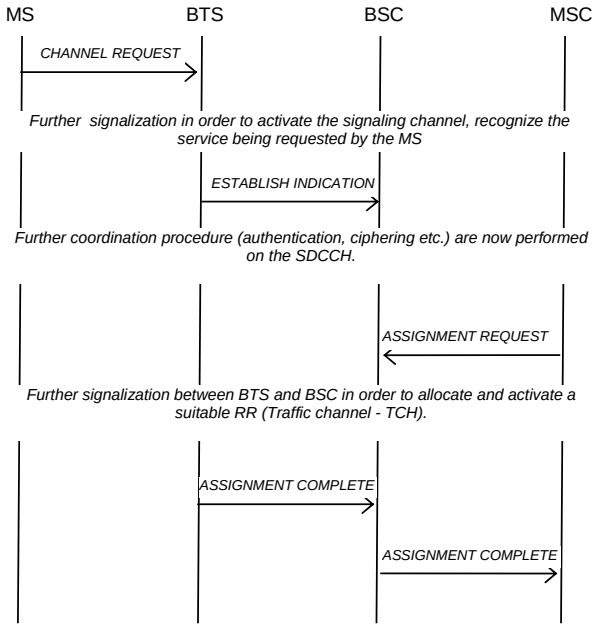

Fig. 2 Message flows for the call set up in GSM.

Note:

Some of the vendors (for example Siemens) provide the possibility to assign TCH directly. In this case the result of Immediate Assignment procedure is occupation of Fast Associated Control channel (FACCH)1 instead of SDCCH. The Assignment procedure for the Direct TCH assignment stays unchanged. On the Siemens side the Direct TCH assignment is used for emergency calls when usually authentication and ciphering are excluded and the call set up is provided up to 1 second instead of standard time frame from 3 to 4 seconds.

3. DEFINITION OF REAL CALL SET UP SUCCESS RATE AND COMPARISON WITH THE EXISTING ONE

As mentioned in the previous paragraph the successful call set up consists of the following parts:

- 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 the Real Call Set up Success Rate (CSSR) is given by the formula:

$$CSSR = \frac{NumTCHAssig}{NumCH\ Re qSpeech}, \tag{1}$$

where *NumTCHAssig* represents the number of successfully assigned TCH (number of *ASSIGNMENT COMPLETE* messages in the Fig. 2) and *NumCHReaqSpeech* represents the number of *CHANNEL REQUEST* messages (see Fig. 2) 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. In other words, the Call Set up Success Rate represents for how big part from the total call attempts the call set up was successful.

Practical implementation of the Eq. 1 means problem because up to now it is not possible to distinguish between the requests for the speech call and other ones. In fact, for example the establishment cause equal to sequence 111xxxxx1, where x is 1 or 0, can represent originating call or procedures that can be completed with a SDCCH according to [3].

One of the possibilities how to solve this problem could be using of simplified formula:

$$CSSR^{*} = \frac{NumTCHAssig}{NumCH\ Re q} \tag{2}$$

where *NumCHReq* represents total number of *CHANNEL REQUEST* messages and *NumTCHAssig* represents the number of TCH assignments (number of *ASSIGNMENT Complete* messages in the Fig. 2). Let us consider that *NumCHReq* = *NumCHReqSpeech* + *NumCHReqNonSpeech*, where *NumCHReqNonSpeech* is the number of *CHANNEL REQUEST* messages not used for MT or MO speech call. Then the Eq. 2 can be modified to the next form:

$$CSSR^{*} = \frac{NumTCHAssig}{NumCH\ Re qSpeech + NumCH\ Re qNonSpeech}. \tag{3}$$

Under condition that *NumCHReqNonSpeech/NumCHReqSpeech* $\leq$ 20 % the formula can be modified using binomial series as follows:

$$CSSR^{*} \approx \frac{NumTCHAssig}{NumCH\ Re qSpeech}\left(1 - \frac{NumCH\ Re qNonSpeech}{NumCH\ Re qSpeech}\right). \tag{4}$$

Afterwards the absolute error in measurement of Call Set up Success Rate using Eq. 2 will be

$$\Delta = CSSR^{*} - CSSR = \frac{NumTCHAssig}{NumCH\ Re qSpeech}\left(1 - \frac{NumCH\ Re qNonSpeech}{NumCH\ Re qSpeech}\right) - \tag{5}$$
$$- \frac{NumTCHAssig}{NumCH\ Re q} == -CSSR * \frac{NumCH\ Re qNonSpeech}{NumCH\ Re qSpeech}$$

In case that *NumCHReqNonSpeech* is equal to zero the Eq. 2 provides exactly the Call Set up Success Rate but this is not real case because in practice the ratio: *NumCHReqNonSpeech/NumCHReqSpeech* is on the range of tenths of percent which can lead to the big systematic error. Therefore the mobile operators break

[1] It is called as Direct TCH Assignment despite the result of Immediate Assignment procedure is occupation of FACCH because to transmit some information on FACCH means to transmit signaling blocks on TCH. During the conversation phase (TCH is occupied) the user data blocks (speech) are transmitted.

away from using of the Eq. 2. In principle the Eq. 2 can be used for calculation of Call Set up Success Rate only in regions with the
NumCHReqNonSpeech/NumCHReqSpeech ≤ 1 %.

Second possibility could be to use in the denominator of the Eq. 1 the number of TCH attempts (*NumTCHAttempt*) instead of *NumCHReqSpeech*. *NumTCHAttempt* represents the number of *ASSIGNMENT REQUEST* messages (see Fig. 2). But in this case the result of the calculation will be TCH Assignment Success rate which is something different than Call Set up Success Rate. Even some of the operators have separate KPIs for Call Set up Success Rate and TCH Assignment Success Rate.

It seems that the best approach promises indirect calculation of *NumCHReqSpeech* according to model in Fig. 3.

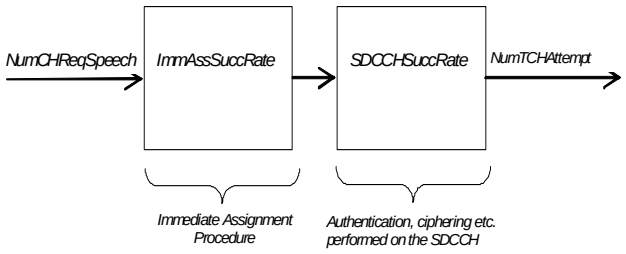

Fig. 3 Model for calculation of *NumCHReqSpeech*

In Fig. 3, *ImmAssSuccRate* represents Immediate Assignment Success Rate given by formula:

$$\mathrm{Im}\,mAssSuccRate = \frac{NumEstInd}{NumCH\ Req}, \tag{6}$$

NumEstInd represents the number of *ESTABLISH INDICATION* messages (see Fig. 2). In other words, the Immediate Assignment Success Rate represents how big part from the total number of requests for channel was successful during the immediate assignment procedure.
SDCCHSuccRate represents *SDCCH* Success Rate given by formula:

$$SDCCHSuccRate = 1 - SDCCHDropRate, \tag{7}$$

where *SDCCHDropRate* is *SDCCH* Drop rate and provides how big part from the total number of SDCCH dropped during the procedures (authentication, ciphering etc.) performed on SDCCH.
From the model in Fig. 3 then we have

$$NumTCHAttempt = Im\,mAssSuccRate * SDCCHSuccRate * \\ * NumCH\ Re\,qSpeech \tag{8}$$

From Eq. 8 then for *NumCHReqSpeech* we can write that

$$NumCH\ ReqSpeech = \frac{NumTCHAttempt}{Im\,mAssSuccRate * SDCCHSuccRate}. \tag{9}$$

Including the Eq. 9 into the Eq. 1 it follows that

$$CSSR = \frac{NumTCHAssig}{NumTCHAttempt} * Im\,mAssSuccRate * SDCCHSuccRate \tag{10}$$

which can be also expressed in the form

$$CSSR = TCHAssSuccRate * Im\,mAssSuccRate * SDCCHSuccRate \tag{11}$$

because $\frac{NumTCHAssig}{NumTCHAttempt}$ represents *TCHAssSuccRate* as it was early mentioned. Currently the Eq. 11 is the best approach and is provided for example by Siemens. A disadvantage can be higher effort on BSC or equipment (for example an offline tools) where the Call set up Success rate is to be calculated because three KPIs (or six partial measurements) enter the Eq. 11. The Eq. 11 provides exactly the Call Set up Success Rate in case the Direct TCH Assignment feature is disabled. Possible distortion when this feature is enabled is described in the next paragraph.

4. CALL SET UP SUCCESS RATE WHEN DIRECT TCH ASSIGNMENT IS ENABLED

As mentioned in the paragraph "Call Set up in GSM" in case when Direct TCH Assignment feature is enabled the result of Immediate Assignment procedure for some of channel requests can be occupation of FACCH instead of SDDCH. The Direct TCH Assignment is used in order to decrease time needed for call set up in such a way that authentication and ciphering are excluded. It means that FACCH is occupied only very short time in comparison to SDCCH occupation which leads to FACCH Success Rate close to 100 %. The model for calculation of *NumCHReqSpeech* is for this case presented in Fig. 4 where
NumCHReqSpeechSDCCH and
NumCHReqSpeechFACCH represent those Channel requests that result in occupation of SDCCH and FACCH, respectively when Immediate Assignment procedure has been finished.

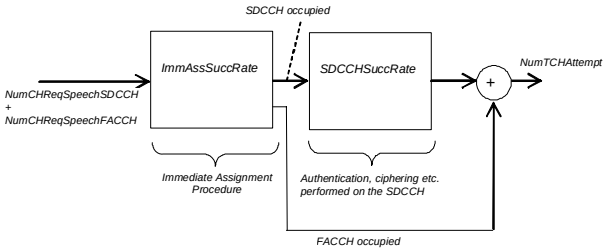

Fig. 4 Model for calculation of *NumCHReqSpeech* when Direct TCH assignment is enabled

From the model in Fig. 4 it follows

$$NumTCHAttempt = NumCH\ ReqSpeechSDCCH * Im\,mAssSuccRate * \\ * SDCCHSuccRate + + NumCH\ ReqSpeechFACCH * Im\,mAssSuccRate \tag{12}$$

which can be also expressed in the form

$$NumTCHAttempt = ImmAssSuccRate * SDCCHSuccRate * \left(NumCH\ ReqSpeechSDCCH + \frac{NumCH\ ReqSpeechFACCH}{SDCCHSuccRate} \right) \quad (13)$$

Using the Eq. 7 we have

$$NumTCHAttempt = ImmAssSuccRate * SDCCHSuccRate * \left(NumCH\ ReqSpeechSDCCH + \frac{NumCH\ ReqSpeechFACCH}{1 - SDCCHDropRate} \right) \quad (14)$$

Since *SDCCHDropRate* does not exceed 0.5 % in practice we can modify it using binomial series as follows:

$$NumTCHAttempt \approx ImmAssSuccRate * SDCCHSuccRate * * NumCH\ ReqSpeech + ImmAssSuccRate * SDCCHSuccRate * * NumCH\ ReqSpeechFACCH * SDCCHDropRate \quad (15)$$

and

$$NumCH\ ReqSpeech = \frac{NumTCHAttempt}{ImmAssSuccRate * SDCCHSuccRate * \left(1 + \frac{NumCH\ ReqSpeechFACCH}{NumCH\ ReqSpeech} * SDCCHDropRate \right)} \quad (16)$$

Including the Eq. 16 into the Eq. 1 we have

$$CSSR^{**} = TCHAssSuccRate * ImmAssSuccRate * SDCCHSuccRate * * \left(1 + \frac{NumCH\ ReqSpeechFACCH}{NumCH\ ReqSpeech} * SDCCHDropRate \right) \quad (17)$$

The Eq. 17 represents exact formula that should be used for calculation of Call Set up Success rate when Direct TCH Assignment feature is enabled. However the ratio $\frac{NumCH\ ReqSpeechFACCH}{NumCH\ ReqSpeech}$ currently cannot be measured (see the paragraph "Definition of Real Call Set up Success Rate and Comparison with the Existing one") therefore the Call Set up Success rate must be calculated using the Eq. 11 with the absolute error

$$\Delta = CSSR - CSSR^{**} = = -TCHAssSuccRate * ImmAssSuccRate * * SDCCHSuccRate * * \frac{NumCH\ ReqSpeechFACCH}{NumCH\ ReqSpeech} * * SDCCHDropRate \quad (18)$$

and relative error

$$\delta = \frac{\Delta}{CSSR} = -\frac{NumCH\ ReqSpeechFACCH}{NumCH\ ReqSpeech} * SDCCHDropRate \quad (19)$$

From the Eq. 19 it follows that the relative error in the worst case will be equal to *SDCCHDropRate* which is maximum 0.5 %.

5. CONCLUSION

The number of channel requests for speech calls cannot be measured therefore there is no simple formula for calculation of Call Set up Success Rate. Hence more complex formula into which enter Immediate Assignment Success rate, TCH Assignment Success Rate and SDCCH Success rate must be used. Currently it is the best approach despite higher effort on the processor part in equipment where the Call Set up Success Rate is to be calculated is expected. Additionally it does not cover the case when Direct TCH Assignment feature is enabled. However as it has been shown in this paper the relative error in the worst case will not exceed 0.5 %. The proposed formula has been implemented in the base stations provided by Siemens.

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BIOGRAPHY

Martin Kollár was born in Spišská Nová Ves, Slovakia, on 7 December 1974. He gained an Ing. (M.Sc.) degree in electronics and multimedia telecommunications from the Faculty of Electrical Engineering and Informatics (FEI), Technical University (TU) Košice and a Ph.D. degree in measuring techniques from the FEI TU Košice, in 2000 and 2003, respectively. From 2003 till 2006, he was an assistant professor at the Department of Theory of Electrical Engineering and Measurement, FEI, TU Košice. Since 2006 he has been an analyst -architect at Siemens Program and System Engineering. His research interests include performance measurement techniques for GSM and GERAN, nonlinear circuit theory, smart sensors based on a flip-flop circuit and testing the analog-to-digital converters.