

Performability Measures of the Public Mobile Network of a Tele Control System

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Abstract. Performability measures of the Public Mobile Network (PMN) of a Tele Control System, under prototypal development inside the EU SAFETUNNEL Project, are predicted by using stochastic models. The Tele Control System has the aim of reducing the number of accidents inside the alpine road tunnels, by implementing safety policies between Instrumented Vehicles and a Tunnel Control Centre, by means of a PMN. The use of the PMN, which supports both Global System Mobile (GSM), for voice connections, and the General Packet Radio Service (GPRS), for data connections, represents the most innovative and challenging research aspect of the system. To compute performability measures for voice and data services, we built modular sub models, hierarchically composed, by using Stochastic Activity Networks (SAN). At the first layer, we have built three sub models to compute pure unavailability and pure performance measures. Then, at the second layer, we have built two composed models. Each composed model joins the pure availability sub model and the related pure performance sub model, in order to compute performability measures, respectively for voice and data packet services.

1 Introduction

A Tele Control System is under prototypal development in the frame of the SAFETUNNEL EU Project [1]. The Tele Control System basically consists of a Tunnel Control Centre (TCC) interconnected to Instrumented Vehicles by a Public Mobile Network (PMN), that supports both Global System Mobile (GSM) connections and the General Packet Radio Service (GPRS) connections. The Tele Control System is designed to implement preventive safety actions in different tunnel scenarios (normal vehicular traffic, incidents, diffusion of emergency information) and the PMN is dimensioned for the expected throughput of voice and data, between the Instrumented Vehicles and the TCC, under such scenarios. The SAFETUNNEL Project designs the Tele Control System and implements a system Demonstrator, that is a prototypal subset of the Tele Control System. The validation of Tele Control System will be performed both by experimental tests and by modelling. A limited number of experimental tests are planned on the actual system Demonstrator; moreover a set of validation measures have to be predicted by system models, because the Demonstrator is not suitable for such measures. In fact the Demonstrator, that operates inside the tunnel, is not suitable for measures which would require long observation time inside the tunnel (that should be closed to the ordinary vehicular traffic, with loss of availability

and money) and measures which would require irreproducible tunnel scenarios (i.e. occurrence of incidents and emergency scenarios). Less than ever, the System Demonstrator is suitable for performance and availability measures, which are typically predicted by modelling and simulation and rarely performed by using experimental data from long, inadequate and costly observations of the whole system (and not of a part of it, that is the System Demonstrator). Due to the complexity of the Tele Control System and according to the Validation Plan, the system validation by modelling will not be exhaustive but will be focused on system relevant properties, that could affect the Tele Control System safety and timeliness [2]. Validation by modelling will address relevant parts of the Tele Control System, including the PMN, which represents the most innovative and challenging research aspect of system. The present paper just deals with performability measures of the PMN [3], intended as performance measures explicitly tied to service degradation/recovery due to components failure and repair activities (availability measures). Performability measures are needed because performance measures, which ignore failures and recovery activities, but just consider resource contention, generally over estimate the system's ability to perform. On the other hand pure availability measures, where performance are not taken into account, tends to be too conservative. To compute performability measures (in terms of voice blocking probability and packet loss probability), we built modular sub models, hierarchically composed, by using Stochastic Activity Networks (SAN). At the first layer, we have built three sub models to compute pure unavailability and pure performance measures. Then, at the second layer, we have built two composed models, respectively for voice and data packet services. Each composed model joins the pure availability sub model and the related pure performance sub model, in order to compute the performability measure.

The paper is organized as follows. Section 2 and 3 describe the basic elements of the Tele Control system and of the GSM/GPRS architecture. Section 4 deals with the PMN modelling assumptions and introduces the performability measures. Section 5 describes the modelling formalism: the Stochastic Activity Networks. Sections 6, 7, 8 describe the PMN performability models and measures. Some numerical results are reported in section 9. In section 10 there are some discussions and conclusions.

2 Tele Control System

The Tele Control System implements its safety functions¹, transferring voice, commands and data between Instrumented Vehicles and the Tunnel Control Centre. TCC must be able to exchange information with more than one Vehicle at the same time in *bi-directional* way. Particularly, informative messages are transmitted in *uplink* (from Vehicles on-board system to TCC) for the purpose of diagnosis and prognostics of vehicles. Commands/messages are transmitted in *downlink* (from TCC to a single vehicle or to a set of vehicles) for notification of a dangerous conditions inside the tunnel, or for setting/updating vehicle parameters (such as vehicle speed, safety intra-vehicles distance). For each Vehicle entering the Safe Tunnel monitored area, the

¹ The Tele Control System safety functions include: 1)Vehicle Prognostics, 2)Access & Vehicle Control, 3)Vehicle Speed and Intra-Vehicles Distances Control, 4)Dissemination of Emergency Information.

TCC sets up a dedicated GPRS connection. TCP transport protocol is used to guarantee the correctness of data by means of integrity checks in the receiver and foreseeing a retransmission mechanism for bad-received packets. Each Vehicle is characterized by a TCP address (IP address + TCP port) in order to be able to communicate to the TCC that is provided of an analogous address too. Moreover, bidirectional voice calls, supported by GSM connection, are also provided between Vehicles and TCC, in case GPRS data transfer are not sufficient to manage an emergency.

3 GSM/GPRS Architecture

GSM [4],[5] is a circuit-switched connection, with reserved bandwidth. At air interface, a complete traffic channel is allocated to a single Mobile Station (MS) for the entire call duration. A cell is formed by the radio area coverage of a Base Transceiver Station (BTS). One or more BTS are controlled by one Base Station Controller (BSC). Such a set of Stations form the Base Station Subsystem (BSS). A BSS can be viewed as a router connecting the wireless cellular network to the wired part of the network. GSM uses a mixed multiple access technique to the radio resources: Frequency Division Multiple Access/Time Division Multiple Access (FDMA/TDMA). Within each BSS, one or more carrier frequencies (FDMA) are activated, and over each carrier a TDMA frame is defined. TDMA allows the use of the same carrier to serve multiple MS. In the GSM system the frame is constituted by eight timeslots and so the same radio frequency can serve up to eight MS. A circuit (a channel) is defined by a slot position in the TDMA frame and by a carrier frequency. Typically one channel (time slot) is reserved to signaling and control. A MS can roam from a cell to a neighboring cell during active voice calls. Such a MS, that has established a voice call, and roams from a cell to another, must execute a handoff procedure, transferring the call from the channel in the old cell to a channel in the new cell entered by the MS.

GPRS is a packet switched connection with shared, unreserved bandwidth. For data services, which is a bursty traffic, the use of GSM results in a highly inefficient resources utilization. For bursty traffic, a packet switched bearer service, such as GPRS, results in a much better utilization of the traffic channels. A radio channel will only be allocated when needed and will be released immediately, after the transmission of packets. With this principle more than one MS can share one physical channel (statistical multiplexing). In order to integrate GPRS services into the existing GSM architecture, a new class of network nodes, called GPRS support nodes (GSN), are used. GSNs are responsible for the delivery and routing of data packets between the MS and the external packet data networks. A serving GPRS support node (SGSN) is responsible for the delivery of data packets from and to the MS [4].

GPRS exploits the same radio resources used by GSM. To cross the wireless link the data packets are fragmented in radio blocks, that are transmitted in 4 slots in identical position within consecutive GSM frames over the same carrier frequency [6]. Depending upon the length of the data packets, the number of radio blocks necessary for the transfer may vary. Mobile Stations execute packet sessions which are alternating sequences of packet calls and reading times. One time slot constitutes a channel of GPRS traffic, called Packet Data Traffic Channel (PDTCH) [4]. On each PDCH, different data packets can be allocated in the same TDMA frame or in different

TDMA frames. When a user needs to transmit, it has to send a channel request to the network through a Random Access Procedure, which may cause collisions among requests of different users. In this case a transmission is tried. The number of maximum retransmissions is one of the GPRS access control parameters. Typically, one of the channels, randomly selected out of the available channels, is dedicated to GSM and GPRS signalling and control.

4 PMN Modelling Assumptions and Measures

The dimensioning of the PMN accounts for several aspects including the length of the tunnel and the length of the tunnel monitored area, the recommended speed of vehicles and the safety distance between vehicles inside the tunnel, the number of carriage ways, the average and the worst demands of voice and data connections, the GPRS expected throughput per physical channel, the bit rate for the information exchange of each vehicle and the GSM expected connections. For GSM connection the same carrier frequency can serve up to eight vehicles. For GPRS connection, we assume that up to two vehicles are allocated in the same time slot, so the same carrier frequency can serve up to sixteen vehicles. One time slot (physical channel) is reserved as long as a voice call remains active, that is until the voice call is voluntarily released, then voice call generates an ON/OFF traffic on PMN. On the other hand, data transfer generates a bursty traffic (namely at vehicle registration/deregistration phases, in case of rare vehicle anomalies or incidents).

One of the channels, randomly selected out of the available channels, is dedicated to GSM and GPRS signalling and control. Then the total number of available physical channels of our PMN is obtained from the product of the number of carriers per the number of channels per each carriers minus one, which represents the control channel.

The PMN under analysis consists of one Base Station System (BSS), which contemporarily implements GSM and GPRS connections. Figure 1 shows the BSS with its essential components. GPRS connection is an updating service of the GSM architecture, which is born to deliver voice calls. We assume that GSM voice calls have higher priority than GPRS data transfer. That is, voice calls are set up as long as at least one physical channel is available in the BSS of interest; data packets can be transmitted only over the channels which are not used by voice connections. The handoff procedure [2], that allows roaming from a cell to a neighbouring cell is meaningful for GSM connections. Vice versa the handoff procedure is neglected for GPRS connections, since the duration of data transfer is typically much smaller than the time spent by a vehicle in a cell.

To sum up, for the sake of building manageable models of our PMN, the following assumptions have been made:

- we will focalize on a single Base Station System, constituted by one Base Station Controller and multiple Base Transceiver Stations
- data exploits the same physical channels used by voice
- channel allocation policy is priority of voice on data
- we account for handoff procedure for voice connection
- we neglect the possibility of the handoff procedure for data connection
- one Control Channel (CCH) is dedicated to GSM and GPRS signalling and control; CCH is randomly assigned to a BTS

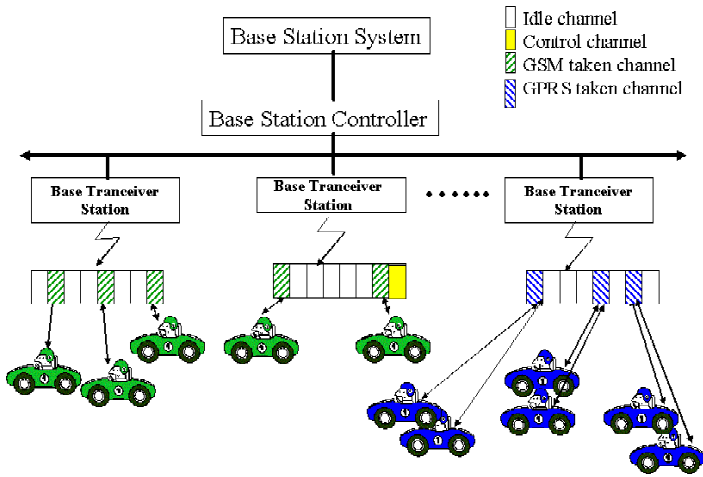


Fig. 1. PMN under analysis

- GPRS implements a point to point connection
- each Instrumented Vehicle embeds a Mobile Station, which allows the temporarily use of GSM and GPRS connections.

4.1 Performability Measures

Considering the PMN under analysis limited to one BSS, as showed in figure 1, the GSM and the GPRS services can be denied, due to at least one of the following contributes: a) the BSS, as a whole, becomes unavailable or b) the BSS is available and all its channels are full or c) the BSS is not completely available and all the channels in it, which are available, are also full.

We named *TSB*, the Total Service Blocking Probability, as the performability measure of the denial of service both for GSM and GPRS connection due to the occurrence of at least one of the contributes a), b), or c).

Regarding the contribute a) the fact that the BSS and its channels are unavailable, depends upon the failure/repair activities of BSS physical components, which include the Mobile Stations, embedded inside the Instrumented Vehicles, the Base Transceiver Stations and the Base Station Controller. BSS components are assumed to fail and be repaired with their own and independent rates. Actually, the reliability figures of Mobile Stations are significantly better than those of the other network components, then we assume the MS as fault free. Each BTS can hosts eight traffic channels or, randomly, could hosts the Control Channel (CCH) plus seven traffic channels.

To sum up, the BSS Total Unavailability (*TU*) is approximately:

$$TU = BCF + CCF + ATF \quad (1)$$

where:

- *BCF* is the unavailability of the Base Station Controller
- *CCF* is the unavailability of the Control Channel (CCF) which depends upon the unavailability of the BTS which randomly can host it.

- *ATF* is the unavailability of all the *BTS*. When a *BTS* which does not host the *CCH* fails, its physical channels become unavailable and the *BSS* works in degraded conditions. If the failure of all the *BTS* (*ATF*) occurs, the consequence is still *TU*, the Total Unavailability of the *BSS*.

To compute the Total Blocking Probability (*TSB*) of our PMN, we have built modular stochastic models, hierarchically composed, by using Stochastic Activity Networks (SAN). Two different layers of modelling have been implemented. At the first layer, we built a model to compute the pure GSM/GPRS unavailability, *TU*, according to formula 1, which represents the contribute a) to *TSB*. At the same layer, we still built two separate models to respectively compute voice and data packet performances. Due to the assumption of priority of voice on data, the performance model of voice just takes into account the GSM connection, while the performance model of data packets has to take into account the contention of the same physical channels between GSM and GPRS. The performance models compute the probability of having all available channels full and represent the contribute b) to *TSB*. Then, at the second layer of modelling, we have built two composed models. A composed model joins the pure availability model and the voice performance model to compute the whole *TSB* for voice connections. The other composed model joins the pure availability model and the data packet performance model, to compute the whole *TSB* for data packet connections.

We have to consider that *TSB* completely measures the loss of voice for GSM connection, because voice is not retransmitted. On the other hand, for GPRS connection, *TSB* affects the loss of data, but does not directly measure it. In fact data packets can be accumulated into a queue and retransmitted according to GPRS access control parameters [4]. Then, for GPRS connection, other than *TSB*, we also compute the probability of data packet loss for exceeding the buffer capacity and the probability of data packet loss for exceeding the maximum number of data packet sessions which can be simultaneously opened.

5 Stochastic Activity Networks

Stochastic Activity Networks (SAN) are a modelling formalism which extends Petri Nets [7]. The basic elements of SAN are places, activities, input gates and output gates. Places in SAN have the same role and meaning of places of Petri Nets. They contain an arbitrary number of tokens. Activities are equivalent to transitions in Petri Nets. They can take a certain amount of time to be completed (timed activities) or no time (instantaneous activities). Each activity may have one or more input arcs, coming from its input places (which precedes the activity) and one or more output arcs going to its output places (which follow the activity). In absence of input gate and output gate, the presence of at least one token in each input place makes it able to fire and after firing one token is placed in each output place. Input gates and output gates, typical constructs of SAN, can modify such a rule, making the SAN formalism more rich to represent actual situations. Particularly, they consist in predicates and functions, written in C language, which contain the rules of firing of the activities and how to distribute the tokens after the activities have fired. As in Petri Nets, a marking depicts a state of the net, which is characterised by an assignment of tokens to all the places of the net. With respect to a given initial marking, the reach ability set is de-

defined as the set of all markings that are reachable through any possible firing sequences of activities, starting from the initial marking. Other than the input and output *gates*, which allow to specifically control the net execution, SAN offers two more relevant high-level constructs for building hierarchical models: *REP* and *JOIN*. Particularly, such constructs allow to build composed models based on simpler sub-models, which can be developed independently and then replied and joined with others sub-models and then executed. The SAN model specification and elaboration is supported by Möbius tool [7] that allows to specify the graphical model, to define the performance measures through reward variables, to compute the measures by choosing a specific solver to generate the solution.

6 The Availability Sub Model

To compute TU (formula (1)), we have built the *availability* sub model of figure 2. The sub model includes the failure/repair behaviour of the Base Station Controller and the failure/repair behaviour of all the controlled Base Transceiver Stations, according to the terms of formula (1). A failed BTS hosts the Control Channel (CCH) with probability c , or complementary host the CCH, with probability $1 - c$. If the failed BTS hosts the CCH, the BTS failure implies the failure of the Control Channel, and in turn, the failure of the whole PMN. If the BTS, doesn't host the CCH, the BTS failure just implies the loss of the physical channels supported by it (eight channels/timeslots).

The marking of place *BTS_UP* represents the number of Base Transceiver Stations which are not failed. The firing of the activity *BTS_Fail* represents the failure of the BTS component. If the failed BTS hosts the CCH, it makes the whole BSS down (output gate *TU_CCH*, shown in table 1). If the failed BTS doesn't host the CCH, the channels which are currently up are decremented by the number of channels associated to the failed BTS (output gate *BTS_loss*). The marking of the place *BTS_DOWN* represents the number of failed BTS; one token in the place *CCH_DOWN* represents the CCH failure. The firing of the activities *BTS_Repair* and *CCH_Repair* represents the repair activities of the related BTS component.

One token in place *BCS_UP* represents that the BCS is not failed. One token in place *BCS_DOWN*, consequent to the firing of the activity *BCS_Fail*, represents the BCS failure. On the failure of the BCS, the whole BSS goes down and all the channels are lost (output gate *TU_BCS*) The marking of the place *working_channels* represents the number of available and idle channels. The marking of the place *channels_in_service* represents the number of available and connected channels. After the repair activities (*CCH_repair*, *BCS_repair*, *BTS_repair*) the channels are again up

Table 1. Definition of the output gate *TU_CCH*

Output Gate Attributes: <i>TU_CCH</i>	
Field Name	Field Value
Function	total_unavailability->Mark() $\rightarrow$ 1; working_channels->Mark() $\rightarrow$ 0; channels_in_service->Mark() $\rightarrow$ 0;

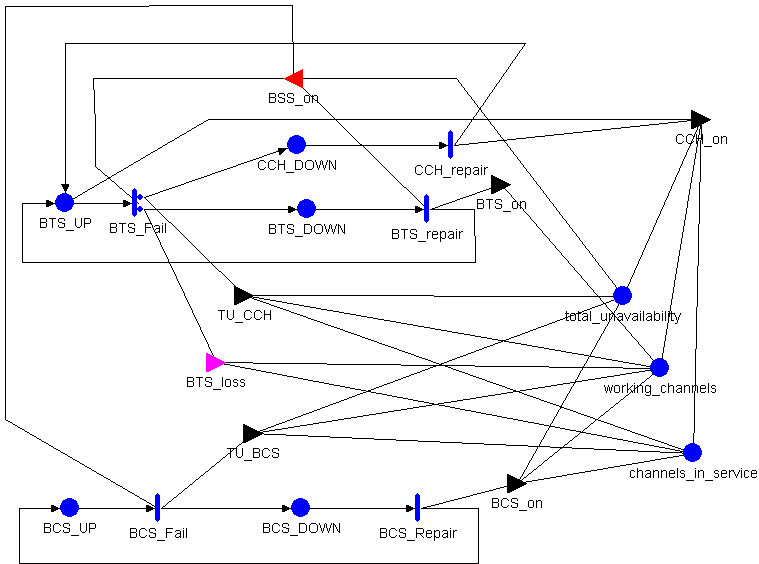


Fig. 2. The availability sub model

and ready to be taken in service (output gates *BTS_ON*, *BCS_ON*, *CCH_ON*). The firing time of the activities is assumed to follow a negative exponential distribution.

7 GSM Performability Composed Model

The *GSM performability* composed model computes the *Total Blocking Probability (TSB)* for voice service. To compute *TSB*, we consider our PMN as completely dedicated to the GSM services, due to the assumption of the priority of voice on data. The *GSM performability composed* model takes into account the contention of the radio channels from the voice calls (either new or continuous) modelled by a pure performance sub model, combined with the possible loss/recovery of the radio channels due to the failure/repair activity of the BSS components. Particularly, *GSM performability composed* model, figure 3, has been built joining the *availability* sub model of section 6, and the *GSM Performance* sub model, which models the pure performance aspects of the GSM service.

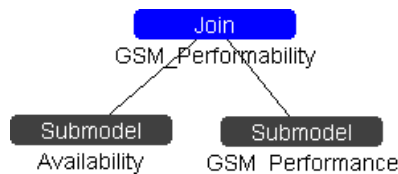


Fig. 3. *GSM performability* composed model

7.1 GSM Performance Sub Model

The *GSM performance* sub model, figure 4, computes two performance measures: the *New Call Blocking probability* and the *Continuous (handoff) Call Blocking probability*, due to all N channels full and not failed. It is assumed that blocked calls are lost and not re-attempted. The *GSM performance* sub model represents the PMN with a number of servers which represents the number of available channels. Moreover, a limited number of available channels, named *guard channels*, are exclusively reserved for the handoff calls. Referring to figure 4, the marking of the place *working_channels* represents the number of not-failed channels, that are currently idle. The marking of the place *channels_in_service* represents the number of not-failed channels, that are currently busy. The firing of transition T_{new_call} represents the arrival of new calls and the firing of transition $T_{continuous_call}$ represents the arrival of a handoff call from neighbour cells. A handoff call will be dropped only when all channels are busy. This is realised by the input gate $I_{Total_channels}$ which enables the transition $T_{continuous_call}$ to fire when all not-failed channels are busy. A new call will be blocked if there are no more than the number of the reserved channels for handoff calls. This is realised by the *input gate* $Reserved_channels$, which enables the transition T_{new_call} to fire when all not-failed and not reserved channels are busy. The firing of the transitions $T_{call_completion}$ and $T_{handoff_out}$ respectively represent the completion of a call and the departure of an outgoing handoff call. All activities are assumed exponentially distributed.

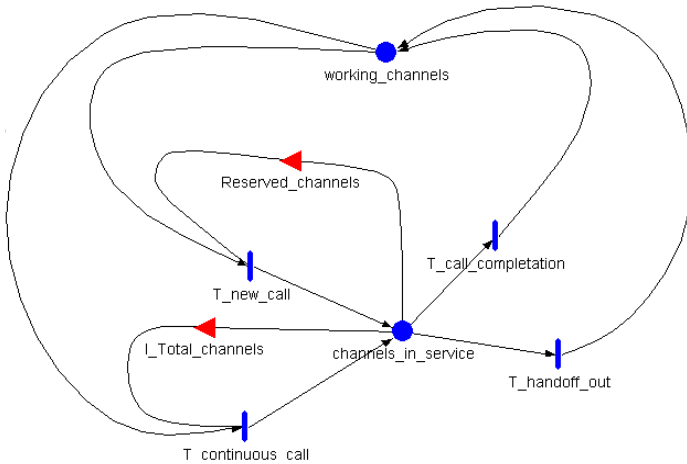


Fig. 4. The *GSM performance* sub model

8 GSM&GPRS Performability Composed Model

The *GSM&GPRS performability* composed model (figure 5) computes the *Total Blocking Probability (TSB)* on packet data service. The composed model joins the *GSM&GPRS performance* sub model, that represents the contention of the radio channels from the voice calls and data packets transfer request and the *availability* sub

model that represents the possible loss/recovery of the radio channels due to the failure/repair activity of the BSS components. In case of GPRS, *TSB* does not directly measure the loss of information contained in data packets because they can be accumulated into a queue and retransmitted. Then, for GPRS connection, other than *TSB*, we also compute the probability of data packet loss for exceeding the buffer capacity and the probability of data packet loss for exceeding the maximum number of data packet sessions which can be simultaneously opened.

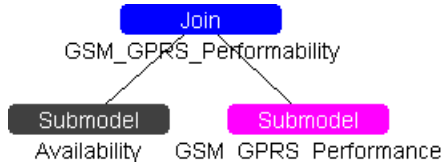


Fig. 5. The *GSM&GPRS* performability composed sub model

8.1 GSM&GPRS Performance Sub Model

The *GSM&GPRS performance* sub model computes the pure performance aspects of the GPRS service, which contends physical channels to the GSM service. Voice calls are set up as long as at least one channel is available in the PMN, while data packets can be transmitted only over the channels which are not used for voice service. A vehicle, which needs to communicate with Tunnel Control Centre or vice versa, tries to open a packet session. If the current number of open data packet sessions is less than the maximum number of data packet sessions which can remain simultaneously active, then a new data packet session can be opened. Into an active data packet session, the incoming data packets are queued in a buffer, as a sequence of radio blocks. Once in the buffer, the radio blocks can be transmitted with the proper GPRS transmission rate. The transfer of radio blocks over the radio link can be either successful, thus allowing the removal of the radio block from the buffer, or results in a failure; in the last case, the radio block is retransmitted.

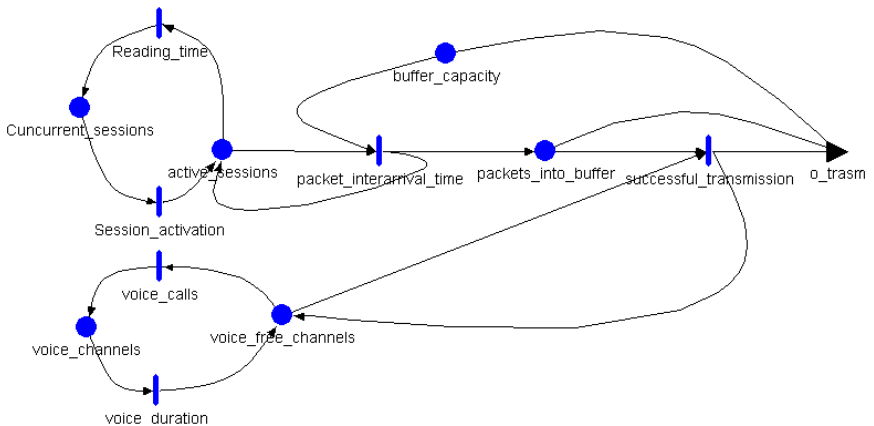


Fig. 6. The *GSM&GPRS* performance sub model

Referring to figure 6, if at least one token is in place *concurrent_section* a data packet session is opened, by the firing of *session_activation* activity. As a consequence one token is added in place *active_section*. Named D , the number of maximum simultaneously active data packet sessions and named d , the number of currently opened data packet sessions, a new session can be opened at the condition that $d < D$. Inside an open data packet session, data packets arrive with the rate of *packet_interarrival_time* activity and are queued into *packet_into_buffer* place. As a first step, we assume that one data packet has the length of one radio block, so each data packet increments the buffer by one unit (one radio block) at the condition that the buffer is not full (if $b < B$, where b is the current values of the radio blocks in the buffer and B is the buffer capacity). Such a condition is controlled by the marking of *buffer_capacity* place. The radio blocks queued in the buffer are transmitted during the same set of 4 TDMA frames by the *successful_transmission* activity which keep into account that the radio block that can be served by the currently available channels (the ones not being occupied by voice).

9 Some Numerical Results

We conduct availability, performance and performability measures, executing the models described in the previous sections, by Mobius analytical solver [7]. The input parameters and their numerical values are summarized in Table 2, 3 and 4.

Some numerical results are shown in figure 7 and 8. Figure 7 shows the *Total Service Blocking Probability (TSB)* for voice service, versus time, computed by the *GSM performability* composed model. The computation of *TSB* is performed by using the *total_blocking* reward variable, which increments its value of 1 when the number of available channels, ready to serve, becomes equal to zero.

Table 2. Input parameters and values of the *availability* sub model

<i>Parameter</i>	<i>Value</i>
rate of BSC_fail	2,31 E-4 h ⁻¹
rate of BSC_repair	1 h ⁻¹
rate of CCF_fail	3.47 E-4 h ⁻¹
rate of CCF_repair	0,5 h ⁻¹
rate of BTS_fail	3.47 E-4 h ⁻¹
rate of BTS_repair	0,5 h ⁻¹
number of BSC	1
number of BTS	4
n. of channels of a BTS	8
number of CCH	1

Table 3. Input parameters and values of the *GSM performance* sub model

<i>Parameter</i>	<i>value</i>
arrival rate of new calls	0,27 s ⁻¹
duration of the calls	180 s
arrival rate of handoff calls	0,027 s ⁻¹
duration of outgoing handoff calls	80 s

Table 4. Input parameters and values of the *GSM&GPRS performance* sub model

<i>Parameter</i>	<i>Value</i>
arrival rate of voice calls	0,5...2,5 s ⁻¹
duration of voice calls	180 s
rate of session activation	2 s ⁻¹
session reading time	15 s
packets inter arrival rate	0,0242 s ⁻¹
rate of suc. packet transmission	0,0513 s ⁻¹
buffer capacity (B)	100
n. of max opened sessions (D)	10,30,50

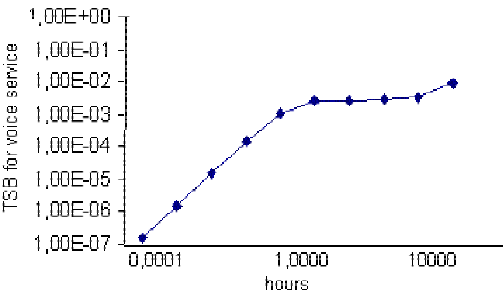


Fig. 7. Total Service Blocking (TSB) probability for voice service

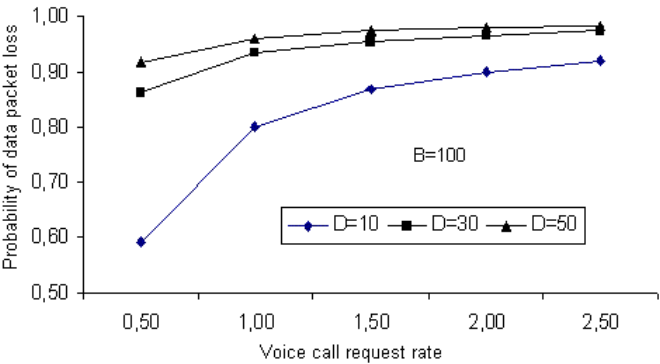


Fig. 8. Probability of data packets loss

Figure 8 shows the probability of data packets loss for data service, due to the buffer overload, versus voice call request rate, computed by the *GSM&GPRS performance* sub model. The measures have been computed for different values of the maximum number of simultaneously opened data packet sessions ($D=10, 30, 50$). We assume buffer capacity, $B=100$.

10 Conclusions and Future Research

The work presented in this paper is in the framework of validation by modelling of a Tele Control system, based on a Public Mobile Network (PMN). We have computed performability measures of the denial of service for GSM and GPRS connections, such as the Total Service Blocking Probability (TSB), to better understand the effects of the degradation of the performance and of the availability of the PMN on the Tele Control system main functions. We have built modular sub models, hierarchically composed, by using Stochastic Activity Networks. Two different layers of modelling have been implemented. At the first layer, we built separate sub models to compute the pure unavailability and the pure performance for voice and data packet services. At the second layer of modelling, we have built two composed models joining the availability sub model and the performance sub models. The first numerical results have been presented. The research is still on going. At short term, we will refine the tuning of the models to the application. At longer term, we are going to join the performability models of the PMN with the performability models of the other parts of the Tele Control System in a whole model to evaluate if and how performability measures of the Tele Control System impact, in time and in value, the safety policies inside the tunnel.

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