UMTS Non Real-Time Sessions Channel Switching Emulation

Van Peteghem, Hugues; Schumacher, Laurent

Published in:
Proceedings of the 65th Vehicular Technology Conference (VTC-spring) - Dublin (Ireland), 22-25 April 2007

Publication date:
2007

Document Version
Early version, also known as pre-print

UMTS Non Real-Time Sessions Channel Switching Emulation

Van Peteghem H. and Schumacher L.
Pôle "Réseaux et Sécurité"
FUNDP - The University of Namur
Namur, Belgium
{hvp,lsc}@info.fundp.ac.be

***Abstract*— We discuss here a scheme to improve the $Rel'99$ UMTS radio resource management. The article focuses on the two different types of transport channel: shared and dedicated. It evaluates the merits of a scheme based on an optimal non real-time session switching between these two kinds of channels. The switching decision may be influenced by several parameters like the downswitch timer's duration, the non-/preemptive split of downswitch timer and the selection of the initial transport channel. Performances of the analysed scheme are evaluated taking into account different metrics: blocking rate, mean packet delay and cell throughput. The results show that an optimal tuning of these three parameters may significantly decrease the number of blocked calls while keeping the other metrics at a satisfactory level.**

I. Introduction

Bandwidth consumption has always been an open issue in computer network research since consumers wish to enjoy an ever growing variety of bandwidth demanding services. These last years, the major answer to this problem has often been over-provisioning: to ensure that consumers receive the bandwidth their services require, we deploy significantly more bandwidth than required. This strategy is easily applied in the case of wired networks with the development of gigabits links based on optical fibres.

Rather than provisioning bandwidth, wireless networks have to address this problem in a different way since it may be very costly and in some cases not applicable to increase their bandwidth due to interference, environmental and regulatory constraints. Therefore, the solution for such networks is mainly based on traffic engineering and optimal radio resource allocation strategies within the framework of existing standards.

One of the wireless networks able to support different services is the Universal Mobile Telecommunication System (UMTS). This access network is able to serve a large population of mobile devices, known as User Equipments (UEs), with a single base station. This advantage inevitably leads to a resource allocation issue. Fortunately, traffic can be distributed over two kinds of transport channel, either dedicated or shared, such that an optimal scheduling is able to solve the resource allocation problem. Many parameters may influence this scheduling. The scheme is based on an optimal value setting of a subset of them: the downswitch timer's duration, its split in two periods (preemptive and non-preemptive) and the selection of the initial channel of a session.

The rest of this paper is organised as follows. Section II exposes different $Rel'99$ UMTS characteristics such as the UE's Radio Resource Control (RRC) states, the transport channels and the traffic classes available. Section III explains the channel switching policy and our parameters' value setting to get the optimal radio resource consumption. Section IV then presents the results obtained and discusses some observations. Finally conclusions are drawn in Section V.

II. RRC States, Transport Channels and Traffic Classes

A. RRC States Simplification

The two basic operational modes of a UE are the `Idle Mode` and the `Connected Mode`. The `Connected Mode` can be further divided into different service states known as Cell_DCH, Cell_FACH, Cell_PCH and URA_PCH. Our focus here is on the UE data flows so we only care about the user plane of the UMTS Terrestrial Radio Access Network (UTRAN); the control plane (signalling) is out of the scope of this work. It is then possible to simplify the UE `Connected Mode` RRC states switching initially proposed in [1] into the following figure:

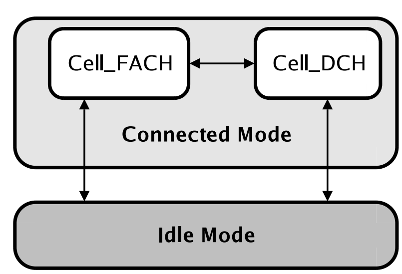


Fig. 1. UE RRC states switching.

A UE in the `Idle Mode` is considered as not active, so we define a UE in this state simply as not connected.

In the Cell_FACH state, no Dedicated CHannel (DCH) is allocated to the UE but a shared channel, the Forward Access CHannel (FACH), can be used instead. This channel carries small amounts of user data using time multiplexing. Its bandwidth is rather small since it is not expected to support large data transfers.

1550-2252/$25.00 ©2007 IEEE

In the Cell_DCH state, at least one DCH is allocated to the UE. This channel transports a single user data flow with a fixed bit rate depending on the Spreading Factor (SF) allocated by the Radio Network Controller (RNC). A shared channel can also be used in this state to carry different user data flows. Since we focus on the $Rel'99$ UMTS, this channel is the Downlink Shared CHannel (DSCH). Its bandwidth is variable since its SF occupies the free room left in the Orthogonal Variable Spreading Factor (OVSF) tree after the DCHs SF allocation.

Table I summarise all these informations.

TABLE I

COMPARISON OF DIFFERENT TRANSPORT CHANNELS

Channel	DCH	DSCH	FACH
SF	Fixed [512 - 4]	Variable [256 - 4]	Fixed [256 - 4]
RRC State	Cell_DCH	Cell_DCH	Cell_FACH
Multiusers	Dedicated	Shared	Shared
Multicodes	No	Yes	No

B. Traffic Classes and Transport Channels

Based on the 3GPP standardisation [2], the four UMTS traffic classes are differently mapped to the three available transport channels (Table II).

TABLE II

TRAFFIC CLASSES AND CHANNELS MAPPING

3GPP Traffic Classes	Authorised Transport Channel(s)
Conversational	DCH
Interactive	FACH, DSCH or DCH
Streaming	DCH
Background	FACH, DSCH or DCH

The Real Time (RT) sessions (Conversational and Streaming) are directly allocated to a DCH. This is natural since this kind of traffic can not tolerate the significant packet delay or the delay variation likely to appear when using shared channels. Since there is no bandwidth reservation mechanism into shared channels, RT sessions are guided to dedicated channels only.

In the opposite way, Non Real Time (NRT) sessions (Interactive and Background) may support a much longer delay. So, these traffics accept to be guided to either dedicated or shared channels since the packet scheduling of the shared channels does not affect the NRT sessions as it does to the RT ones.

As RT sessions use dedicated channels only, channel switching will only influence the NRT sessions.

III. CHANNELS SWITCHING POLICY

A. NRT Traffic

Following the UMTS standard, the first channel allocated to a NRT session is not the only one this session will be able to use until it closes down. Indeed, channel switching is permitted and even encouraged since it can optimise the radio resource consumption.

If a NRT session uses a shared channel (DSCH or FACH), it will continue using this channel until we get an indication that the current burst might be long (the packet queue length exceeds a fixed threshold), then the RNC shall try to allocate a DCH to that session. If the OVSF tree has enough room to accept this new DCH, the NRT session moves from the shared channel to its new DCH.

On the counter part, when no more packets are sent over the DCH, a timer is initialised and the session remains on the DCH during this period. If there are no new arrivals within this timeout period, the session is switched back to a shared channel.

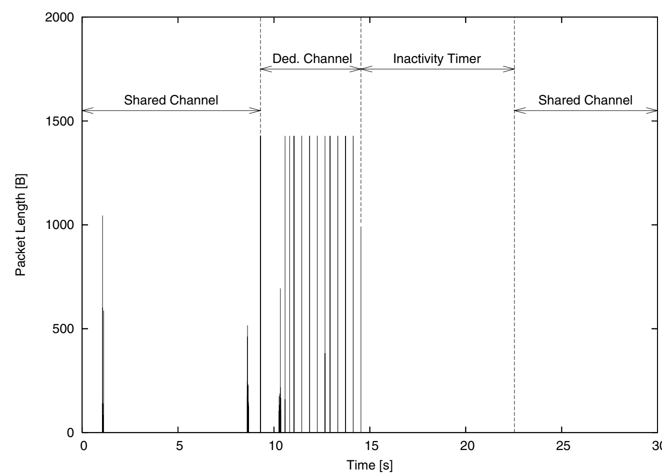


Fig. 2. Channel switching.

These two parameters are respectively known as upswitch threshold (from shared to dedicated channel, expressed in bytes) and downswitch timer (from dedicated to shared channel, expressed in seconds) [3]. Figure 2 illustrates these mechanisms with upswitch threshold and downswitch timer respectively fixed to $500\ B$ and $8\ s$.

B. Switching from Cell_FACH to Cell_DCH

Being in Cell_FACH means that the UE is active and does not support any RT session. It can only support at least one low bandwidth demanding NRT session which is satisfied with FACH bandwidth. Switching from Cell_FACH to Cell_DCH happens when a DCH has been requested. This may be caused by the NRT session exceeding the upswitch threshold or by a new RT session beginning. In the former case, the NRT session will leave the FACH and continue into its new DCH. In the later case, the RT session will start in its own DCH and the NRT session which was not transferring enough data to claim a DCH, will not stay in the FACH (since the UE is now in CELL_DCH) but will proceed in the shared channel of the Cell_DCH state: the DSCH.

C. Switching from Cell_DCH to Cell_FACH

When a session has to leave its DCH, be it due to a RT session end or a NRT session downswitch, and if no other DCH is allocated but at least one session is still active (in the

DSCH), the UE falls back to the Cell_FACH state. The NRT session assigned to the DSCH leaves it and proceeds in the FACH.

D. Evaluation of the Parameters Optimal Values Set

The UMTS standard does not give any guideline for setting the value of the upswitch threshold or the downswitch timer. Our idea here is to evaluate the best possible values of these parameters leading to an optimal resource consumption.

We will not try to find the optimal upswitch threshold value since it has been identified through extensive simulations [4]. This upswitch threshold has to be smaller than the average packet size. This means that as the packet waiting buffer is filled with only one packet (the NodeB can not emit packets as quickly as they arrive), the session responsible of this excess is directly upswitched. This strategy will lead to open a DCH for large connections as quickly as possible while preventing small connections from opening one, keeping in mind that reserving a SF and opening a DCH is time costly.

So, we have three remaining objectives. First we have to identify the NRT best suitable value for the downswitch timer. If the downswitch timer is high, a NRT session will remain longer on a DCH and, if it has to send more packets after an inactivity period (i.e. a web page reading time), it has not to upswitch again since it has kept its DCH. The connections undergo less upswitches and the DCH allocation time affects the packet delay in a less significant way. But the drawback in this situation is that other connections may have to stay in the shared channel due to expensive OVSF tree occupation. From the opposite point of view, using a small downswitch threshold will lead to rapidly free the OVSF tree by switching back to the shared channel after using a DCH, but in this case, sessions will suffer from multiple upswitches and DCH allocation time will significantly increase the packet mean delay. A tradeoff is therefore to be found between these two options.

A second objective is based on the strategy initially proposed in [3]. This strategy splits the downswitch timer in two distinct periods. The timer begins in the non-preemptive mode. In this mode, the session admission mechanism is exactly the same as with a normal downswitch timer. A NRT session keeps its SF no matter of other new sessions needs. After a period of inactivity into the non-preemptive mode, the downswitch timer moves into the preemptive mode. In this case, the NRT session keeps its SF until the end of its downswitch timer unless another session needs this SF. So, the idea behind identifying the best possible downswitch timer, is to evaluate the benefit of splitting the downswitch timer in two periods.

Besides the downswitch timer dimensioning, the third objective is to determine whether it is beneficial or not to directly open a DCH at the beginning of a NRT session or to allocate it to a shared channel. When a UE starts a NRT session, does its session get a dedicated channel (DCH) straight ahead or a shared one (DSCH or FACH) first? The UMTS standard gives no particular directive about it and thus, this is another parameter to be identified.

The merits of the proposed scheme/values will be measured with different metrics: the blocking rate, the mean packet delay and the cell throughput.

IV. Results

A. Testing Environment

Our work is based on a computer testbed emulating the UTRAN. It consists of 9 PCs respectively standing for the RNC, 4 NodeBs and 4 sets of UEs. We emulate 4 macrocell trisectorial NodeBs, each of them managing a population of UEs over a 27 km^2 world surface. More details about our emulation platform could be found in [5].

Synthetic traffic whose distribution complies with the characteristics of the 4 UMTS traffic classes [2] is generated from (to) the RNC to (from) the PC emulating a given UE in the downlink (uplink). In order to characterise those traffic classes, it might be useful to focus on four representative applications (Table III) [6].

TABLE III
TRAFFIC CLASSES AND APPLICATIONS

3GPP Traffic Classes	Representative Applications
Conversational	VoIP
Interactive	Web browsing
Streaming	Video streaming
Background	E-mail

Our UEs are mobile and evolve in an urban area. They are mapped on four specific UE speeds. In the urban area scenario, the UE speed distribution is the following: 30% at 3 km/h, 40% at 30 km/h, 20% at 70 km/h and 10% at 120 km/h.

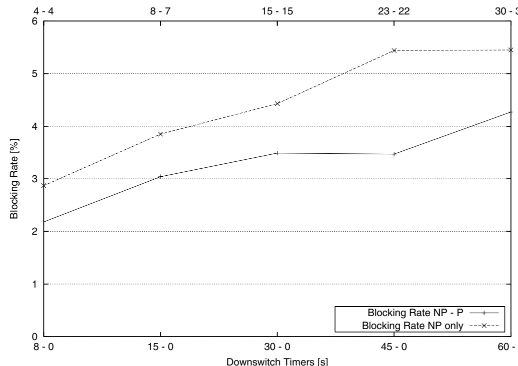
All the emulation parameters are summarised in Table IV:

TABLE IV
EMULATION PARAMETERS

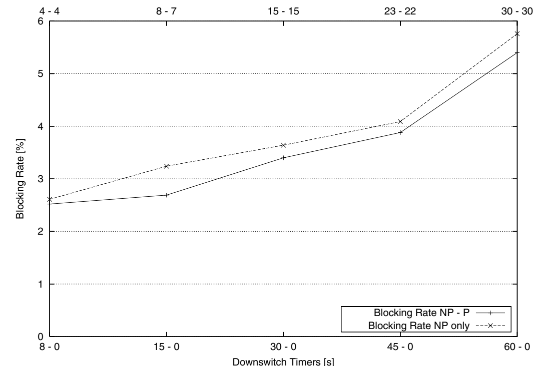
Number of UEs per sector	7
Emulation length [s]	6,000
Downswitch threshold [s]	8; 15; 30; 45; 60
DCH allocation time [ms]	900
FACH SF	64

B. Observations

We have run a single emulation for every downswitch timer value (split or not) allocating either a dedicated or a shared channel first. We have then been able to identify a set of values leading to an optimal use of the wireless interface

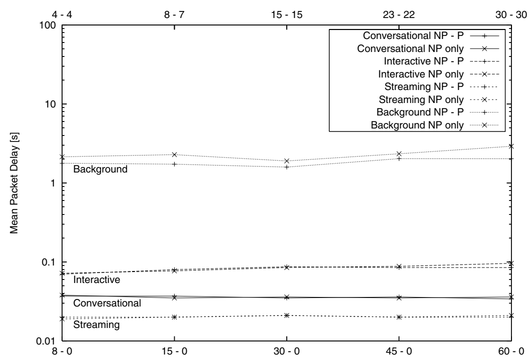


(a) Dedicated first.

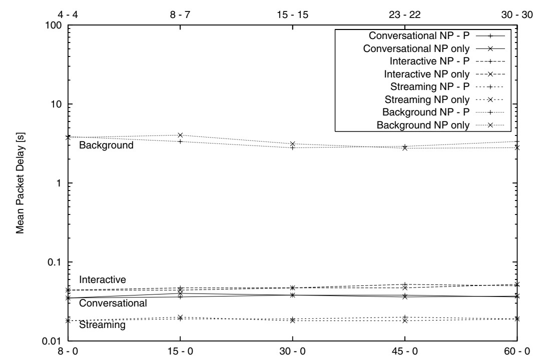


(b) Shared first.

Fig. 3. Blocking rate Vs. Downswitch timers.

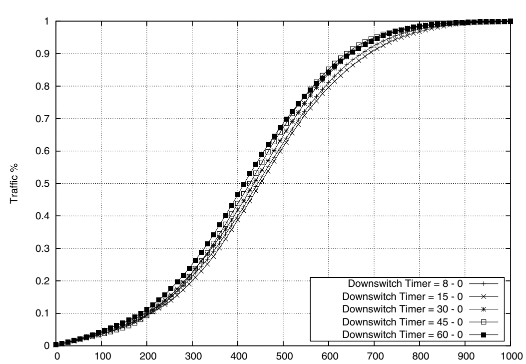


(a) Dedicated first.

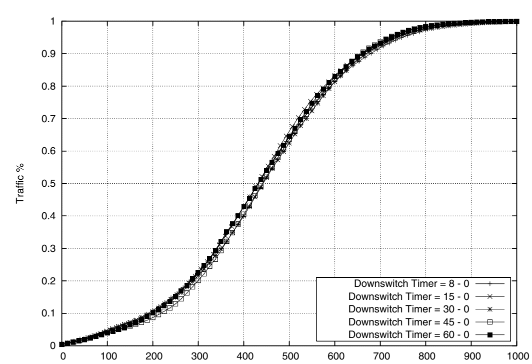


(b) Shared first.

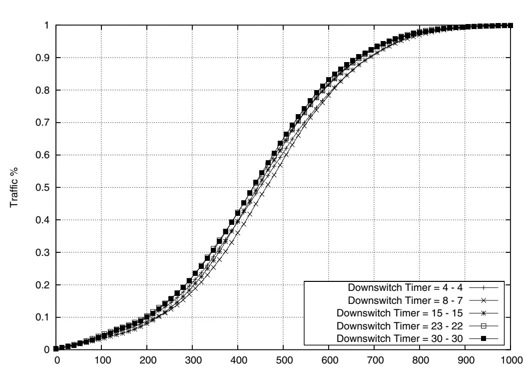
Fig. 4. Packet delay Vs. Downswitch timers.



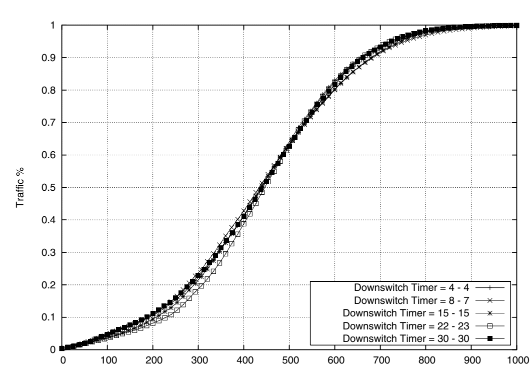
(a) Dedicated first, NP.



(b) Shared first, NP.



(c) Dedicated first, NP - P.



(d) Shared first, NP - P.

Fig. 5. Cell throughput Vs. Downswitch timers.

of the UMTS in terms of blocking rate and cell throughput while keeping acceptable packet delays regarding the traffic class. To illustrate these results, Fig. 3 represents the blocking rate and Fig. 4 shows the mean packet delay experienced by the four traffic classes. These metrics are plotted as a function of the downswitch timer, either non-preemptive only (NP, lower time scale) or split in non-preemptive/preemptive periods (NP-P, upper time scale). Finally, Fig. 5 presents the cell throughput cdfs of all the emulations.

From the downswitch timer point of view, it seems that dividing the downswitch timer in two equivalent periods (a preemptive one and a non-preemptive one) is beneficial. Indeed, as shown on Fig. 3, the blocking call rate is significantly reduced (almost 2% reduction in the best case) whereas mean packet delay (Fig. 4) and cell throughput (Fig. 5) are approximately unchanged.

Following the results depicted on the Fig. 4 and Fig. 5, it appears that opening a DCH at the beginning of a new NRT session, without even knowing whether it will be a large connection or not, is a better choice. Indeed, as the DCH allocation time is included into the initial connection establishment time, the average background delay of the session is then approximately reduced by about 30%. The only negative impact of this scheme resides in the Interactive traffic mean packet delay (Fig. 4(b)) which is smaller when allocating a shared channel first. This could be easily explained by a medium cell load factor (mean between 35% and 40% in the emulations). Since the DSCH bandwidth depends of the DCH SF consumption, if the OVSF tree is lightly occupied, it leaves a large remaining bandwidth to the DSCH which easily emits the Interactive packet bursts without exceeding the upswitch threshold. That is why the Interactive traffic encounters a shorter mean packet delay when allocating a shared channel first.

Focusing on the mean packet delay (Fig. 3(a)) and the cell throughput (Figs. 5(a)-5(c)), it appears that a short downswitch timer (between 8 and 15 seconds) gives the best possible results.

From these observations, the results of our testbed's emulations are inline with those from analytical computations [7] and from simulations [8]. However we refine their strategy since we focused on different performance metrics. For the NRT sessions, the optimal strategy seems to be:

- to begin the session directly in a DCH (if possible depending on the OVSF tree occupancy),
- to assign a short downswitch timer (as proposed in [8]), and
- to split the downswitch timer in two equivalent periods, the first one non-preemptive and the other preemptive.

V. Conclusion

We have presented our results in terms of radio resource management. We have confronted our observations to simulations results from the literature and it appears that these two sets of results are converging. We have then analysed an improved dedicated channel's downswitch timer based scheme which seems to optimally meet the UMTS network requirements such as a low blocking rate, a high cell throughput and a low mean packet delay.

References

[1] Technical Specification Group Radio Access Network, "TS 25.331 V7.1.0, Radio Resource Control (RRC) protocol specification," 3^{rd} Generation Partnership Project (3GPP), Tech. Rep., June 2006.

[2] ——, "TS 23.107 V6.4.0, Quality of Service (QoS) concept and architecture," 3^{rd} Generation Partnership Project (3GPP), Tech. Rep., Mar. 2006.

[3] B. J. Prabhu, A. Altman, K. Avratchenkov, and J. Abadia Dominguez, "A simulation study of TCP performance over UMTS Downlink," in *Proceedings of the* 58^{th} *Vehicular Technology Conference (VTC-fall)*, Orlando (FL - USA), Oct. 2003.

[4] X. Dubois, "Performance of different TCP versions over UMTS common/dedicated channels," Master's thesis, FUNDP - University of Namur (Belgium), June 2005.

[5] H. Van Peteghem and L. Schumacher, "Emulation of a Downlink Spreading Factor Allocation Strategy for Rel'99 UMTS," in *Proceedings of the* 64^{th} *Vehicular Technology Conference (VTC-fall)*, Montreal (Canada), Sept. 2006.

[6] ——, "Description of an IPv6 Linux-Based UTRAN Testbed," in *Proceedings of the* 2^{nd} *International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TridentCom)*, Barcelona (Spain), Mar. 2006.

[7] L. de Bruynseels, "Tuning Inactivity Timer Seetings in UMTS," Commsquare Technical Whitepaper, Tech. Rep., Jan. 2005.

[8] M. Chuah, L. Wei, and X. Zhang, "Impacts of Inactivity Timer Values on UMTS System Capacity," in *Proceedings of the* 3^{rd} *Wireless Communications and Networking Conference (WCNC)*, Orlando (FL - USA), Mar. 2002.