UMTS HSPA and R99 Traffic Separation

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Abstract This paper presents a general traffic separation approach to transmit HSPA traffic in the existing ATM-based UMTS network, together with Release 99 (R99) traffic. The traffic separation technique enables QoS differentiations of HSPA and R99 traffic, while at the same time aims to achieve a maximum utilization of the transport resources in the radio access network. The potential benefit of applying traffic separation and its impact on the performance of the transport network as well as the end users are explored in this paper. The quantitative evaluations are provided by means of simulations. The results presented are obtained from a UMTS simulation model developed in this work which transmits both HSPA and R99 traffic, either with traffic separation enabled or disabled.

1 Introduction

Universal Mobile Telecommunication Systems (UMTS) is a key standard of the third-generation (3G) WCDMA-based cellular network. With the development and expansion of 3G cellular networks, UMTS evolution continues to unfold, with the range of the offered services rapidly extending from primarily voice telephony to a variety of appealing data and multimedia-based applications. It is expected that data services like Internet access, email, FTP upload/download, will constitute a dominant traffic share in UMTS networks. In order to significantly improve the support of such delay-tolerant data services with enhanced resource efficiency and service quality, High Speed Downlink Packet Access (HSDPA) [1] and High Speed Uplink Packet Access (HSUPA) also named as Enhance Uplink [2] are introduced by 3GPP Release 5 and Release 6 individually, as the evolution of UMTS to enhance the transmission of data packet traffic on the downlink and uplink separately. They offer a much higher data rate (up to 14.4 Mbps in the downlink with HSDPA and 5.76 Mbps in the uplink with HSUPA), lower latency, increased system capacity and thus facilitate improved data services. HSDPA and HSUPA are jointly referred to as High Speed Packet Access (HSPA) [3]. So far, HSPA services have been already supported in the existing ATM-based UMTS networks to enhance data transmissions. Besides, the UMTS system still accommodates a significant amount of Release 99 (R99) traffic such as voice telephony. In R99, user traffic is transported via Dedicated Channels (DCHs) over the radio interface. For HSPA traffic, in order to support their new features like fast Hybrid Automatic Repeat Request (HARQ), fast NodeB scheduling, and using a shorter 2ms Transmission Time Interval (TTI) (mainly for HSDPA and optionally for HSUPA), HSDPA establishes a new downlink transport channel called High-Speed Downlink Shared Channel (HS-DSCH) that is shared by all HSDPA UEs in the cell. In HSUPA, for each UE a new uplink transport channel called E-DCH (Enhanced Dedicated Channel) is used to provide high-speed uplink traffic transmission. HSPA traffic is characterized by high peak data rates and high burstiness. To support such HSDPA traffic on the downlink and HSUPA traffic on the uplink, not only the UMTS air interface but also the backhaul of the UMTS access network, namely UMTS Terrestrial Radio Access Network (UTRAN), will require considerably high transport capacity for the provisioning of high-speed transmission of packet data. In addition, R99 and HSPA services have rather different QoS requirements: R99 mainly carries delay sensitive traffic like voice or streaming services; whereas HSPA traffic is primarily interactive and background traffic which is insensitive to the delay. Thus, how to efficiently transport R99 and HSPA traffic in the same radio access network while guarantying their individual QoS requirements is a big challenge for designing the evolved UMTS network.

This paper introduces a general traffic separation approach to transmit both HSPA and R99 traffic in the existing ATM-based UMTS networks, providing a differentiated QoS support for each type of traffic according to its individual QoS requirements. The traffic separation technique is based on using separate ATM Virtual Paths (VPs) or Virtual Circuits (VCs) for transmitting different types of traffic each with a different ATM QoS class. The major contribution of this paper is to investigate how much performance gain can be achieved by applying traffic separation in terms of user throughput, packet losses, and link layer transport efficiency, and in addition what will be the impact on the dimensioning of the transport network, i.e. the Iub interface between the RNC and the NodeB. To achieve a cost-efficient dimensioning for the transport network, an optimum configuration shall be desired. For the performance analysis, we take the HSDPA and R99 traffic scenario as an example for the investigations in this paper, where only HSDPA and R99 traffic are transmitted. The rest of the paper is organized as follows: Section 2 describes the problem of carrying HSDPA and R99 traffic without any traffic separation. Section 3 introduces the basic concept of traffic separation. Section 4 addresses configurable parameters for the traffic separation, and possible traffic separation configurations for transmitting R99, HSDPA and HSUPA traffic in the same radio access network. Section 5 presents the simulation results and the performance analysis. The end gives conclusions and the future work.

2 Problem Description

Figure 1 illustrates the evolved UMTS system with integrated R99 and HSPA services. It is seen that one UMTS cell supports (1) normal UMTS R99 users like traditional voice users; (2) HSDPA users who require HSDPA service for high-speed data transfer on the downlink, e.g. Internet access; (3) HSUPA users who only uses HSUPA service for uplink data transmissions, e.g. FTP upload; (4) or HSPA users who use HSUPA on the uplink and HSDPA on the downlink simultaneously. HSPA technology is integrated directly into the existing UMTS nodes, i.e. NodeB and RNC, via software/hardware updates. Thus, the Iub interface between the RNC and NodeB carries both HSPA and R99 traffic.

R99 and HSPA traffic have different delay requirements on the transport network. There is an extremely strict delay constrain on the Iub interface for DCH channels of R99, not only due to the delay requirements of the user traffic itself but also because of the requirements derived from supporting radio control functions such as outer-loop power control and soft handover. The excessively delayed Frame Protocol packets (their delay is larger than predefined delay boundaries) will be discarded at the NodeB as they become too late to be sent over the air interface for the allocated time slot. However, HSPA traffic has significantly lower delay requirement on the Iub interface. Because for both HSDPA and HSUPA a fast scheduling is introduced at the NodeB which reserves the time slot on the air interface replacing the scheduling at RNC in R99, and furthermore there is buffering in the NodeB which supports fast HARQ. Thus, the delay requirements for HSPA are essentially only due to the service itself, which are mainly delay-tolerant best effort services that have loose constraints on the delay and delay variations. Thanks to the R99 traffic having a much more stringent delay requirement on the Iub interface, the R99 traffic is usually given a higher priority to transmit over the HSPA traffic.

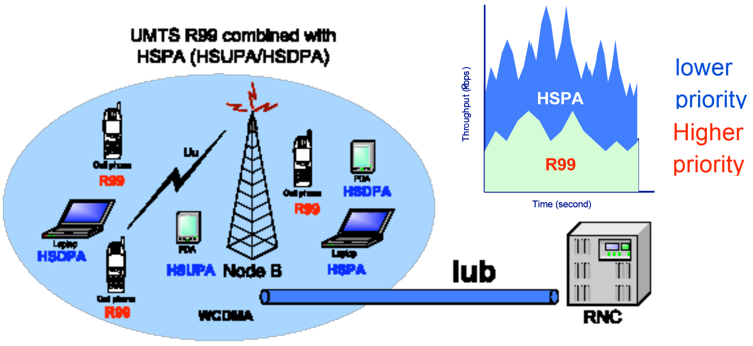


Fig. 1 UMTS Network supporting R99 and HSPA traffic

In the currently deployed UMTS system, the UTRAN transport network is ATM-based. In the case without using any traffic separation at the Iub interface, the R99 traffic and HSPA traffic are carried within a single, end-to-end ATM CBR (Constant Bit Rate) VP (Virtual Path). Without traffic separation, there are two major problems: (1) the transport network treats all UTRAN traffic with equal priority. Thus, the stringent delay requirements of the R99 traffic can not be guaranteed as it strongly depends on the behavior of HSPA traffic. Moreover, in case of congestion on the Iub link, the network will discard ATM cells irrespective of their importance, e.g. high priority R99 or inband signaling traffic could be skipped in favor of low priority HSDPA or HSUPA data. (2) With CBR for the common VP, a fixed transport bandwidth is reserved without considering any potential multiplexing gain. Thus the high quality ATM service category CBR is overspecified for the transport of Best Effort HSPA traffic, and this causes unnecessary cost in terms of leased ATM bandwidths.

3 Concept of Traffic Separation

The basic idea of traffic separation technique is to apply separate ATM Virtual Paths (VPs) or Virtual Circuits (VCs) with different ATM QoS categories to transmit different traffic types. One example of using traffic separation to transmit R99, HSDPA and HSUPA traffic at the Iub interface is depicted in figure 2. In this example, each traffic type is carried by one individual ATM VP. R99 traffic is transported with ATM CBR (Constant Bit Rate) [4] service category. It is defined as high priority traffic class, where bandwidth is reserved up to requested Peak Cell Rate (PCR) with guaranteed cell loss ratio and cell transfer delay. This also means a high transport cost. While the transport of Best Effort HSDPA and HSUPA traffic uses ATM traffic class UBR (Unspecified Bit Rate) [4] or UBR+ [5][6]. UBR is a best effort service and is the lowest class of service in ATM. It is defined as low priority traffic class, which utilizes all bandwidth unused by the high priority traffic. Therefore it does not provide any guarantees for bandwidth, cell loss ratio and cell transfer delay. This traffic class has a lower transport cost. UBR+ is similar to UBR, but bandwidth is guaranteed up to a minimum rate - MDCR (Minimum Desired Cell Rate). With UBR+, the HSPA inband signaling traffic can be guaranteed by MDCR.

As the R99 traffic consists of a considerable amount of symmetric voice traffic, CBR traffic class is elected for providing high QoS for the real time services and also symmetric PCR is configured on both directions. On the HSDPA and HSUPA path, it allows an asymmetric configuration of UBR/UBR+ VPs or VCs, e.g. asymmetric PCR or MDCR settings, to support the asymmetric traffic property of HSPA traffic, i.e. HSDPA user data is only transmitted on the downlink and there is a small amount of inband signaling traffic on the uplink, and HSUPA user data is only transmitted on the uplink with a small amount of inband signaling on the downlink.

With traffic separation, the network transmission cost for the low priority

HSPA traffic will be reduced. The transport of Best Effort HSDPA/HSUPA traffic with UBR/UBR+ allows the low priority HSPA traffic to use any free bandwidth in the transport network. Depending on the structure of transport network, significant multiplexing gain can be achieved for the HSDPA/HSUPA path(s). Moreover, by separating the HSPA and R99 traffic on different ATM paths, data loss in the Realtime R99 path can be avoided in case of network congestion, e.g. during bursts of Best Effort HSPA traffic. By using different ATM service categories for R99 traffic and HSPA traffic, the transport network is able to handle the R99 and HSPA traffic with different priorities and during congestion it can preferably discard the Best Effort HSPA traffic. Thereby, the QoS of the R99 traffic is protected from the bursty HSPA traffic.

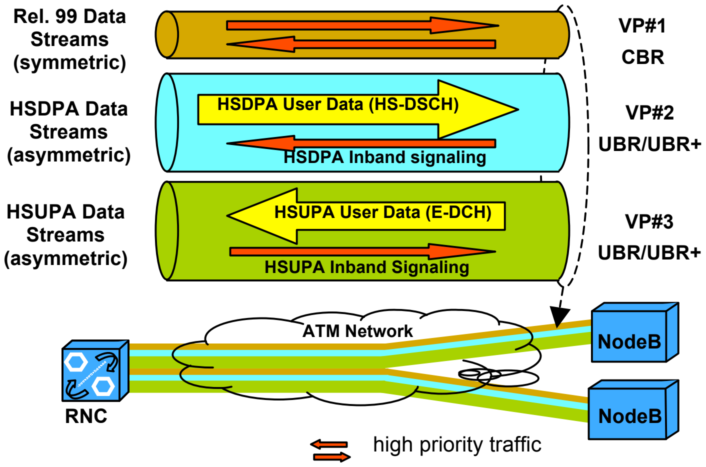


Fig. 2 Concept of Traffic Separation

4 Configuration of HSPA and R99 Traffic Separation

For setting up a traffic separation scenario, we need to configure the following ATM parameters:

- PCR (Peak Cell Rate) is the upper limit of the traffic that can be submitted to the link.
- MDCR (Minimum Desired Cell Rate) defines a minimum guaranteed cell rate on UBR VC. It is optionally configured on either a VC or VP connection.

PCR is required to configure for both ATM CBR and UBR/UBR+ service categories. Maximum allowed bandwidth can be set different for the uplink and downlink by means of an asymmetric PCR configuration of VPs and VCs. MDCR is only configurable for UBR+ VP/VCs.

To transport HSDPA, HSUPA and R99 traffic simultaneously in the UTRAN transport network, there are mainly four possible scenarios to be considered:

1. 3 VPs: 1 CBR VP for R99, 1 UBR/UBR+ VP for HSDPA, 1 UBR/UBR+ VP for HSUPA;
2. 2 VPs: 1 CBR VP for R99, 1 UBR/UBR+ VP for HSPA with separated VCs to transmit HSDPA and HSUPA;
3. 2 VPs: 1 CBR VP for R99, 1 UBR/UBR+ VP for HSPA without separated VCs to transmit HSDPA and HSUPA;
4. 1 VP: 1 Common CBR VP or VC to carry all traffic types.

Scenario 1 applies three VPs each transferring one traffic type. Scenario 2 and 3 uses two VPs: 1 VP is assigned for R99 and the other one for the HSPA traffic. For these two cases, the HSDPA data traffic will be mixed with HSUPA inband signaling traffic and the HSUPA data traffic will be mixed with HSDPA inband signaling traffic. The difference of scenario 2 and 3 is whether to use separate VCs for transmitting HSDPA and HSUPA traffic. With separated VCs, each UBR/UBR+ VC can be configured with different PCR or MDCR for HSDPA and HSUPA individually. Moreover, in order to protect the HSPA inband signaling traffic which has high priority, Cell Loss Priority bit (CLP) that is defined in the ATM cell header can be used to select which cell to discard in case of congestion: CLP=1: for low priority traffic, cell may be discarded by ATM network in case of congestion; CLP=0: for high priority traffic, cell should not be discarded by ATM network. So we can set different CLP value for the separated VCs to differentiate the inband signaling traffic and HSPA traffic so that the HSPA inband signaling traffic can be protected. In scenario 4, all R99, HSUPA and HSDPA traffic share one common CBR VP/VC, i.e. there is no traffic separation in this case. For scenario 1, 2 and 3, the transport of HSPA traffic can either be on a UBR or UBR+ VP. If UBR+ VP is used, there is a guaranteed minimum bandwidth for transmitting the HSPA traffic, with which a minimum QoS is assured for the requested HSPA services.

5 Result Analysis

This section presents the simulation results. For the analysis of traffic separation, following we take the HSDPA and R99 traffic scenario as an example in this paper for the investigations. In the following part, the results of applying traffic separation to transport both HSDPA and R99 at the Iub interface is presented and compared to the scenario without traffic separation. The parameter settings for the traffic separation and its impact on the dimensioning will be also discussed. Additionally one example of the Iub dimensioning with traffic separation and without traffic separation is given and their transmission efficiency is compared. Though the case of transporting HSDPA, HSUPA and R99 traffic will not be presented in this paper, the general impact of applying traffic separation on the performance and the Iub dimensioning will be similar.

5.1 Simulation Scenario Description

The simulation scenario consists of one NodeB and one RNC. As mentioned above, in this paper we focus on the HSDPA and R99 traffic scenario for the performance analysis. The simulation model of HSDPA and R99 were developed in OPNET [11]. R99 model implements all functions and radio protocols according to the 3GPP specifications. In the HSDPA model, a Round Robin air interface scheduler is used in the simulations. In addition, in order to protect the congestion on the Iub link, flow control and congestion control schemes are applied in the Iub. The HSDPA traffic is modeled with 20 Internet users browsing the web. The web traffic model is defined by ETSI standards [7], the traffic model parameters are given in Table 1. Each user requests multiple pages where the inactive time between pages follows the geometric distribution. The same traffic model is used for generating the R99 traffic where multiple Packet Switched (PS) Radio Access Bearers (RABs) are available for transmitting the data.

When no traffic separation is applied in the Iub interface, R99 and HSDPA traffic are sharing one common ATM CBR VP, where the AAL2 priority is applied which assigns higher priority to R99 traffic over the HSPA traffic. While in the case of using traffic separation, two ATM VPs are established: the transport of R99 traffic is over one ATM CBR VP and the transport of HSDPA traffic is on an ATM UBR+ VP. Here UBR+ VP is set to low priority.

Table 1. ETSI Traffic Model

Page Interarrival Time (IAT) (Reading Time)	Geometric distribution mean interarrival time = 5 seconds
Page size	Pareto distribution parameters: Shape=1.1, location=4.5 Kbyte, max page size = 2 Mbyte mean page size = 25 Kbyte

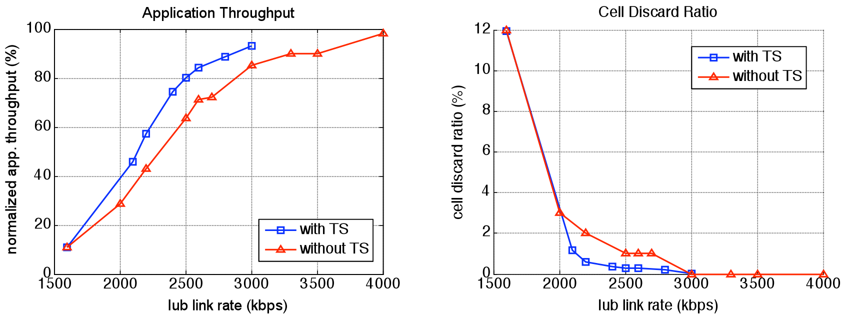
The following metrics are used for performance evaluation:

- Application Throughput: the average throughput of transferring a web page at the application layer, excluding reading time period. The normalized application throughput is given in simulation results defined as the ratio of the application throughput under certain Iub link bandwidth to the maximum application throughput under an ideal Iub capacity.
- Cell Discard Ratio: in case of congestion of the Iub link, the ATM cells are discarded. The packet discard ratio is measured as the ratio of discarded ATM cells to the total ATM cells sent to the Iub link.
- TCP Retransmission Counts: the total number of TCP retransmissions.
- Link Utilization: the Iub link throughput over the given Iub link bandwidth. The link throughput includes transport network overheads as well as all TCP/RLC retransmissions.

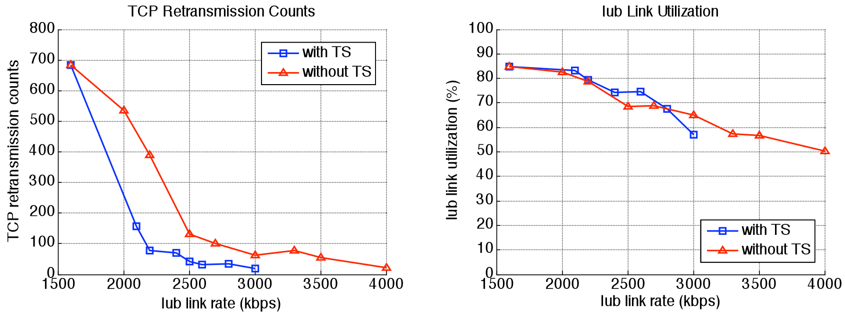
5.2 Impact of Traffic Separation

In this section, the influence of traffic separation (TS) is investigated by comparing to the scenario without traffic separation technique in use in the transport network. In this example, there is in average 815.9kbps HSDPA traffic and 968.7kbps R99 PS traffic on the Iub link. In both with and without traffic separation cases, the offered HSDPA and R99 traffic is fixed while the common Iub link rate is step by step increased. For the configuration with traffic separation, the PCR of CBR VP for transport of the R99 traffic is set to 1600kbps, whereas the MDCR of UBR+ VP for transmitting the HSDPA traffic is increased from 0kbps up to 1400kbps which results in the increase of the total Iub link bandwidth.

Figure 3 compares the performance difference of using and not using traffic separation. It shows that with the usage of traffic separation technique, the end user application throughput is improved while the cell losses and resultant TCP retransmissions are reduced significantly. The major reason is that traffic separation provides a minimum bandwidth guarantee for HSDPA traffic, thus the HSDPA traffic will get less influence from the R99 traffic. Though the link utilization is similar in both scenarios, there is more link load contributed by RLC and TCP retransmissions in the case of no traffic separation.



(a) Normalized application throughput (b) Cell discard ratio



(c) TCP retransmission counts (d) Iub link utilization

Fig. 3 Performance comparisions: with TS and without TS

From these results, we can conclude that to achieve the same application throughput or cell discard ratio target, using traffic separation needs less bandwidth on the Iub link, which means a more efficient utilization of the transport resources. For example, to achieve 90% normalized application throughput, applying traffic separation requires 2800kbps while no traffic separation requires 3300kbps on the Iub link. The obtained bandwidth saving is 15%. To guarantee less than 1% cell discard ratio, using traffic separation requires minimum 2100kbps bandwidth while no traffic separation requires minimum 2500kbps on the Iub link. The obtained bandwidth saving is 16%.

5.3 Impact of MDCR Settings for UBR+ VP/VC

This part discuses the influence of MDCR settings of ATM UBR+ VP/VC on the overall performance, based on the results of the traffic separation scenario in the above example shown in figure 3. As the PCR of CBR VP for transport of the R99 traffic is fixed to 1600kbps, the MDCR of UBR+ VP (MDCR = the total Iub link rate – allocated bandwidth on R99 path) for transmitting the HSDPA traffic varies from 0kbps up to 1400kbps. It can be observed from figure 3 that with the increased MDCR rates the end user application performance is improved considerably: the normalized application throughput is increased from 11% to 95%. Because with a higher MDCR rate, there is more bandwidth reserved for HSDPA traffic, and therefore the performance is better. Besides the improvement of application performance with a higher MDCR setting, the network performance is also enhanced. It is observed that RLC delays, cell discard ratio, number of TCP retransmissions are all decreased when MDCR increases. But on the other hand, the link utilization drops down due to a higher Iub link bandwidth caused by larger MDCR rates is configured to transfer the same offered traffic. Therefore, MDCR should be chosen as a compromise of the system performance and the Iub link utilization. That means, MDCR rate should be set properly to achieve the maximum link utilization while stratifying the QoS target.

Moreover it is observed that the application performance is much more sensitive to the MDCR setting than transport network performances. When MDCR is larger than 500kbps (i.e. Iub link rate = 2100kbps), the transport network performance such as cell discard ratio, TCP retransmissions, has been improved drastically. And afterwards, with further increased MDCR rate, the pace of the improvement is reduced and becomes more stable. But the application throughput is still quite low with 500kbps MDCR rate: only 46% of normalized application throughput is achieved. In order to achieve more than 90% of the application throughput, the MDCR need to be set higher than 1200kbps. So it is basically a choice of network operation to decide the MDCR rate based on its predefined QoS target. If the transport network performance is more important, then a smaller MDCR is adequate. If the end user application performance is the main target of the dimensioning, the MDCR rate needs to be configured to a relative higher value.

5.4 Dimensioning Results

This section presents the results of dimensioning of the Iub link, which transmits the HSDPA and R99 traffic either with or without Traffic Separation (TS) technique. In the following example, R99 traffic contains 50% web traffic (web traffic model is defined in Table 1) and 50% voice traffic with AMR codec. The voice model consists of a series of ON and OFF periods with a service rate of 12.2kbps with Adaptive Multi-Rate (AMR) codec specified by 3GPP. ON and OFF states are exponentially distributed with a mean duration of 3 seconds [8]. HSDPA consists of purely web traffic (Table 1). In the following results, we fix the R99 traffic load and gradually increase the offered HSDPA traffic to the Iub link, and investigate the bandwidth demand for transferring the combined HSDPA and R99 traffic satisfying the predefined QoS targets of both traffic types. In this example, the QoS target for R99 traffic is 1% packet discard ratio and for HSDPA 95% normalized application throughput.

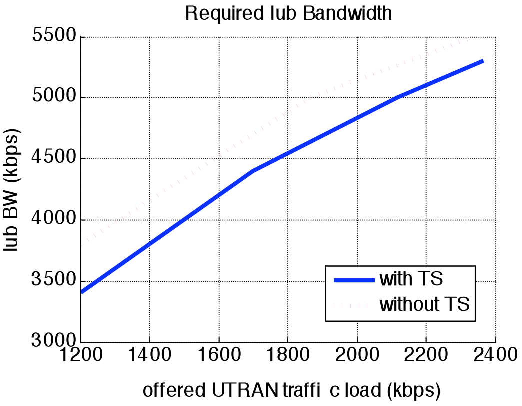


Fig. 4 Required Iub Bandwidth for different UTRAN load

Figure 4 shows the required Iub link bandwidth over different offered UTRAN traffic loads in kbps. The offered UTRAN traffic is the total sum of traffic entering UTRAN network including HSDPA and R99. It shows that with the increased traffic demand, the required Iub bandwidth to achieve the predefined QoS targets is increasing. It can be also obviously seen that, the required Iub bandwidth for the traffic separation scenario is much lower than that for the case without traffic separation. Therefore it is concluded that applying the traffic separation technique brings a significant bandwidth saving for the Iub dimensioning, which reduces the transport cost.

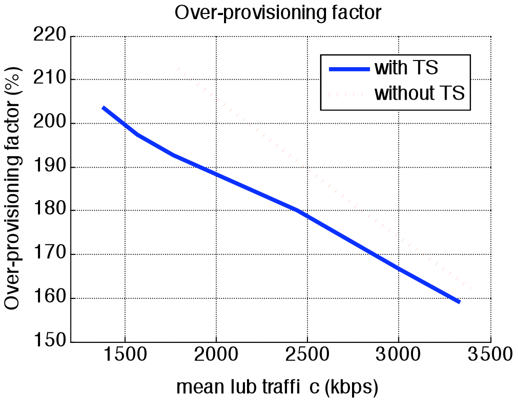


Fig. 5 Over-provisioning factor over Iub link throughput

The required capacity can be also expressed in terms of “Over-provisioning factor”, β, which relates the capacity in the link (C) to the aggregated mean bit rate R_{iub} on the Iub link as given in the formula: $C = \beta \cdot R_{iub}$ [9]. This parameter indicates in addition to the mean traffic load on the Iub link how much extra bandwidth is needed in order to fulfill the QoS requirements. Figure 5 shows the obtained over-provisioning factor in percentage of the mean Iub traffic. As observed from figure 5, the degree of over-provisioning decreases for higher traffic load on the Iub link in both with TS and without TS scenario. That means, with a larger traffic load a higher multiplexing gain is achieved which results in decreased over-provisioning factor. Furthermore, with traffic separation technique less extra bandwidth is required for transmitting the same amount of the traffic on the Iub link. And moreover, at the lower traffic load range, the over-provisioning factor of without traffic separation is much higher than that of the traffic separation scenario, and with the increase of the aggregated traffic load their gap is slowly reduced. This implies the traffic separation is able to achieve more bandwidth savings (compared to without traffic separation) at a lower mean Iub traffic load, where the room for the potential multiplexing gain is more.

6 Conclusion

This paper proposes using a traffic separation approach to transmit HSPA and R99 traffic transport in the same radio access network. We investigated the impact of using traffic separation, and explored its advantage compared to the case without traffic separation by analyzing the example of HSDPA and R99 traffic scenario. The simulation results show that the using traffic separation technique greatly improves the end user performance as well as the transport network performance, which in turn saves the bandwidth on the Iub link for achieving the same QoS level. Therefore, it brings a more efficient utilization of the transport resources in UTRAN and reduces the transport cost for the dimensioning. By investigating the different MDCR settings, it is concluded that MDCR should be chosen as a compromise of the system performance and the Iub link utilization, and also dependent on the QoS target defined by the network operator.

In this paper, we mainly present the traffic separation results for HSDPA and R99 traffic scenario. In the future work, we will further evaluate the performances of applying traffic separations for the transport of HSDPA, HSUPA and R99 traffic in the UTRAN transport network, according to the four possible traffic separation scenarios introduced in section 4. Traffic separation approach is a generic approach for transmitting different services (each with different QoS constrains) over different paths in the transport network. As another example, it can be also applied in a Carrie Ethernet-based UTRAN (using Pseudo-Wire Emulation (PWE) [10] to emulate the ATM service over Ethernet as the transport network), a UBR path can be used for transmitting the best effort data service while the delay sensitive real time service like voice telephony is transmitted over a CBR path.

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