The Effect of QoS Parameters for Mixed Services upon Network Capacity in 3rd Generation Radio Access Networks

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Abstract: Call Admission Control (CAC) is an essential part of radio resource management in wireless communications, where CAC algorithms are employed to provide Quality of Service (QoS) and efficient radio resource utilization in 3rd generation radio access networks (3GRAN). This paper investigates the effect of QoS parameters upon network capacity on the uplink of a 3GRAN, when the network consists of a traffic mix encompassing circuit switched (CSW) and packet switched (PSW) services in a shadow-fading environment. The results show that the overall capacity is constrained by the service with stricter QoS requirements.

1 Introduction.

As 3rd generation networks are expected to support a high packet switched (PSW) component from the support of wireless Internet services, the overall objective of the study is to observe and understand how service characteristics of bit-rate and required Eb/N_0 for that service, influence the performance of radio resource management (RRM) in supporting both PSW and circuit switched (CSW) services when mixed, and the resulting system capacity.

In 3rd generation networks, the required quality of service (QoS) [1] and the system throughput determine the desired system operating point. In some cases (for PSW services) the QoS will not be a constraint and the preferred operating point will be that of maximum throughput. To observe the overall QoS requirement, 98% of the users must be satisfied. A user of a CSW service is satisfied if all three of the following constraints are fulfilled:

- The user does not get blocked when arriving to the system.
- The user has good quality reception more than 95% of the call time (not in outage).
- The user does not get dropped. The user gets dropped by being in outage for a continuous period of $T_{drop}(service)$.

A user of a PSW service is satisfied if all three of the following constraints are fulfilled:

- The user does not get blocked.
- A packet does not get dropped.
- The average packet throughput shall not be below 10% of the service’s nominal source rate. This throughput considers the time from generation of the packet access request to the generation of the successful transmission acknowledgement.

The remainder of this paper is organised such that: Section 2 provides a description of the simulation parameters and the various traffic mixes used in this study; Section 3 gives a full description of the simulation results and the associated findings; Section 4 provides the conclusions to this paper.

2. Simulation Parameters

The Simulation is composed of four sets of Monte Carlo simulations corresponding to a different percentage ratio in the combination of CSW speech and PSW UDD144 services, denoted mixes ‘a’ to ‘d’, and are shown together with the service requirements in Table 1.

Service	Average number of bits per call or session N_{bc}	$E_b/(N_0+I_0)_{req}$ (dB)	Average target receive power per frame or packet S_{Rx}	Bearer source bit-rate R_b	Traffic Mixes (%)			
					a	b	c	d
Speech	480 kbits	5.4	$1.84\times10\times^{4}C$ W	8 kb/s	50%	75%	25%	0%
UDD 144	481 kbits	3	$1.18\times10^{5}\times C$ W	60.8 kb/s	50%	25%	75%	100%

Table 1: *Service Requirements and Simulation Traffic Mixes for Speech and UDD144*

The service requirements in Table 1 for CSW speech and PSW UDD144 are based upon the guidelines set out in [2], operating in the uplink, and the average target receive power per frame, or packet, S_{Rx}, is expressed as a function of a power-control constant C, where $C << 1$. Note that the voice model has a duty cycle that is set at 0.5.

The test environment model is based on a 19 cell wrap-round configuration using hexagonal cells and a BS separation of 6 km as described in the guidelines of [3] for a Vehicular A Environment.

The mobility model is such that UEs are uniformly distributed, vehicle speed = 120 km/h, probability to change direction = 0.2, maximum angle for direction update = 45°, decorrelation length = 20 metres.

The RRM parameters employed here are as follows: CAC Queue Size = 2000 access-requests; Packet Session Access Request Time-Out (T_{CAC}) = 1 s; MAC Queue Size = 20 access requests; Packet Access Request Time-Out (T_{MAC})= 1 s; and Maximum number of retransmissions = 8.

The UTRA Simulator incorporates a shadow-fading model, based upon the model in [4], and has been set to have a standard-deviation of 10 dB and a correlation factor between shadow-fading samples of 0.97

3. Simulation Results

When observing the % of unsatisfied calls/sessions (P_{unsat}) performance, in Figure 1, the speech service can be seen to reach its QoS limit at an offered-load (G_{TOTAL}) of 450 kb/s for mixes 'a' and 'b', and 600 kb/s for mix 'c'. Conversely, in Figure 2, UDD144 reaches its QoS limit at 750 kb/s for mixes 'a', 'c' and 'd', and 900 kb/s for mix 'b'. As the 'preferred' operating point in the network is where the QoS of all services in the combination is met, the capacity of the network can be seen to be constrained by the performance offered to speech by RRM.

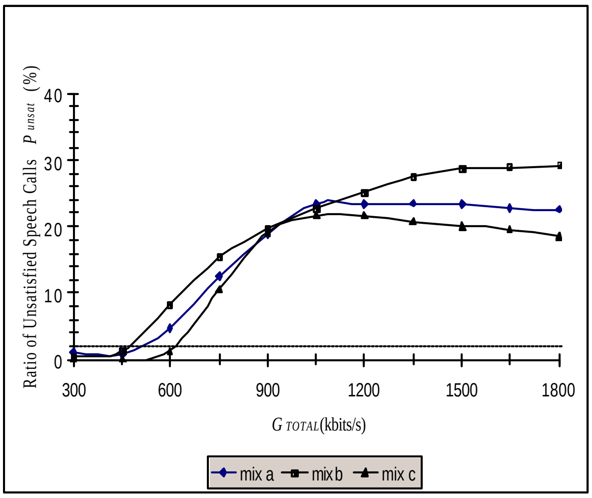

Figure 1: *Ratio of unsatisfied speech calls versus total cell-area offered load (G_{TOTAL}) with shadow fading.*

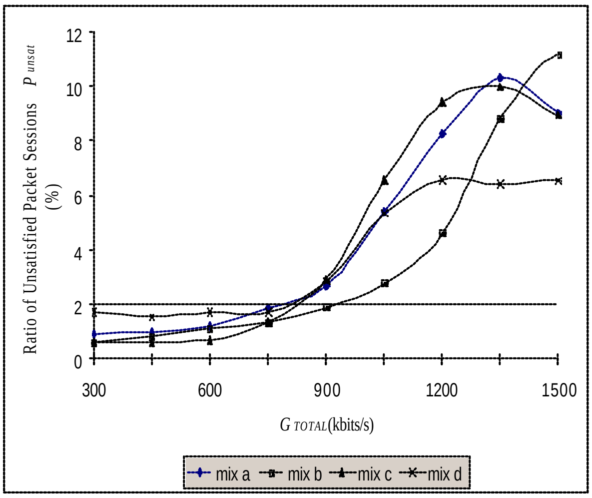

Figure 2: *Ratio of unsatisfied packet sessions (P_{unsat}) versus total cell-area offered load (G_{TOTAL}) with shadow fading.*

The reason for this can be seen in Table 2, where we observe that for any of the mixes 'a' to 'c', at a G_{TOTAL} value exceeding the 'preferred' operating-point, the % calls/sessions blocked in hand-over admission (P_{hblk}) and % calls/sessions blocked in call-admission (P_{cblk}), both of which contribute to P_{unsat}, are much higher for speech than for UDD144. In fact for speech, the sum total of P_{hblk} and P_{cblk} dominates P_{unsat}, while both the % calls/sessions dropped (P_{drop}) due to short-term congestion (applies only to CSW services where calls are dropped after a contiguous period of outage exceeding a specified limit) and the % unsatisfied 'completed' calls/sessions (P_{fail}) (completed CSW calls are unsatisfied when the total fraction of time in outage exceeds 5%, while an unsatisfied completed PSW session is one with an active session throughput less than 10% of the nominal bearer bit-rate, 14.4 kb/s for UDD144) are negligible for speech in all mixes. This is because unlike for a PSW session request, a CSW speech call request is not queued at Node B whenever resource is not immediately available, but is instantly blocked. The fact that speech P_{drop} and P_{fail} are zero, when both P_{hblk} and P_{cblk} are unacceptably high, indicates a restrictive admission policy for CSW speech services, at the expense of capacity.

Considering the P_{unsat} performance for UDD144 in Figure 2, and considering any pair of mixes, at the same G_{TOTAL}, there appears to be a tendency for UDD144 in the mix with the higher PSW component to perform worse over mid offered-load ranges, while the converse becomes true at higher offered-loads. This trend is clearly depicted when observing mixes 'b' and 'd'. In the mid offered-load range, each UDD144 session in the mix with the higher UDD144 component experiences higher levels of interference (Effect1) at hand-over admission and during communication and so has a higher probability of being unsatisfied.

Effect1 stems from the disparity between the values of the ratio of average target receive power per frame or packet (S_{Rx}) to average number of bits per call or session (N_{bc}) for both speech and UDD144 (see Table 1). Both speech and UDD144 have roughly the same average number of bits per call (480 kbits), and so deliver the same contribution to G_{TOTAL}, but UDD144 requires a higher value of S_{Rx}, and so contributes more to interference. Therefore, for the same G_{TOTAL}, and assuming no CSW calls were blocked, there will be more resource available (a higher interference margin) for the support of a UDD144 call in mixes with a lower UDD144 ratio.

	Mix a, G_{TOTAL}=600 kb/s		Mix b, G_{TOTAL}=600 kb/s		Mix c, G_{TOTAL}=750 kb/s	
	Speech	UDD144	Speech	UDD144	Speech	UDD144
% Unsatisfied calls /sessions (P_{unsat})	4.6	1.20	8.31	1.10	10.5	1.34
% Unsatisfied completed calls/sessions (P_{fail})	0	0.05	0	0.15	0	0.25
% calls/sessions blocked in call-admission (P_{cblk})	1.2	0	2.15	0	3.1	0
% calls/sessions dropped (P_{cdrp})	0	N/A	0	N/A	0	N/A
% calls/sessions blocked in hand-over admission P_{hblk}	3.4	1.15	6.15	0.95	7.4	1.08

Table 2: *Mix performance beyond operating point*

The effect dominant at higher loads (Effect2), where mixes with a higher UDD ratio perform worse, for the same G_{TOTAL}, is the result of an 'implicit' priority or bias in favour of CSW services by the CAC and MAC functions of the simulator. This implicit priority is the result of the sequential ordering of commands in the software code for the MAC and CAC functions, where CSW calls are served first before packet sessions and individual packets. However, this priority mechanism is non-pre-emptive, so UDD packet transmissions in progress are not pre-empted to accommodate a new or hand-over CSW call. This implicit priority becomes increasingly dominant at higher offered-loads as the available resource diminishes.

Both Effect1 and Effect2 are observed in the mean packet transfer delay (D_T) performance of UDD144 in Figure 3; Effect1 at mid offered-loads and Effect2 at higher offered-loads.

The P_{unsat} performance for speech, Figure 1, gives an idea of how strong the bias is in favour of CSW services. Here we observe that in mixes with a higher UDD144 component speech performs better over most of the observed range, suggesting that CSW speech calls are not exposed excessively to the higher UDD144 interference. This is because a CSW call is only exposed to interference from a PSW session when there is an ongoing packet transmission at the instant the CSW call is requesting call/handover admission.

At light loads, where the number of ongoing packet transmissions are few, the UDD144 interference as perceived by CSW speech services is light and the CSW services benefit from their higher access priority. However, at the mid-offered-load region, the performance of speech in all the mixes appears to converge. Here UDD144 interference to CSW services is becoming high due to a significant number of ongoing packet transmissions and cancels the effect of the implicit priority. Beyond this region the performance of speech in the mixes diverges again according to Effect2. In this high offered-load region, the bias in favour of CSW services has taken its toll on UDD144 performance. With the number of CSW services requesting admission now so high, connected UDD144 sessions having lower priority rarely get a chance to transmit, and CSW calls experience less of the higher UDD144 interference. Thus, in this region, the UDD144 UE buffers become full, with a large number of packets lost due to encountering a full buffer (Figure 4) and the loss increases with increasing offered-load.

In the high offered-load region, we observe that the gradient of the P_{unsat} performance for CSW speech lessens ('flattens-out') with increasing offered-load, as the interference contribution from UDD144 lessens with increasing UDD data loss.

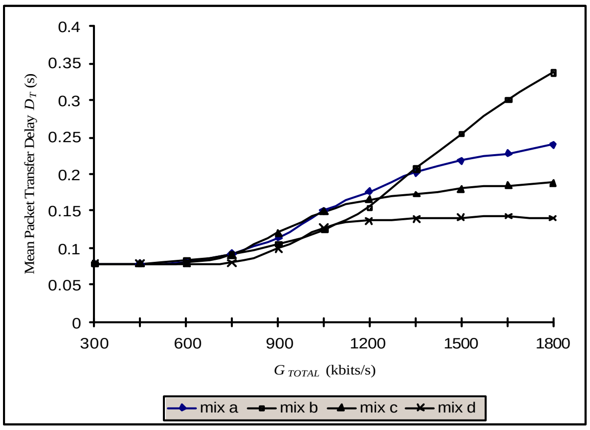

Figure 3: *Mean packet transfer delay (D_T) versus total cell-area offered load (G_{TOTAL}) with shadow fading*

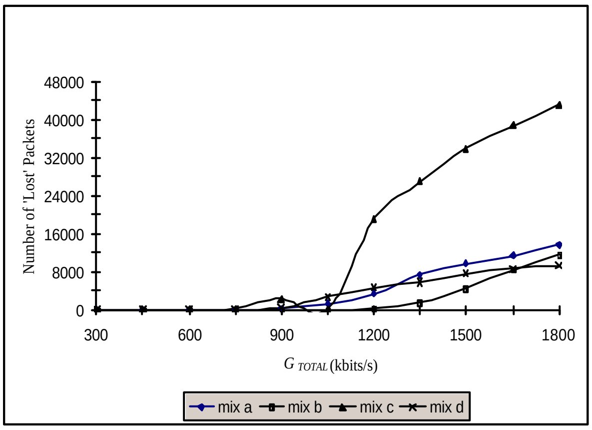

Figure 4: *Number of 'lost' packets versus total cell-area offered load (G_{TOTAL}) with shadow fading.*

The impact of the implicit priority, i.e. Effect 1, on UDD144 performance can also be seen from the 'lost' packet performance in Figure 4. Here we would expect that the number of UDD packets lost in any mix will be related to the partial offered-load, which differs from mix to mix. The mix with a higher partial offered-load will lose a higher number of packets at very high offered-loads, and in support of this, we observe that more packets are lost in mix 'c', at high loads than in mix 'a', and that there is more loss in mix 'a' than in mix 'b'. However, mix 'd' appears out of place exhibiting the most moderate gradient of rise in lost packets with increasing G_{TOTAL}. The presence of CSW services in mixes 'a' to 'c', and the higher priority offered by RRM to the CSW services, is responsible for the steeper slope of rise in the number of lost packets in these mixes than in mix 'd', which contains no CSW component.

It is worth noting, that under high-loads packets are also lost (or rather dropped) from the UE buffer, when their access-requests are timed-out, however this is negligible compared to those lost because of meeting a fully occupied UE buffer. Packet data lost from failed retransmissions are not considered here; since these blocks having being involved in previous transmissions contribute to interference in the system, unlike the two other causes of packet data loss.

4. Conclusions

It has been shown that in a mix containing both CSW and PSW services, the network capacity will be limited by the QoS performance of the CSW component. It was observed that the main cause is that CAC policy for CSW services is too restrictive. A possible solution to mitigate these problems could be to queue new CSW calls for a reasonably small amount of time if immediate call admission is not possible. Small delays may not be annoying to the user as opposed to frequent busy signals. Alternatively, another solution my exist in a QoS measure based admission policy, which attempts to balance the P_{unsat} performance of all services in the mix, by using short-term measurements of P_{unsat} to decide on the priority of admission.

References.

[1] 3GPP, "Technical Specification Group Services and System Aspects, QoS Concept (3G TR 23.907 version 1.3.0)", 1999

[2] ETSI SMG2, "Updated Annex C of ETSI's RTT Proposal", Tdoc SMG2 UMTS-ITU 62/98, 14-15 September, 1998

[3] ETSI SMG2, "Universal Mobile Telecommunications System (UMTS); Selection Procedures for the Choice of Radio Transmission Technologies of the UMTS", ETSI Document TR 101 112, version 3.2.0, 1998.

[4] Gudmundson, M., "Correlation Model for Shadow Fading in Mobile Radio Systems", *Electronics Letters*, Vol. 27, No. 23, November 1991.