Admission Control at UMTS Spectrum Sharing

Anders Dahlén and Andrés Alayon-Glasunov
TeliaSonera Mobile Networks R&D, Mårbackag. 11, 123 86 Farsta, SWEDEN.
E-mail: {Anders.Dahlen | Andrés.Alayon}@teliasonera.com.

Abstract: **This paper studies admission control algorithms effect on capacity and QoS fairness between operators that share UMTS spectrum. We compare some admission control algorithms for mixed packet switch and circuit switch traffic by simulating a hot spot scenario. A new algorithm achieves the best result.**

1. INTRODUCTION

There is a growing interest in network sharing concepts. New models for business aspects as well as resource management for shared wireless networks can be found in e.g. [1]. Network-sharing is interesting for reducing cost when building coverage and gives capacity gains at high loads, especially in hot spot areas.

3GPP Release 6 introduces enhanced network sharing support [2] in UMTS. The Release 6 3GPP standard gives two possible architectural network sharing configurations, Gateway Core Network (GWCN) and Multi-Operator Core Network (MOCN). In GWCN the operators shared MSC/SGSN as well as RAN. In MOCN the operators have separate CN nodes, and only share RAN. In a Release 6 UE the user is able to select among operators in a spectrum network-sharing configuration. This is achieved by broadcasting several PLMN identities. For a pre-release 6 UE the network "selects" core network operator among the sharing operators. 3GPP Release 6 introduces a rerouting mechanism in an MOCN configuration. This means that the SRNC can redirect a pre-release 6 UE to another core network operator if registration fails. In a GWCN configuration the shared MSC/SGSN determines which operator the pre-release 6 UE shall register to.

Sharing spectrum between operators implies large requirements on radio resource management to achieve a high capacity. Furthermore, operators sharing network will require QoS fairness and/or fair distribution of radio resources among the operators. Therefore, this paper investigates capacity and QoS fairness between operators that share UMTS spectrum. Several admission control algorithms are proposed and compared by simulating an indoor traffic hot spot scenario with mixed PS and CS services.

2. SPECTRUM SHARING

Sharing spectrum can be very attractive. For example, in rural areas UMTS coverage can be offered with much lower investment costs, and in urban and hot spot areas capacity gains can be achieved. A UMTS FDD capacity gain of 28-49% speech and video Erlangs is claimed in [3], when two operators have one dedicated carrier each and two shared carriers compared to when the operators have two dedicated carriers each; see Figure 1. This capacity gain is due to the increased trunking efficiency as channels are pooled together between the operators.

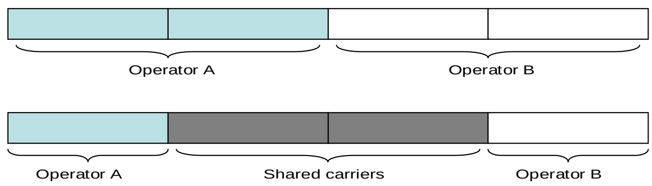

Figure 1 - Shared network scenario studied in [3].

When operators share spectrum fairness of resource allocation can become an issue. For example, a service request from a customer of operator B might be rejected because operator A uses all radio resources. In [3] it is suggested to share the power equally between the operators. Hence, operator A and B will only be allowed to use half of the power resources each. Even if two operators have approximately an equal amount of traffic generated by their customers during a day, week or year, the relative load at busy hour may be different. Moreover, sharing the power equally between the operators will give an inefficient capacity usage, since a customer of operator A may be prohibited from service even if there are radio resources, assigned for operator B, available. Hence, some trunking gain is lost.

The trunking gain lost on the speech capacity can be estimated by using the Erlang B formula. This formula gives the probability that all servers, N, are busy for the traffic intensity ρ. Hence, this is the probability of blocking a user that arrives to the cell. The Erlang B formula is

$$P(N) = \frac{\frac{\rho^N}{N!}}{\sum_{n=0}^{N} \frac{\rho^n}{n!}} . \qquad (1)$$

Assume 100% speech service and that the UMTS access in a cell is a queuing system with 50 servers and no waiting line. At 40 Erlangs, i.e., 20 Erlangs to each operator, we get 2% grades of service (blocking). At half number of servers, i.e.

25, we get 17 Erlangs to each operator at the same grade of service. Hence, dividing half power to each operator gives a capacity drop of 15%. An operator gains in allowing the other operator to use his half of the resources if he in return is allowed to use the other operator's half of the resources. Dividing half the power to each operator does not give a Pareto efficient solution [4], i.e. both operators will be better off by not dividing the resources in between them.

What happens if one operator has 50% more load than the other operator? If the 50 servers are not divided between the operators they would share 40 Erlangs and in average operator A can have 0.6*40 = 24 Erlangs and operator B 0.4*40 = 16 Erlangs. If the servers are divided as 30 servers for operator A and 20 servers for operator B, at 21 Erlangs respectively 13 Erlangs operator A and B gets 2% grades of service. Hence, capacity drops about 12% for operator A and 19% for operator B. Assume instead that 25 servers are dedicated for each operator. If operator A has 24 Erlangs and operator B has 16 Erlangs, the grades of service will be around 10% for operator A and 1% for operator B. Without dividing the resources between the operators both operators would get 2% grades of service.

Here we will assume that two operators share an UMTS carrier in a hot spot area. In this shared network study we consider a mix of CS (speech) and PS (HTTP) traffic, whereas [3] studied CS (speech and video) traffic only. The shared network system level simulator described in [5] is used for this purpose. We focus on admission control algorithms affect on capacity and QoS fairness between operators. A reference admission control method is used. It does not address any network sharing aspects, but only performs ordinary admission control for the purpose to achieve a good QoS. Three admission control methods, which allow some operator resource usage control, are tested. Two of the methods use the scheme to divide the power usage between the operators. The third method is a new method proposed here. It uses the bit rate elasticity of TCP flows in an attempt to achieve a fair QoS between the operators.

3. ADMISSION CONTROL

Admission control is performed on OVSF code usage and power usage. Hence, service requests are blocked if the OVSF code usage or power usage of a cell excides a limit. The following admission control method is applied to guarantee a good QoS.

Bit rate elasticity: If total OVSF code usage or total power usage of a cell excides a limit at a service request, allow reduction of bit rate of already allocated radio links. Deny a service request when OVSF code usage or power usage of a cell excides the limit even if bit rate of already allocated radio links would be reduced.

This method is used as a reference method when comparing the simulation results. It should give a rather fair distribution of bit rate between the users. However, utilisation of resources may be unfairly distributed among the operators. At block of service requests we never reduce bit rate of allocated radio links below the bit rate of the service request. At power block of speech requests we allow reducing bit rate of dedicated PS radio links to 64 kbps.

3.1 Shared network admission control

To cope with the shared network fairness issue we will in addition to the method above add some further admission control mechanisms. The here studied admission control algorithms can somewhat simplified be described as following below:

1. Half power: Let each operator use half the power that the limit in the QoS admission control algorithms above allows. Hence, deny a service request of an operator A customer if the power usage in the cell for that operator excides the limit divided by two. The QoS admission control check follows if the request passes this check. See Figure 2.

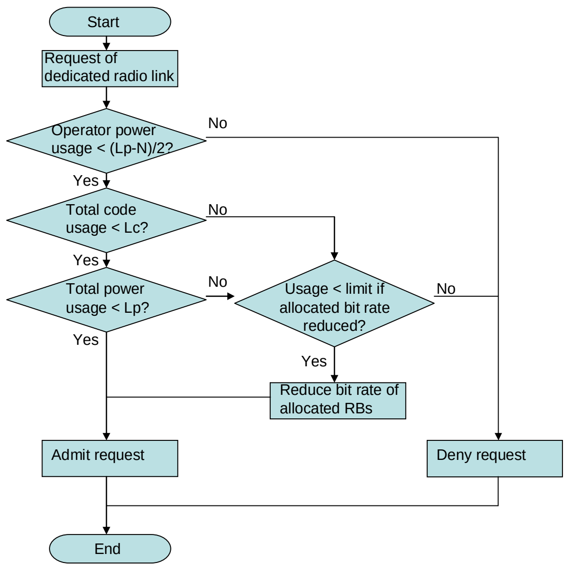

Figure 2 - Admission control algorithm 1.

The idea of the "half power" method is to make sure that resources are available for an operator that uses little radio resources. A service request from operator A is denied if operator A uses more than half the power resources. In this way there will be radio resources available for operator B when its customers make a service request.

2. Bit rate elasticity with operator usage comparison: When trying to reduce the bit rate of already allocated radio links in the QoS admission control algorithm, radio links belonging to

the operator that uses at the moment most radio resources are primarily targeted. See Figure 3.

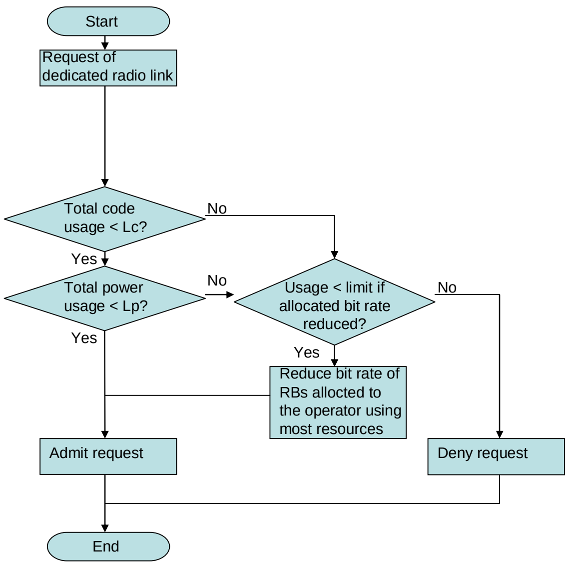

Figure 3 - Admission control algorithm 2.

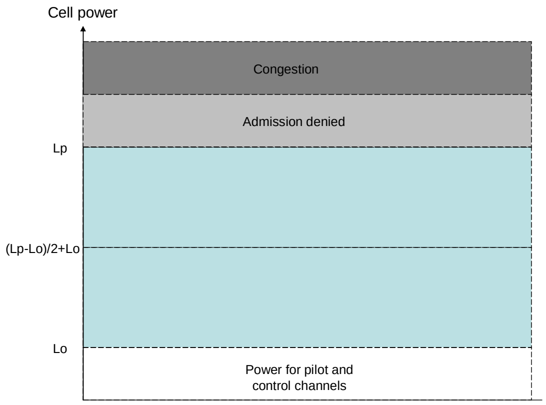

Figure 4 - At the highest cell power level congestion prevails, radio links are removed and all service requests are denied. At the second highest cell power level admission control might deny service requests, or reduce bit rate of allocated radio links. If "half power" scheme is applied, admission control might deny a service request of an operator that uses more power resources than (Lp-Lo)/2.

The idea of the "bit rate elasticity with operator usage comparison" method is to admit service requests of operator A and B as long as a good QoS can be guaranteed. If a customer requests a service and all resources are allocated, bit rate of allocated radio links may be reduced. Firstly, the bit rate is reduced for radio links used by the operator that for the moment uses most radio resources. Secondly, the bit rate is reduced for other radio links. This ought to give a fair distribution of bit rate. In principal, this method allows operator A to borrow resources from operator B, which are not used, and vice versa. Once operator B needs its resources, operator A have to give it back. However, since we do not remove radio links of the operator that uses most resources but only reduce the bit rate of interactive radio links, operator B might not get all resources back.

4. CONGESTION & COVERAGE CONTROL

The simulator is provided with congestion and coverage control methods that removes allocated radio links. The congestion control removes radio links if the total power excides a certain limit, and the coverage control removes a radio link if it requires more power than the maximum allowed power for that radio link type. The congestion control prioritises to remove PS radio links over CS radio links. A principal sketch of the threshold based admission control and congestion control is given in Figure 4.

5. QoS MEASURES

The QoS quantities studied here are: CS and PS blocking, CS dropping and PS average bit rate per file. A CS block is registered if a CS service request is not admitted by the admission control (no queing line is applied). A CS drop is registered when congestion or coverage control removes a CS radio link. For each file transfer the bit rate is derived and the average bit rate is registered. The PS service is assumed to be elastic, and if admission control denies a PS service request that service request is queued. A PS blocking is registered for each 10 seconds that a PS service request is queued. Moreover, if the congestion or coverage control removes a PS radio link the UE makes a new request of service, which might be queued. Started file transfers are then retained from where it was interrupted. No PS drop is registered. In practise the TCP session may timeout if the queuing delay is to long. Here we get a lower registered bit rate and registered blocks.

6. SIMULATION RESULTS

The following assumptions are made in the simulator: We assume zero delay for switching down bit rate of allocated radio links and for setting up new radio links. Since TCP traffic is bursty, an allocated PS radio link is removed first when it has been inactive for 1 second.

The studied scenario is a hotspot cell where the other-to-own cell interference ratio (I-factor) distribution is such that there is a high probability for a terminal to get a low I-factor compared to a normal urban cell scenario. This means that the studied cells can carry higher load than normal urban cells. In the simulation there are two operators with equal offered load. A simulation where the operators have unequal offered load can be found in [7]. The traffic is speech and HTTP only. Of the offered load in Bytes 25% is speech and 75% is

HTTP as described in [6]. This traffic mix gives a high possibility to utilize the bit rate elastiticity of TCP flows to achieve good speech QoS and flexibility to allocate a rather fair resource distribution among the operators. At other scenarios the results may be different.

No CS droppings have been registered in the simulations, which is not surprising because at congestion there is always a PS radio link to remove and the speech radio link's maximum power is set high. In a simulator with mobility etc dropping will probably occur.

The results are normalised with the result received when applying only the QoS admission control. Algorithm 1 is the method that blocks a request if an operator uses more than half power, algorithm 2 is the method that reduce bit rate of radio links allocated to the operator that uses most resources. We expect that the CS blocking will be high for algorithm 1 when applying blocking of speech requests at half power. Therefore, we divide algorithm 1 into

a) applying speech and HTTP blocking at half power

b) applying HTTP blocking at half power only.

The result of the simulation is displayed in Figure 5. The result is an average of a few busy hour simulations. CS blocking, PS blocking and bit rate is shown for the two operators when applying the different admission control methods. See Figure 6 for a clearer view on the received bit rates.

We see that CS blocking becomes very high when speech requests are blocked when an operator uses half power, i.e. when algorithm 1a is applied. The CS blocking becomes around 11% which is unacceptable. When only HTTP requests are blocked at half power operator usage, i.e. when algorithm 1b is applied, the CS blocking is similar to the reference method. For algorithm 2 the CS blocking is somewhat higher than the reference method but still at acceptable 2%. The higher CS blocking of algorithm 2 is probably due to the fact that this method gives a better PS service than the reference method.

The PS blocking gives a different blocking pattern due to the queuing of HTTP requests. For algorithm 1a and 2 the PS blocking is lower than for the reference method and the bit rate is higher than for the reference method. For algorithm 1b, blocking only HTTP requests at half power, the PS blocking is almost doubled compared to the reference method, and the bit rate is about the same as the reference method. The reason why algorithm 1a gives a better PS QoS that algorithm 1b is most likely due to algorithm 1a blocks much more of the speech requests, which makes more resources available for PS services.

Due to the high CS blocking, algorithm 1a is not an attractive method even if PS QoS is satisfying. For algorithm 1b it is difficult to see any gain compared to the reference method. It gives a much worse PS blocking than the other methods and the PS blocking is high already for the reference method. Potentially, it might give good fairness, which we will study in the end of this section. Algorithm 2 gives a worse CS blocking than the reference method but a much better PS blocking and a higher bit rate. We believe that by lowering the admission control thresholds for PS requests, it is possible to reduce the CS blocking and at the same time increase the PS bit rate and PS blocking. In such case, algorithm 2 would clearly be better than any of the other methods. Since the PS blocking is high for the reference method and CS blocking low, whereas algorithm 2 gives an acceptable CS blocking and a low PS blocking, algorithm 2 seams preferable. Moreover, algorithm 2 gives a higher bit rate and some control of the resource usage between the operators. It is clear that algorithm 2 is much better than algorithm 1a.

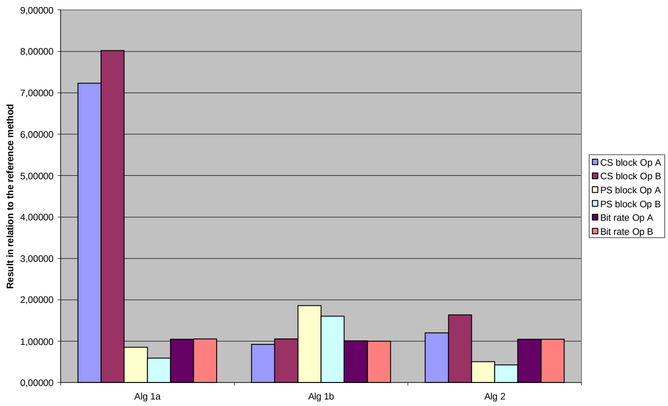

Figure 5 - CS blocking, PS blocking and bit rate when two operators have equal offered load.

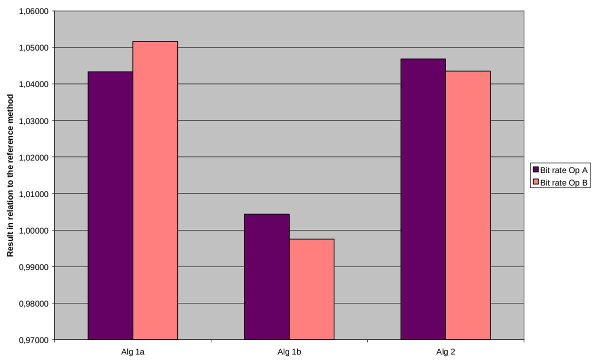

Figure 6 - Bit rate at equal offered load.

In the simulation above the operators has equal offered load and the admission control algorithms tries to divide the radio resources fairly among the operators. Next we also estimate the fairness. As a fairness measure we use the standard deviation. First we compute the difference between operator A's and operator B's QoS in each simulation. The standard deviation of these values is determined, which is normalised by the average mean QoS of the two operators, i.e.:

$$fairness = \frac{std(|x_i^A - x_i^B|)}{[mean(x_i^A) + mean(x_i^B)]/2}, \qquad (2)$$

where std() is the standard deviation, mean() is the average value, and x_i^A is received QoS value for operator A at sample *i*. Finally, the results displayed in Figure 7 are normalised with the result received when applying only the QoS admission control, i.e. the reference method. A value below one indicates better fairness than the reference method, and a value above one a worse fairness than the reference method.

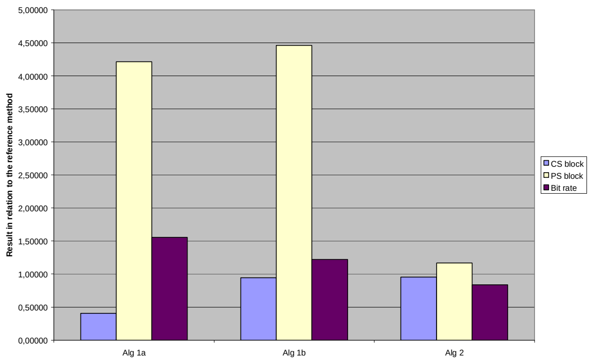

Figure 7 - Fairness between operators; Low value indicates high fairness.

Algorithm 1a is the only method that applies a half power blocking on speech requests. This method is also the only method that achieves essentially better fairness of the CS blocking. Algorithm 1b and 2 indicates a somewhat better fairness than the reference method. This is difficult to explain from theory, and potentially the difference compared to the reference method is within margin for error. All methods do have difficulties in achieving fairness on PS blocking rate, especially algorithm 1a and 1b. The PS blocking varies much more than the other QoS quantities, why algorithm 2's fairness value is probably comparative with the reference method. The reason to a poor fairness of algorithm 1a and 1b might be because we do not apply bit rate switching of allocated radio links at a half power blockings. The bit rate is only fairer for algorithm 2 compared to the reference method. This is also what algorithm 2 aims at achieving.

In conclusion algorithm 2 achieves the best fairness, but none of the methods achieves any impressively higher fairness than the reference method, which does not apply any network sharing admission control mechanism at all.

7. CONCLUSIONS

We have studied admission control algorithms effect on capacity and QoS fairness between operators in a shared UMTS network. We have considered two operators that share an UMTS carrier in a hot spot area. The service mix is 25% speech (CS) and 75% HTTP (PS) traffic of the offered load. Three admission control methods, which allow some operator resource usage control, have been tested. Two of the methods (algorithm 1a and 1b) use the scheme to divide the power usage between the operators. Algorithm 1a performs blocking of both CS and PS service requests at half power, whereas algorithm 1b only applies blocking of PS service requests. The third method (algorithm 2) is a new method proposed here. It uses the bit rate elasticity of TCP flows in an attempt to achieve a fair QoS between the operators. A reference admission control method has been used as well. It does not address any network sharing aspects, but performs ordinary admission control for the purpose to achieve a good QoS.

Due to high CS blocking, algorithm 1a is not an attractive method. It gives a poor capacity. The QoS fairness for PS service is also poor. For algorithm 1b, the PS blocking is high. Thus, also this method gives a poor capacity. It gives about the same bit rate as the reference method. The QoS fairness for PS service is poor even for this method. Algorithm 2 achieves the best fairness, but not any impressively higher fairness than the reference method. It also gives the best capacity, and the highest bit rate for PS services.

ACKNOWLEDGEMENT

This work has been performed in the framework of the project IST-EVEREST (www.everest-ist.upc.es), which is partly funded by the European Community. The financial support from the European Community of EVEREST project is much appreciated.

REFERENCES

[1] J. Hultell, K. Johansson, J. Markendahl, "Business models and resource management for shared wireless networks". In Proceedings IEEE Vehicular Technology Conference (VTC) fall, Los Angeles, CA, US, September 26-29, 2004.
[2] 3GPP TS 23.251: "Network sharing; Architecture and functional description".
[3] M. K. Pereirasamy, et. al., "An Approach for Inter-Operator Spectrum Sharing for 3G Systems and beyond". In Proceedings of the 15th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC'2004, Barcelona, Spain, Sept 2004.
[4] Microeconomic Theory, D. G. Luenberger, McGraw-Hill, 1995.
[5] EVEREST IST-2002-001858 D14 – "Simulation tools: final version capabilities and features".
[6] EVEREST D13 – "Target Scenarios specification: vision at project stage 2".
[7] EVEREST IST-2002-001858 D15 – "Report on the evaluation of RRM/CRRM algorithms".