PROVIDING QOS IN 3G-WLAN ENVIRONMENT WITH RSVP AND DIFFSERV

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Abstract: Here we present the end-to-end QoS mechanism in 3G-multiaccess network environment. As multi-access wireless WLAN and wired xDSL wideband multi-access technologies has emerge and become more popular a need for interoperability with different technologies and domains has become necessity. There is also a need for end-to-end QoS management. We show a scenario where the UE-GGSN connection is covered by RSVP and RAN network part uses partial over dimensioning and real-time controlled ATM queuing. DiffServ covers WLAN-Core QoS and radio interface between WLAN AP and WLAN UE uses IEEE's 802.11e. Our interest is to find out how well 3G traffic classes can survive in different traffic conditions in the end-to-end case.

1 INTRODUCTION

With the evolution of QoS-capable 3G wireless networks, the wireless community has been increasingly looking for a framework that can provide effective network-independent end-to-end QoS control. One bigger problem arises with this kind of diverse networks. It is the dissimilarity of traffic characteristics and QoS management methods. Problem with WLAN networks is the high error rate probability. 802.11e standard has been applied trying to correct the situation by enabling the use maximum of eight separate priority queues for prioritizing higher priority traffic compared to other traffic [802.11e]. QoS supported WLAN uses the Enhanced Distributed Coordination Function (EDCF). It is the basis for the Hybrid Coordination Function (HCF) [802.11e]. Our research is also related to 3GPP WLAN interworking standardization [TS23.234].

RSVP has been used in domains where there is no direct radio interface. In the RAN case we have assumed that the radio interface between BTS and UE in RAN will be handled similarly to WLAN but with different methods defined by 3GPP standardization. As RAN is based on ATM the basic assumption has been that the RAN correctly dimensioned to carry al traffic coming from and going to UE direction so by default RAN QoS is out of scope of scenarios in this paper.

This research is part of the 3G–WLAN Interworking research program made during years 2002-2004 [Wallenius E., Hämäläinen T., Nihtilä T., Luostarinen K.] and [Hämäläinen T., Wallenius E., Nihtilä T., Luostarinen K.]

2 MAPPING QOS ATTRIBUTES TO CROSS DOMAIN INTERFACES

3GPP has defined four traffic (QoS) classes and three subclasses (Interactive THP, Traffic Handling Priority) that can have their own QoS attributes [TS 23.107]. All traffic in the 3G network will be handled according to the operator and service's requirements at the each of these traffic classes. The main QoS method to be used at the core network is supposed to be DiffServ [TS22.934]. Addition to that 3GPP has defined RSVP as an additional UE originated QoS method [TS23.917] in Rel6 between

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UE-SGSN and GGSN. It can be used at the situations where scalability problems will not arise (small networks). 3G traffic classes are: Conversational class for voice and real-time multimedia messaging. Streaming class for streaming applications (Video On Demand (VOD) etc.), Interactive class for interactive applications (eCommerce, WEB-browsing, etc.), Background class for background applications such as email and FTP. QoS values for each traffic classes are defined in [TS23.107]. In DiffServ domain four priority queues can be implemented for the each 3G traffic classes. The three THPs (Traffic Handling Priority) are also available for Interactive class to further sub-classify Interactive class traffic by inserting it to three separate queues. 3G to DiffServ mapping process can be policy based controlled and the mapping can be indicated at the IP level by the DSCP (DiffServ Code Point) inserted to the TOS field by DS classifier/marker mechanism or by the actual application that generates the control plane traffic. Table 1 shows the PHB actions with DSCP mappings.

The nature of RSVP functionality differs significantly from DiffServ. RSVP uses end-to-end signaling enabling a single UE to reserve end-to-end transport capacity from the network or RSVP can be used by Bandwidth Broker and COPS-PR protocol to set appropriate traffic filters to routing nodes to achieve similar capacity reservation than by UE signaling.

3 SIMULATION ENVIRONMENT AND PARAMETERIZATION

The goal is to study what are throughputs, delays and dropping rates in RSVP and DiffServ cases. Simulation environment in Figure 1 consists of 18 Access points which each connected to UEs with different traffic priorities. Six core network nodes build up a ring and each of them has three access points. WLAN stations send data at the rate of 2.5Mb/s. Stations no. 1 and no. 3 generate CBR traffic and stations no. 2 and no. 4 send VBR traffic. The stations start sending at time interval 3-4.5 seconds randomly. Simulation time is 40 seconds and the used packet size is 1000 bytes for all stations..

Table 1: RSVP parameterization

3GPP Traffic class	Bandwidth Mb/s	Bucket size bytes
Conversational	3.0	3000
Streaming	2.5	2000
Interactive (3 THPs)	2.0	1500
Background	2.0	1500

UEs for AP 1-9 are sending and 10-18 receiving. Available bandwidth within the core network was 8 Mb/s.

In the core network all wired capacity was reserved for RSVP use and best effort queue size was 5000 bytes in every node.

We used traffic parameterization shown in Table 1.

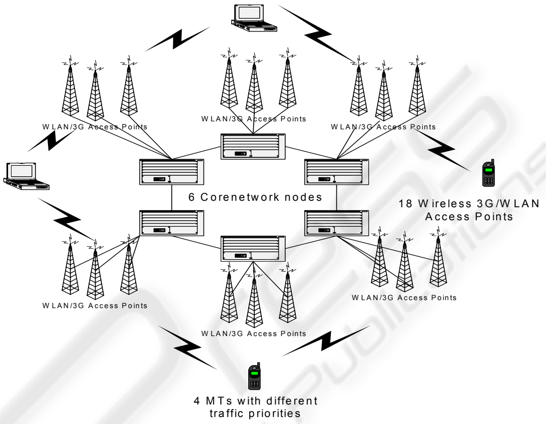

Figure 1: Simulation environment

As link capacity is small compared to number of reservations some of the reservations does not success and traffic related to them goes in the network as best effort traffic. RSVP uses WFQ queuing. DiffServ uses Token Bucket Polices and its parameterization is presented in Table 2.

Table 2: DiffServ token bucket parameterization

3GPP Traffic class	CIR Mb/s	Bucket size bytes
Conversational	3.0	3000
Streaming	2.5	2000
Interactive (3 THPs)	2.0	1500
Background	2.0	1500

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DiffServ uses RED queuing in drop tail mode. In-profile packet queue lengths are 30 packets for each class and out-of-profile packet queues are 60 packets long.

We used four priority levels in both scenarios. EDCF parameters of different Traffic Classes are shown in the following Table 3.

Table 3: EDCF parameters

3GPP Traffic class	Conv.	Stream	Interact.	Backgr.
CWMin	7	10	15	127
AIFS (CWOffset)	2	4	7	15
CWMax	7	31	255	1023

To emulate the process of packet transmission errors we extended the simulator by implementing a two-state Markov model in the air interface. In our error scenario, the channel switches between a "good state" and a "bad state", G and B respectively: Packets are transmitted correctly when the channel is in state G, and errors occur when the channel is in state B. When the channel is in state G, it can either remain in this state, with probability ω_1 or make the transition to state B, with probability 1-ω_1. Likewise, if the channel is in state B, it remains in this state with probability ω_2 and changes state with probability 1-ω_2.

Table 4: Transition probabilities for 2-state MMPP

Error rate	ω_1	ω_2
0%	0	1
20%	0.16	0.63

All test were done with network simulator NS-2 with IEEE 802.11 EDCF functionality implemented by Project-INRIA [Ni Qiang]. We ran several different error rate scenarios but we find 0 and 20% error rates most illustrative.

3.1 Scenario 1: RSVP case

3.1.1 RSVP throughputs

As can be seen in Figure 2 Interactive class has higher throughput than Streaming class.

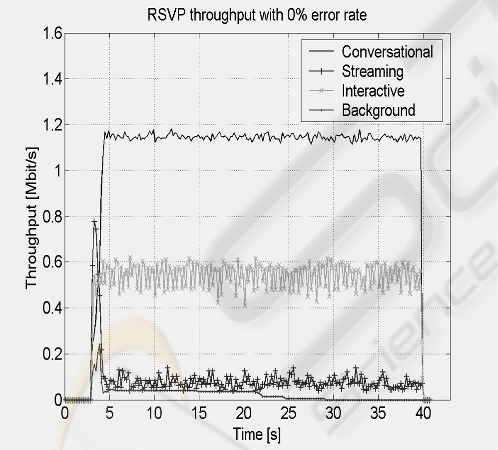

Figure 2: RSVP throughput with 0% error rate

This is caused by the random nature of reservation signalling.

The reservation probabilities are shown in Table 5.

In case that there is already 6Mb/s reservation for two Conversational class flows only Interactive and Background classes can reserve the rest of the bandwidth.

Other traffic characteristics follow very well expectations on throughput delay.

Table 5: Reservation probabilities

Mb/s	**Conv.**	**Stream**	**Interact.**	**Backgr.**
8	0.25	0.25	0.25	0.25
6	0.25	0.25	0.25	0.25
5.5	0.25	0.25	0.25	0.25
5	0.25	0.25	0.25	0.25
4	0.25	0.25	0.25	0.25
3.5	0.25	0.25	0.25	0.25
3	0.25	0.25	0.25	0.25
2.5	0	0.33	0.33	0.33
2	0	0	0.5	0.5
Average	0.194	0.231	0.287	0.287

Throughput is best and delay follows the throughput being higher than in other classes due to the high throughput.

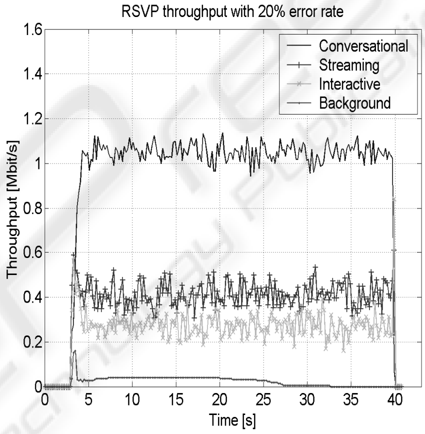

Figure 3: RSVP throughput with 20 % error rate

Also can be seen in Figure 2 and Figure 1 that the traffic flows are smoother in lower error environment.

Average throughputs on each traffic class also follow well our expectations. Throughputs are in preferable order, Conversational highest and background lowest.

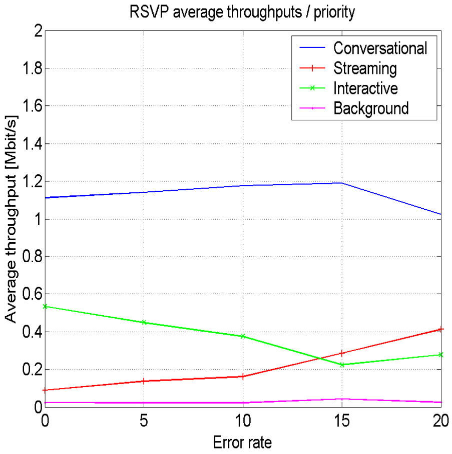

Figure 4: RSVP average throughputs / priority

Figure 4 shows also slight rise of throughput in Interactive class and corresponding declining in Background class for higher error rates. This can be caused by differences in reservation success between classes.

3.1.2 RSVP Delays

Delay behaviour is similar as throughput. All aggregate flows, traffic classes, are in correct order and delay is adequate low (< 0.5 ms) in both Conversational and Streaming class for their 3G usages. Also Interactive and Background classes are far below their worst-case scenario values, several seconds. See Figure 5 and Figure 6.

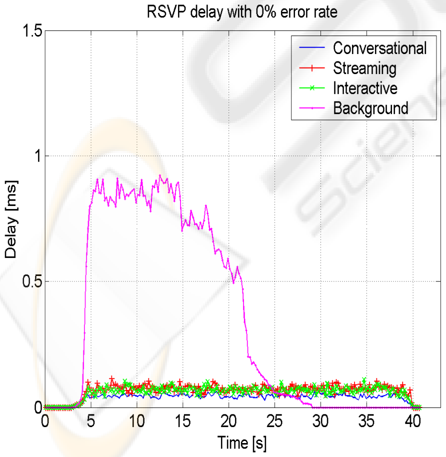

Figure 5: RSVP delay with 0% error rate

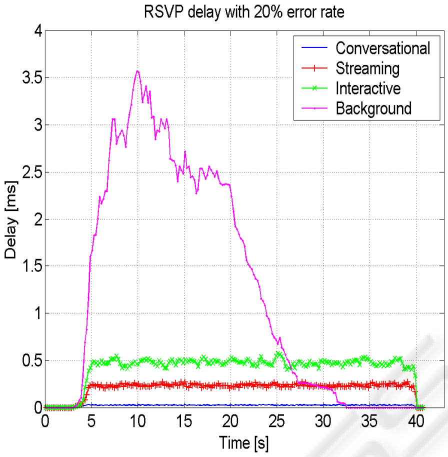

Figure 6: RSVP delay with 20% error rate

3.1.3 RSVP packet dropping

RSVP packet dropping follows the throughput being higher in higher throughput classes as expected. In this case a better describer for packet dropping would probably be percentage value, which would turn the order of curves into opposite order.

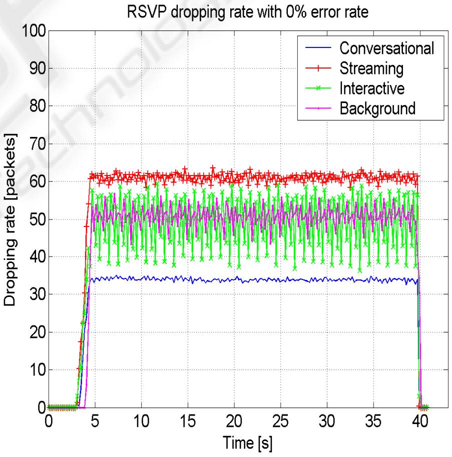

Figure 7: RSVP dropping rate with 0% error rate

Dropping rate is very stable when the dropping rate is 0% Figure 7 but becomes unstable and rising with error rate 20%.

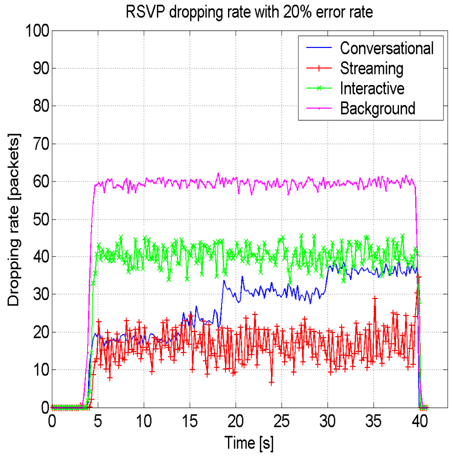

Figure 8: RSVP dropping rate with 20% error rate

3.2 Scenario 2: DiffServ case

3.2.1 DiffServ throughputs

DiffServ show different kinds of throughput results than RSVP. Conversational traffic is dominant and other traffic classes are very close to nil. The obvious difference is that RSVP has much better control over lower priority flows and therefore it would be a better solution for Interworking QoS control purposes.

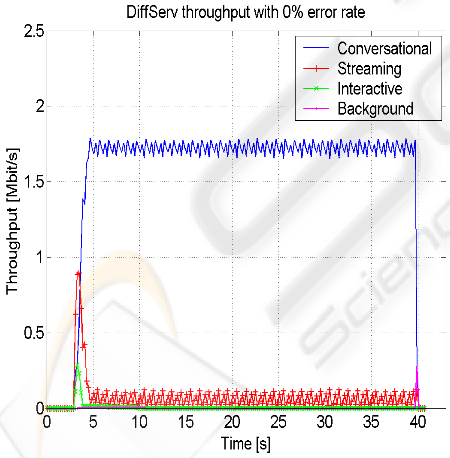

Figure 9: DiffServ throughput with 0% error rate

As can be seen form Figure 9 traffic with priorities 3 and 4 disappears within 10 seconds after beginning of the test. This means also that the delay for priorities 3 and 4 becomes 0 (zero), as there is no traffic in priority classes 3 and 4 as shown in next chapter.

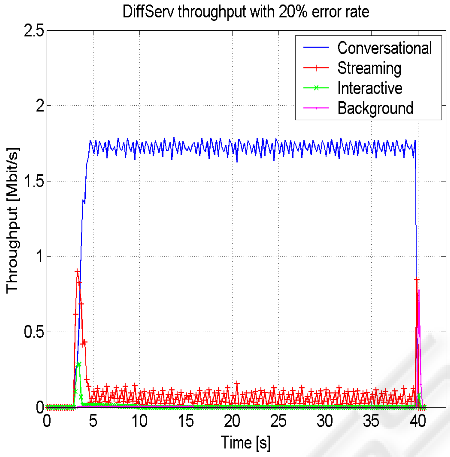

Figure 10: DiffServ throughput with 20% error rate

Difference between throughputs with 0% and 20% error rate is significantly low.

Figure 11 shows that the average throughputs of the classes are the same between different error rates. This indicates that throughput behavior is very stable when using DiffServ in opposite to RSVP, which causes large variations in class throughputs between error rates.

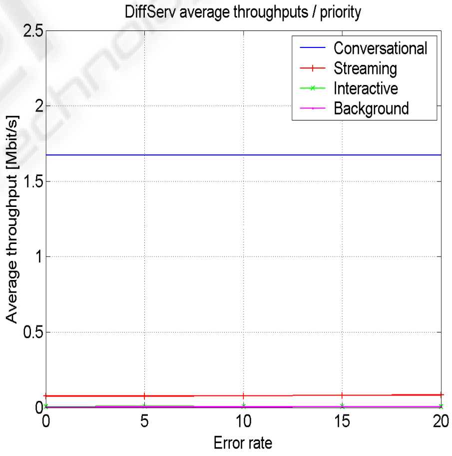

Figure 11. DiffServ average throughputs / priority

Still, this stable behavior is achieved in cost of lower priority class throughputs, which are close to zero.

3.2.2 DiffServ delays

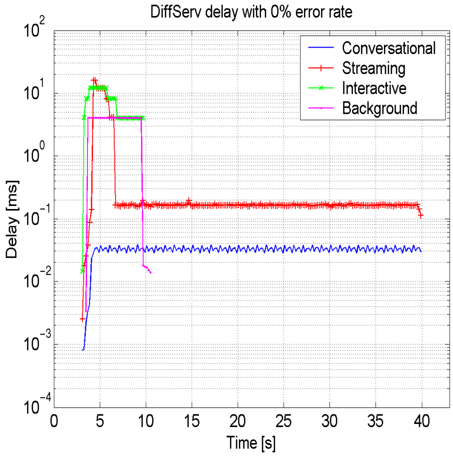

Figure 12: DiffServ delay with 0% error rate.

As presented in Figure 12 the delay for flows with priorities 3 and 4 become zero (vanishing from logarithmic scale). This actually means that after a few seconds after stations have started to send flows with priorities 3 and 4 are not reaching their target receiver node but are totally dropped during transmission. Similar effect occurs with 20% error rate in Figure 13.

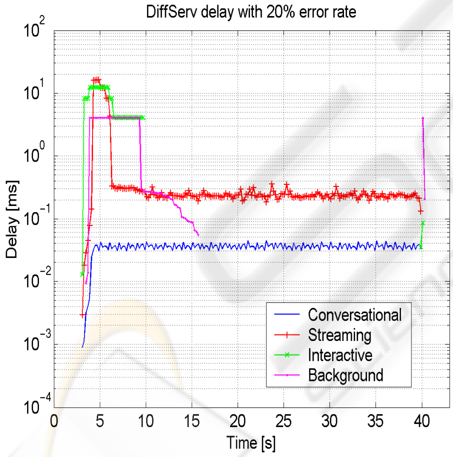

Figure 13: DiffServ delay with 20% error rate

3.2.3 DiffServ packet dropping

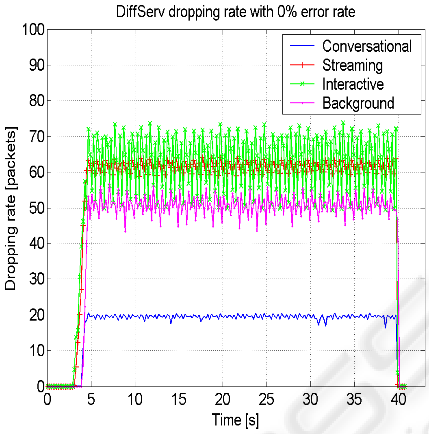

Figure 14: DiffServ dropping rate with 0% error rate.

As shown in Figure 14 dropping rates are located as could be predicted according to their priorities.

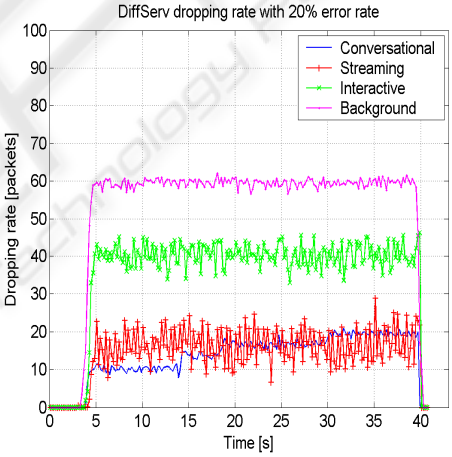

Figure 15: DiffServ dropping rates with 20 % error rate.

Naturally as presented in Figure 15 increased error rate increases dropping rate accordingly. High air interface error rate affects the dropping rates, so that there seems to be lower dropping rate in 20% error rate scenario. As the air interface corrupts packets, fewer of them reach the wired network. Hence, there is smaller probability of congestion in the wired network.

3.3 Test conclusions and recommendations

3.3.1 Combined throughputs

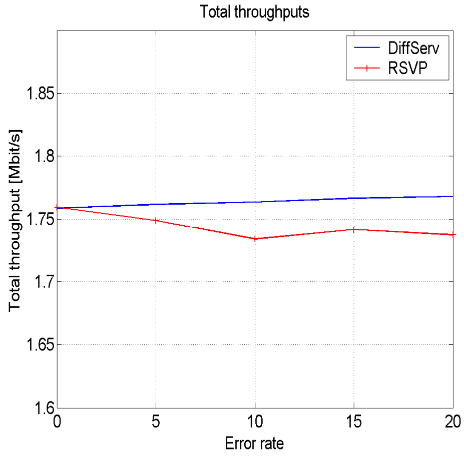

Figure 16: Comparison of total throughputs with RSVP and DiffServ

Figure 16 shows that the throughput in DiffServ case is slightly better than in RSVP case. That is expected due to the resource reservation nature of RSVP. In DiffServ case all traffic classes can have unlimited number of flows compared to RSVP's bandwidth limiting functionality and access control. The difference between these techniques is almost negligible due to the fact that both RSVP and DiffServ achieve the maximum capacity of the network. This is due to the amount of traffic in the network: the flows are sending traffic so intensively that there is always a demand of bandwidth for best effort traffic and hence the network is never idle.

4 CONCLUSIONS AND FUTURE WORK

4.1 Achievements

In this paper we provided architecture for end-to-end QoS control in a wired-wireless environment with effective QoS translation. We used DiffServ and RSVP in the core network and 3G/WLAN and 802.11e at the wireless part of the tests.

Results show clearly that RSVP can keep delays smaller than in the DiffServ case. Paper also shows that the best and most suitable combination of QoS control would be RSVP-802.11e hybrid. Suitability materializes especially in the control of lower priority flows enabling them more and more controllable bandwidth with lower and controllable delay.

4.2 Future Studies

Next we will expand our simulations to cover a real operating size network and study how the operating parameters can be tuned e.g. by using dynamic policy based management.

Also further development of 3G interworking with other access methods is gaining increasingly importance and to achieve solid and robust Interworking QoS is the next top research challenges for the future.

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