Reservation Based QoS Provision for Mobile Environments

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ABSTRACT. *With the fast adoption of IP-based communications for mobile computing, users are expecting a similar service in wireless and wired networks. This raises the need for setting guarantees to the quality of the offered service (QoS), despite the technology of the access network or the mobility of the terminal. This generates a new challenge for QoS provision, as it will have to deal with terminals changing their point of attachment to the network. In this paper an optimisation for the operation of reservation based QoS is given for mobile environments: the coupling of the reservation protocol RSVP with different per-host micro-mobility protocols. The micro-mobility and QoS signalling mechanism are coupled either loosely via a triggering mechanism, or more tightly so the QoS and mobility information is carried by the same protocol. Qualitative and quantitative results of this coupling are presented. The procedure includes the comparison of performance parameters such as delay, loss and throughput when protocols are coupled and de-coupled*

KEY WORDS: *QoS, micro-mobility, mobile networks, coupling, RSVP,HAWAII.*

1. Introduction

With the fast adoption of IP-based communications for mobile computing, users are expecting a similar service in wireless and wired networks. Multimedia applications, including Voice-over-IP (VoIP), require a predictable and constant forwarding service from the connecting network. Among the proposals to provide this treatment to flows, the de-facto signalling mechanisms for resource allocations are the Integrated Services [BRA 94] and the Resource Reservation Protocol (RSVP) [BRA 97]. These have been designed to provide explicit resource reservations on a per flow basis mainly in fixed networks.

Using these mechanisms for provisioning and maintaining QoS in the dynamic mobile environment raises some difficulties. While the mobile node can potentially change its point of attachment to the network many times during a session, the challenge is to maintain the original requested level of service as the mobile moves. This implies that the resource reservations set up with RSVP need to be rearranged after a handover.

In addition to the challenge of maintaining QoS after handovers between access points, there are other factors in mobile networks affecting the provision of assured QoS. As an example consider the frequent changes of IP-addresses due to Mobile IP (MIP) operation [PER 96], the variable quality of the wireless link and the contention of wireless link resources between mobile nodes.

So far, mobility and QoS mechanisms have evolved independent of each other. The standard RSVP refreshes can repair reservations on changed paths periodically, but it is unaware of the origin of the changed path. We propose to couple the mobility protocol with RSVP. This would allow a faster reservation set up after a handover and therefore would minimise the disruption caused to flows with reserved resources. Our simulation results will show that coupling the mobility protocol with the resource set up signalling decreases the disruption significantly.

In the text we implicitly refer only to soft-state mechanisms such as RSVP, although our discussion can be applied to hard-state mechanisms as well.

2. Protocol Coupling.

Reservation-based QoS implicitly assumes a fairly stable path across the network. When reservation are in place the changes in routes are only reflected in the reservation after a refresh message have passed along the new path, which can have a high latency from end-to-end from mobile to correspondent node. In the dynamic mobile environment performance is less than optimal. Refresh and soft-state mechanisms on reservation based protocols such as RSVP were originally designed to deal with broken links which seldom happen.

Advanced mechanisms such as RSVP Local Path Repair were designed to repair efficiently RSVP reservations after route changes, but does not work if the route change is not explicitly visible to the router through a change in its routing table. The most common mobility management protocols, such as MobileIP or Hierarchical MobileIP [GUS 01], do not provide this feature. Furthermore, because a routing change would always involve a mobile terminal being the divergence or convergence node (responsible for triggering or halting the local path repair process) this mechanism introduces an extra signalling overhead on the mobile terminal.

2.1 Cooperation between protocols.

The solution to the previous problem resides on the collaboration between mobility and QoS protocols. We can couple somehow the QoS signalling mechanisms with the underlying local mobility mechanisms. This collaboration or coupling can be designed in several ways although we can identify three major levels or ‘flavours’:

— **Not coupled at all**: This is the actual state, where both protocols are completely unaware of each other, apart from the external effects such as route change.

— **Loose coupling**: The triggering of some action inform a protocol about changes in the other.

— **Hard coupling**: Both mobility and QoS information are carried together by some mean, for example adding QoS information to the mobility messages. A clear example of this is INSIGNIA [LEE 00].

Selection of one of this options is a trade-off between applicability, complexity and performance. By maintaining the protocols unaware of each others we cannot take any advantage of particular properties of protocols so performance cannot be improved, although transparency is maintained. This allows a free and independent development of protocols. On the other side, the hard coupling has the possibility to achieve optimum performance at a higher cost in applicability and development as existing solutions have to be changed. In general a deep coupling among network elements is not a good design practice as it may collide with some of the architectural principles of Internet design such as layered approach and end to end design [CAR 96].

2.2 Loose coupling of QoS and mobility protocols.

The solution we propose for the mobile environment is loose coupling the QoS mechanism and the local mobility protocol. By enhancing the QoS mechanism for the mobile environment, local path repair is possible and changes to the reservation are localised to the area affected by the change in topology, with no processing or signalling load placed upon the mobile terminal.

In our ‘loose’ approach, a change in the position of the mobile node, and hence the actualisation of routing information in the network, triggers the generation of RSVP local PATH repair mechanism. This mechanism repairs only the part of a QoS reservation that is broken, which means that the reservation can be installed faster because end-to-end signalling is not required. The signalling must not be generated until there is path stability within the network. Implementation of this mechanisms implies changes in all nodes involved in the QoS provision using RSVP but not to the mobile node.

2.3 Complementary mechanisms.

In a mobile environment loose coupling provides an improve in performance but it may not be enough. There exist a number of mechanisms that complement the coupling:

QoS signalling priorization: Loose coupling provides a mechanisms where reservation can be installed as soon the new path is stable, allowing a better usage of resources and minimizing disruption when handover occurs. But if there is a heavy load in the new links and QoS messages are lost repeatedly then soft-state will timeout and data packets will fall to best-effort, so a QoS violation may occur. By prioritizing QoS signalling packets this effect can be minimized and the new reservation can be installed. This priorization can be performed with different mechanisms such as DiffServ [CAR 98] or just reserving a fixed amount of bandwidth with Class Based Queuing (CBQ)-like queues on routers [FLO 95]. If no resources are available (i. e. there are other reservations in place) then the reservation may not be reinstalled. This can be solved with in-advance reservation mechanisms such as MRSVP [TAL 98]. However, these are out of scope of this document.

On going packet priorization: We will call ‘in handover’ packets those belonging to a flow that have lost their reservation because of a change in the path due to a handover. That change makes them being routed through nodes that don’t have (yet) information about the reservation and hence are treated as best-effort.

Many modifications to RSVP for mobile have attempted to establish the reservation before the handover actually occurs. In this proposal we avoid doing this approach. Firstly, because not all handovers are planned and have the time to do this, secondly because of the signalling and processing overhead, and possible inefficiencies in use of network resources which are inevitable as the new route can not be determined until after the move. Therefore we need a way to handle traffic that temporarily does not have any reservation. Priorization of these packets provides a mechanism for reservation–based handover traffic to access guard bands of bandwidth, reserved purely for high priority handover traffic. Priorization of on-going data that has to be tunnelled to the new destination provides improved QoS without requiring that short-lived reservations (which produce processing and signalling overhead) need to be established [BUR 01].

This mechanism can also be used in reservation procedures that are installed hop by hop within the network and that are affected by mobility. It allows the traffic to have a high priority whilst the network waits for the data path to stabilise before attempting to repair the network layer QoS, for example using the RSVP repair mechanism seen before.

Context transfer protocols: A context transfer protocol transfers state information about the mobile's QoS requirements during handover from old to new access router. This exchange can be triggered in several ways, for example by hand-over indications received from the link layer or, in the case of tunnel-based micro-mobility, by indications received from tunnel ends.

The context transfer protocol requires the support of all mobility-aware nodes in the access network. The protocol needed for this procedure, and the parameters that must be exchanged, are being subject of study in the Internet community. The concept of a transfer protocol is now being studied by IETF Seamoby Working Group [SEA 01]. In particular, the terms in which seamoby defines the transfer context is broader than the one discussed here, as it transfer not only mobility or QoS parameters, but security, header compression and others.

Additionally, when RSVP local path repair is used, the context transfer protocol enables a reduction of the signalling load over the wireless network.[1]

Of all these mechanism, only QoS signalling priorization is a real requirement for our loose coupling proposal. However, all these mechanisms altogether can become a framework for seamless handover if applied when reservation based QoS are in place.

3. Simulations

This section presents different simulations that support the most relevant theory assumptions presented above. This will validate the proposed enhancements, both qualitatively and quantitatively, by applying them to simulated real environments using the commented protocols.

Simulations have been performed with network simulator version 2 (NS-2) [BRE 00]. We present here simulations of HAWAI [RAM 99] as micro-mobility protocol with RSVP as QoS signalling protocol in the scenario depicted in detail in figure 1.

We have chosen a scenario that could typically correspond to a small company. It is a basic tree topology that provides an initial model for testing our proposals. This topology is extracted from the set of topologies used for evaluating the BRAIN

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[1] Seamless handover = fast and loseless handover.

architecture [BRA 01]. The topology allows evaluating different distances of the “cross-over” routers from new access router (one, two and three hops) when the terminal is changing its point of attachment -access router.

The access network is composed of access routers with radio interfaces and intermediate routers, which connect the access routers. One of this intermediate router acts as gateway to other networks. The links in the access network are duplex links characterised by 512 Kbytes of bandwidth and 10 ms one way delay. Notice that the delay value depends strongly on the network technology so this value may vary.

HIPERLAN/2 [HIP 00] technology has been used for the wireless links. As the HIPERLAN/2 links were not directly supported by ns-2, they were modelled using Nokia link layer simulations performed in the framework of the BRAIN project [BRA 01]. Nokia has evaluated the HIPERLAN/2 air interface behaviour for different levels of offered traffic.

We have characterised the HIPERLAN/2 link used by each mobile as two fixed simplex links (up and down) with two parameters to be determined: delay and bandwidth. For the traffic load used in our simulations and attending Nokia results, these link parameters were set to 3.2 Mb for bandwidth and 15 ms for delay.

We have located the correspondent node outside the access network. It is just one hop away from the gateway although it could be located in any other place in the Internet. It is sending VoIP traffic towards a mobile node inside the domain. We will consider that the mobile node changes its position between consecutive access routers during the call time as shown in figure 1.

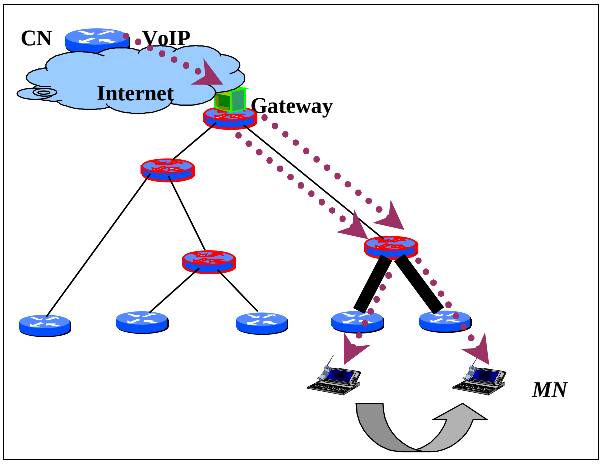

Figure 1*: Network***.**

Firstly, the behaviour of HAWAII and RSVP, acting independently, is shown. After that, the performance enhancements of loose coupling both protocols are evaluated, together with the priorization of RSVP signalling messages. The simulation results include the comparison of some performance parameters such as delay, packet loss and throughput when both protocols are coupled and de-coupled.

The simulation features different stages. At the beginning the correspondent node performs the reservation and begins transmitting voice packets towards the mobile node. 100 seconds after the beginning, the handover between consecutive cells takes place. This implies a modification of the routing tables using HAWAII and the necessity to reserve bandwidth across the new path with RSVP messages. In our study, only planned handover is considered. Planned handover means that the mobile node is aware of the proximity of the handover and so it can react. In this type of handover, the mobile node maintains simultaneous connections with new and old access router long enough to avoid dropped packets during handover. As we will see, if we want to optimise network resources, then we have to couple both protocols in order not to waste extra time making the reservation after the handover occurs.

Links between the intermediate node and the base stations are loaded up to 100% by background traffic in order to show the benefits of reservation with RSVP for the voice traffic. On the other hand it allows us to compare the performance benefit of the coupling and also the benefit of priorization of RSVP messages.

The speech traffic model extracted from [BRA 01] can be described as a birth-death process with a Poisson distributed arrival process and an exponential distributed call duration. In a conversation each party is alternating active and silent periods. Only during the active phase, IP packets carrying speech information are transmitted. We are going to simulate this traffic considering that active and silent periods are generated by an exponential distributed random variable. The mean value of this variable will equal T_on during active periods and T_off during silent ones.

The main parameters of the VoIP traffic model used are shown below:

- Activity interval: 50 %
- Mean call duration: 120 sec
- Mean active phase T_on: 3 sec
- Mean silent phase T_off: 3sec
- Payload of IP packet: 32 Bytes
- IP packet rate: 12.2 KBps

We measured the delay associated to the VoIP packets that travelled one way. This assumption is correct since links have different queues for the different ways. Packets from the sender do not interfere with packets coming from the mobile node, so the delay obtained for that link sense is correct. More details on implementation and procedures can be found at [BRA 01].

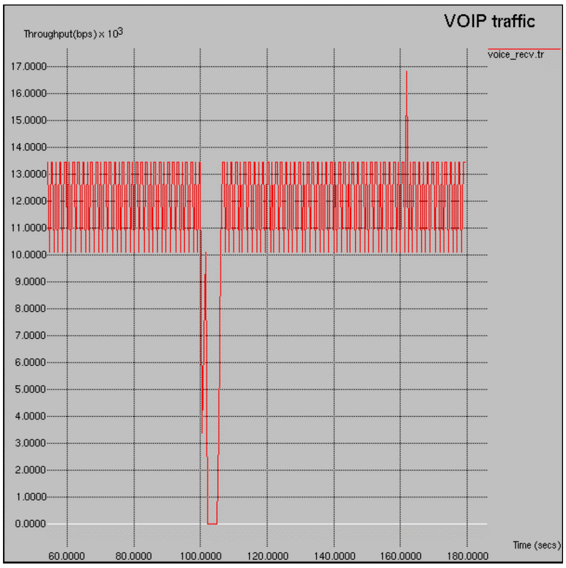

Figure 2: *Throughput of VoIP Traffic when de-coupled*

3.1 Simulation Results

In this section we will show the performance of HAWAII and RSVP when de-coupled and loosely coupled. For both cases, we reserved a fixed amount of bandwidth for RSVP signalling messages as proposed in section 2. We added a WFQ (Weighted-Fair Queuing) for RSVP messages with a certain rate to the link to avoid RSVP message loss. The simple formula n*s*8/30 (n is the number of sessions which are going to traverse the link and s is the expected average message size in bytes, so the formula represents 1/30 of all the bandwidth needed for all RSVP packets as if they were refreshed every second: for a 3 sec refresh rate that is 10% of all RSVP signalling traffic) should yield a good approximation of the necessary bandwidth. The rest of the times we assume that RSVP signalling won't be severely affected by link load. This value have to be higher if frequent reservation changes occurs. Considering a message size close to 100 bytes and 30 sessions per cell, we obtained 750 bps on the wireless link. For the core fixed part, we reserved 1500 bps due to aggregation of RSVP messages.

In order to understand completely the figures, we must remember that there was a planned handover at 100 seconds.

De-coupled case.

This case shows the performance of HAWAII and RSVP when both protocols are completely unaware of each other.

Figure 2 shows the throughput of VoIP traffic when de-coupled. When the handover is performed at 100 seconds, the new route only has a reservation to the crossover route. The interference traffic through the new path, which is much higher than VoIP traffic, prevents VoIP packets to arrive to the mobile host. So it is necessary to wait until the reservation is established in the new hops to recover the traffic. Approximately at 105 seconds, a new reservation is already established through the new path, so VoIP packets can arrive again to the mobile node. Thus the throughput recovers its sustained rate before the handover.

As we can see in figure 3, some VoIP packets are lost during handover until the reservation through the new path is established. Note that loss graphs here are measures in packets lost per second; they are not accumulated. Just after the handover, up to 60 packets are lost, which means that the call is seriously disrupted. The absence of packet loss between the two peaks is a result of the VoIP traffic pattern: there is no traffic in that precisely moment, so it is not lost.

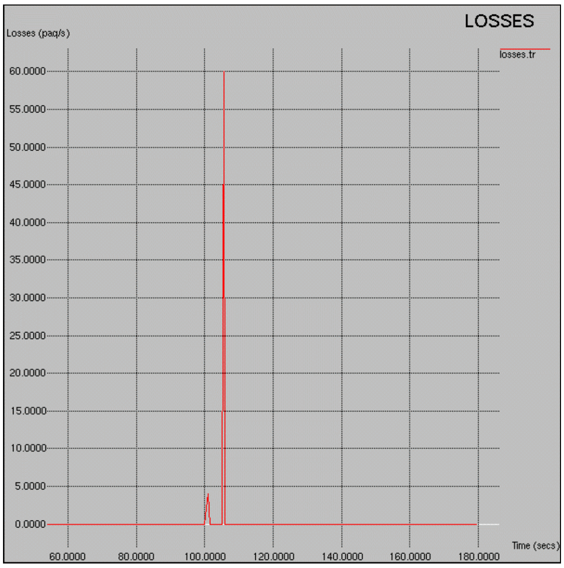

Figure 3: *Packets of VoIP Traffic Lost per Second when De-coupled.*

As a consequence of the handover, VoIP packets that are not lost suffer a great delay during a long period as shown in figure 4. Topology is simple so the cause of this delay is just the same as above: the absence of reservation once the new path is established. The rate of the interference traffic is much higher than the VoIP rate and the link is saturated, so best effort queue is full. Packets suffer a delay proportional to the length of the queue and some of them, as we have previously seen, are discarded

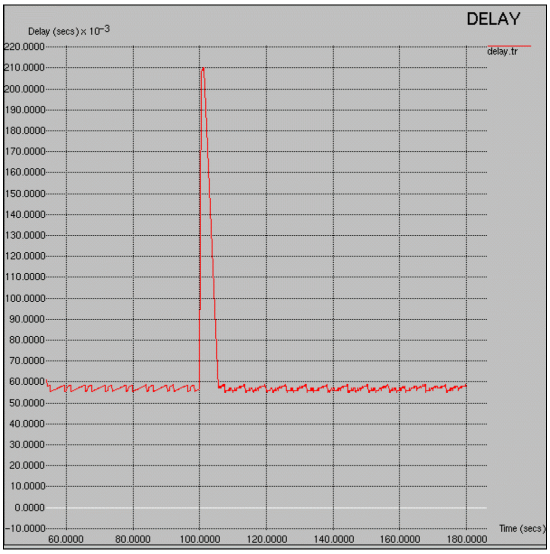

Figure 4: *Delay of VoIP Traffic when De-coupled.*

Loose-coupling case

This case is similar to the previous case with the only difference that HAWAII and RSVP protocols are loosely coupled as commented in section 2. We have designed a mechanism to couple both protocols, so they can exchange information during handovers. Just after the new route is established, the RSVP agent is informed and a refresh of the reservation is sent immediately.

Figure 5 confirms our thesis. Throughput of VoIP traffic is affected by handover at 100 seconds, but it is much more sustained than in the de-coupled case. Figure 6 shows that packet loss during handover is minimized. Down to 3-4 packets are lost, mainly due to the proper handover (note the scale when comparing to the loss of the de-coupled case). The rest of the loss caused by the absence of reservation is eliminated just because RSVP refresh messages are sent as soon as the new route is established, so the impact of the interference traffic is minimum. Finally figure 7 shows the handover impact on the delay. Although maximum delay cannot be reduced, the interval of affected packets is drastically reduced (compare with figure 6). The only packets that suffer increased delay, are those ongoing while the handover is taking place.

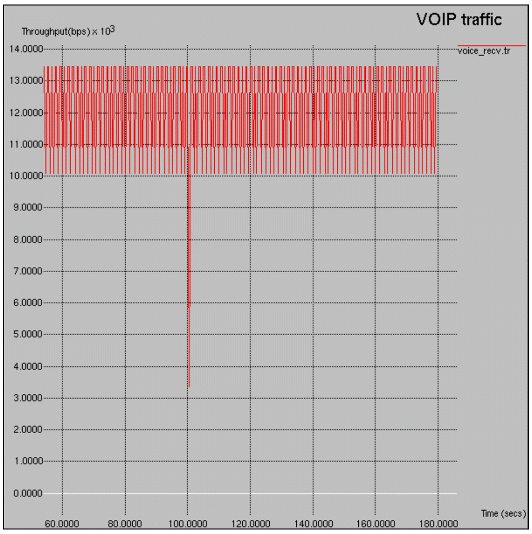

Figure 5: *Throughput of VoIP traffic when Coupled.*

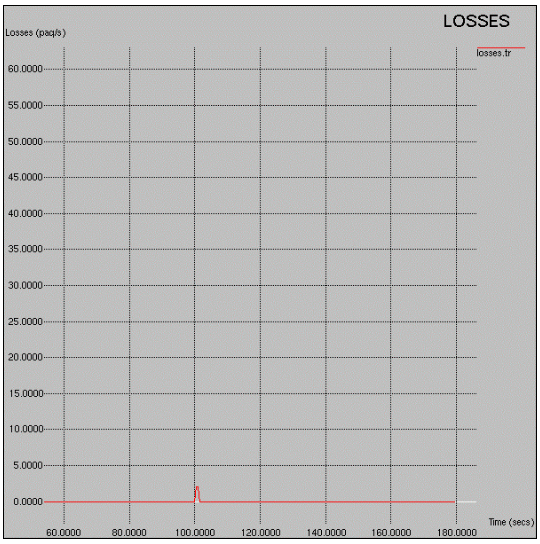

Figure 6: *Packets of VoIP traffic Lost per Second when Coupled.*

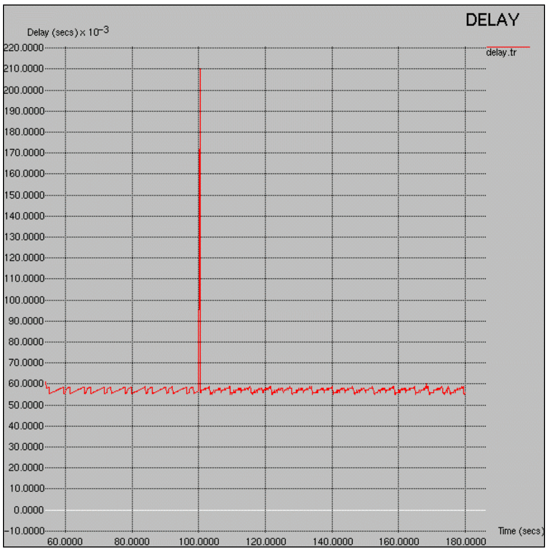

Figure 7: *Delay of VoIP Traffic when Coupled.*

4. Summary

We present an enhancement to QoS reservation operation in a mobile environment based on the collaboration of mobility and QoS protocols. Although several ways of collaboration can be explored we have chosen the loose coupling as the more promising one, where mobility and QoS mechanisms exchange information via triggering when handover occurs. We have noticed from simulations that the coupling of protocols provide a clear advantage in some scenarios. Although the handover itself cannot be accelerated it allows reservations to be installed as soon as the new path is stable. This effect is especially interesting in scenarios as the one shown, where interference traffic can make relevant traffic to be discarded. We have simulated also other complementary mechanisms such as QoS signaling marking to offer a framework for seamless handover when QoS reservation based mechanisms are used.

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References

[BRA 94] BRADEN, R., ET. AL., "Integrated Services in the Internet Architecture: an Overview", Internet Engineering Task Force, Request for Comments (RFC)1633, June 1994.

[BRA 97] BRADEN, R., ET. AL. "Resource ReSerVation Protocol (RSVP) -- Version 1, Functional Specification", Internet Engineering Task Force, Request for Comments (RFC) 2205, September 1997.

[BRA 01] IST-1999-100050 BRAIN D2.2 "BRAIN architecture specifications and models, BRAIN functio-nality and protocol specification", March 2001.

[BRE 00] BRESLAU L., ESTRIN D., FALL K., FLOYD S., HEIDEMANN J., HELMY A., HUANG P., MCCANNE S., VARADHAN K., XU Y., AND YU H., "Advances in network simulation", IEEE Computer, 33(5):59(67), May 2000.

[BUR 01] BURNESS A., MSc Thesis "Towards Full Quality of Service Support in a Mobile, Wireless Internet", University of Essex, January 2001.

[CAR 96] CARPENTER, B. "Architectural Principles of the Internet," Internet Engineering Task Force, Request for Comments(RFC)1958, June 1996.

[CAR 98] CARLSON M., WEISS W., BLAKE S., WANG Z., BLACK D., AND DAVIES E., "An Architecture for Differentiated Services", Request for Comments (RFC) 2475, Dec 1998.

[FLO 95] FLOYD, S., JACOBSON, V., "Link Sharing and Resource Management Models for Packet Networks", IEEE/ACM Tran. on Networking, Vol. 3, No. 4, 365-386, Aug 1995.

[GUS 01] GUSTAFSSON, E., JONSSON, A., PERKINS, C. "Mobile IP Regional Registration", Internet Draft (work in progress), March 2001.

[HIP 00] ETSI TR 101 683 V1.1.1 (2000-02), "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; System Overview".

[LEE 00] LEE, S.B., GAHNG-SEOP, A., ZHANG, X., AND A.T. CAMPBELL, "INSIGNIA: An IP-Based Quality of service Framework for Mobile Ad Hoc Networks", Journal of Parallel and Distributed Computing (Academic Press), Special issue on Wireless and Mobile Computing and Communications, Vol. 60 No.4. p.374-406, April 2000.

[PER 96] PERKINS, C., "IP Mobility Support", Internet Engineering Task Force, Request for Comments (RFC) 2002, October 1996.

[RAM 99] RAMJEE, R., LA PORTA, T., THUEL, S., VARADHAN, K., WANG, S.Y., "HAWAII: a domain-based approach for supporting mobility in wide-area wireless networks". Proc. of the 7th International Conference on Network Protocols (ICNP) 1999, pp. 283 – 292.

[SEA 01] IETF Seamoby WG. http://www.ietf.org/ html.charters/seamoby-charter.html

[TAL 98] TALUKDAR A., BADRINATH B., ACHARYA A., "MRSVP: A Resource Reservation Protocol for an Integrated Services Packet Network with Mobile Hosts", Proceedings of ACTS Mobile Summit'98, June 1998.