Supporting Real-Time Applications in All-IP Wireless Networks: Architecture and Mechanism

Youssef Iraqi, Majid Ghaderi and Raouf Boutaba

{iraqi, ghaderi, rboutaba}@bbcr.uwaterloo.ca

Abstract— **We propose an all-IP wireless network architecture that does not require any change inside the network and can interwork with the existing wired network. This architecture is based on the operation of IntServ over DiffServ network. The standard RSVP protocol is used for signaling and reservation.**

I. Introduction

A. Background

Future wireless Internet will support global roaming across multiple wireless and mobile networks. For example, a user can roam from a cellular network to a satellite-based network to a high-bandwidth wireless LAN. With this feature, users will have access to different services through increased coverage with reduced access cost.

Wireless IP networks consist of two components, wireless access networks and an IP backbone network. There are important issues that should be addressed in wireless IP networks in order to provide a seamless service on both fixed and mobile environments. Perhaps the most important issue is quality of service (QoS) provisioning. Current wired IP only offers the *best effort* service which treats all packets from all users equally. It is based on a strict FIFO strategy. In wireless environments due to specific characteristics of wireless channel, QoS provisioning is even more challenging.

Compared to wired networks, wireless IP networks have a number of unique characteristics. First, wireless channel resources are limited and highly dynamic. Also, they are prone to bursty and location-dependent errors. Second, a mobile user may move from a lightly loaded cell to a heavily loaded cell. It is possible that resource contracts made in one cell may not be valid when the user moves to another cell. This makes it difficult to provide seamless QoS for mobile users.

Lots of research has been done to address the QoS provisioning problem in wired IP networks and a number of QoS architectures have been proposed. To date, the IETF has adopted two architectures for providing end-to-end QoS in wired IP networks: Integrated Services (IntServ) [1] and Differentiated Services (DiffServ) [2]. The two architectures differ significantly in terms of scalability and router behavior. IntServ works on a per-flow basis and maintains individual states for all accepted flows, which leads to scalability problems. On the other hand, DiffServ merges individual flows into fewer aggregates. Each aggregate is associated with a particular forwarding behavior known as Per Hop Behavior (PHB) [2]. These PHBs are local and their link-by-link connection results to end-to-end quality of service.

Three services are provided in the IntServ model: (1)*guaranteed service* which guarantees a reliable upper bound on the maximum packet delay and is suitable for real-time intolerant applications, (2) *predictive service* which supplies a fairly reliable delay bound, and (3) *best effort* which does not provide any guarantee and is suitable for elastic applications.

In DiffServ, most classification and policing is done at the network edge. In the core, routers only examine the Differentiated Services field in the IP packet header to determine how to send the packet next, as opposed to maintaining state for each individual flow. This forwarding procedure will initiate a specific Per-Hop Behavior in the network. The IETF has defined two PHB classes: (1) *expedited forwarding* which can be used to build a low loss, low latency, low jitter, and assured bandwidth service through DiffServ domains and (2) *assured forwarding* which is allocated a minimum amount of forwarding resources in each node.

B. Related work and motivation

IntServ and DiffServ have been designed for wired networks. They must be extended in order to be able to operate in wireless networks. In this subsection we investigate the proposed architectures for wireless IntServ and wireless DiffServ.

Integrated Services have been extensively studied in wired networks. There have been many proposals for supporting real-time services in this framework. Among these proposals, the work by Jamin [3], [4] has received a considerable attention. Using measurements instead of *a priori* traffic characterization in admission control, is the main idea of his work. He uses a priori traffic characterization only for new flows and uses real measurements for existing flows to make the admission decision.

In IntServ framework, flows are required to provide token bucket parameters at connection time. Each flow is described by an average rate r and bucket depth b. Jamin uses token bucket description of flows to analyze the effect of accepting a new flow on delay bounds of existing flows. If accepting a new flow will violate delay bounds of existing flows, then admission control will reject it.

Assume that there are N priority classes such that class i has higher priority than class j providing $1 \leq i < j \leq N$. Let b_i and r_i denote the sum of bucket depths and average rates for all flows in class i. And let μ denote the link capacity. Then,

Theorem 1 (Parekh [5]) The worst-case class j delay, with FIFO discipline within the class and assuming infinite peak rates for the sources, is

$$D_j^* = \frac{\sum_{i=1}^{j} b_i}{\mu - \sum_{i=1}^{j-1} r_i}$$

for each class j. Further, this delay is achieved for a strict priority service discipline under which class j has the least priority.

B.1 Wireless Integrated Services

Talukdar *et al.* [6] extended the work of Jamin to wireless environments. Their scheme aims at accommodating real-time applications which cannot tolerate any QoS degradations due to mobility. They have assumed that the mobility of a user is predictable so that *mobility can be characterized precisely by mobility specification* which consists of the set of cells the mobile user is expected to visit during the life time of the flow. This is a very strong requirement and usually it is not feasible in practice. They have defined three service classes to which mobile users may subscribe: (1) mobility independent guaranteed service (MIG), (2) mobility independent predictive service (MIP), and (3) mobility dependent predictive service. Mobility independent services provide respective services regardless of the user mobility as long as the mobile is conforming to its mobility and traffic specifications. In turn, the mobility dependent service depends on the location of user and indeed is very similar to best effort service.

According to Talukdar *et al.* [6], to implement this service model it is not enough to reserve resources along the path from the destination to the current location of the mobile host; *it is necessary to make reservations along the paths to other locations the mobile host may visit.* However, it is not necessary to initiate the data flow along each of those paths. Data flow is initiated only along the path from the sender to the current location of the mobile host. Mobile RSVP [7] is proposed as an extended RSVP [8], [9] protocol to handle this type of reservation in wireless Integrated Services networks.

B.2 Wireless Differentiated Services

In a series of papers Mahadevan *et al.* [10] have studied whether DiffServ, as defined for wired networks, is suitable for wireless networks. According to their study, several enhancements including signaling and mobility considerations should be made into DiffServ.

To deal with resource reservation issue, they have proposed two mechanisms assuming that DiffServ classes are served by a Class Based Queuing scheduling algorithm [11]. In the first mechanism, a certain percentage of bandwidth in each cell is reserved for the mobiles entering the cell. When a mobile executes a handoff, it will enter this class for a while and after that it will be assigned to its own class. In the second mechanism, a lower priority application is asked to release some of its bandwidth for the high priority application.

According to their study, due to user mobility static provisioning of DiffServ is not sufficient in wireless environments. When a mobile executes a handoff, it is necessary to allocate resources dynamically. In addition to this, a signaling protocol is required as opposed to implicit admission control in DiffServ. This signaling protocol should consider the low bandwidth and mobility characteristics of the wireless network.

The previous wireless IntServ and wireless DiffServ approaches have drawbacks of their respective underlying architectures. Maintaining a per-flow state in every router is not scalable, and aggregation does not allow for quantitative services to be offered to flows. Furthermore, assuming that the exact mobility specification of a user is known beforehand is unrealistic. Also, reserving bandwidth in all the cells that the mobile user will visit is too conservative and will lead to poor network utilization. Both approaches require significant changes in the network infrastructure either by changing the behavior of routers inside the network or by introducing new signaling protocols.

In this paper, we propose an all-IP wireless network architecture that does not require any change inside the network and can interwork with the existing wired network. In this architecture, the standard RSVP protocol is used for signaling and reservation. The proposed approach will allow flexible network resource management while achieving high resource utilization.

The rest of this paper is organized as follows. In section II we present our all-IP wireless network architecture. Sections III and IV present the reservation protocol and the scheduling algorithm. Finaly, section V concludes the paper.

II. All IP wireless architecture

As we mentioned earlier, scalability concerns of the IntServ model in wired Internet forced the research community to design the DiffServ which is a simpler and more scalable framework. However, some disadvantages related to the static nature of the DiffServ model have been discovered. Therefore, cooperation of the two models have been proposed [12], [13] to develop a dynamic and scalable architecture for wired Internet, which would be able to offer end-to-end quality of service.

In addition to this, QoS provisioning mechanisms based on reservation are pretty popular in wireless networks but DiffServ does not support explicit reservation. According to Mahadevan *et al.* [10] fundamental changes, including the addition of a signaling protocol, have to be made into the current DiffServ architecture to make it suitable for wireless environment.

In a wireless environment, resource utilization is a serious issue. This static nature of the DiffServ model will degrade the network performance. Therefore, we have designed our all-IP wireless network architecture based on the cooperation of IntServ and DiffServ as depicted in Figure 1. In

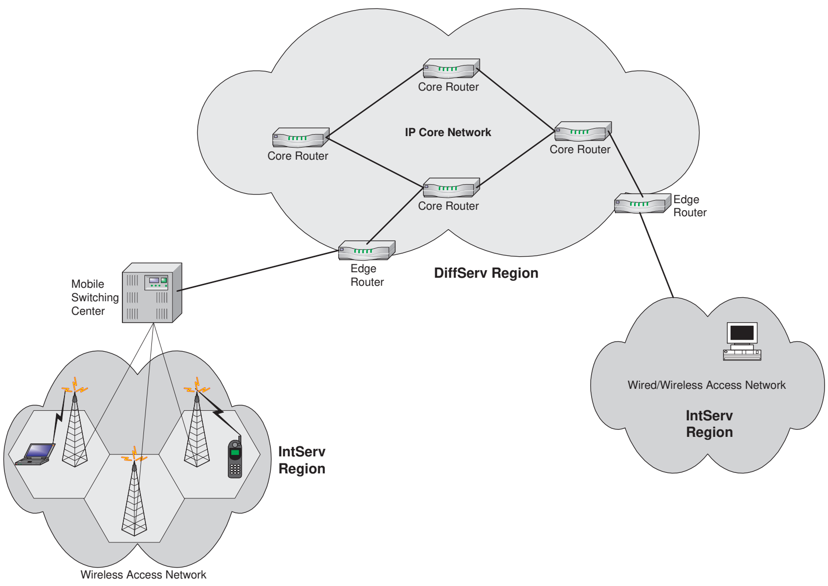

Fig. 1. All-IP wireless network architecture

this architecture IntServ operates at the wireless access network while core IP network is operating DiffServ. Since a wireless link can not accommodate a large number of flows as opposed to backbone links, scalability will not be the problem here. By using IntServ and RSVP in wireless access network, quantitative services can be offered to mobile users. When IntServ is used to provide access to DiffServ network, the most important node in the network is the edge router on the border of network regions. The router must implement two interfaces for IntServ/RSVP and DiffServ. Once a flow is admitted by the IntServ interface, its traffic is mapped to an appropriate PHB and packets will be marked accordingly. In the simplest case, guaranteed service is mapped to the EF PHB [14] and predictive service is mapped to an appropriate AF class [15].

III. Reservation Protocol

An important feature of our proposed architecture is that it operates with RSVP without any required change. This is because our admission control algorithm *explicitly* reserves resources in the local cell, where a connection request has been generated, but it *implicitly* reserves resources in other cells. Therefore, the normal operation of RSVP is enough to operate in this combined environment as addressed by Bernet *et al.* in [12].

RSVP [8], [9] uses two types of messages to setup the reservation states in the routers, PATH message to setup the data flow path and RESV message to make the bandwidth reservation. The signaling process for end-to-end QoS starts when the sending host generates a PATH message. The PATH message is carried towards the receiving host. In the IntServ region the standard processing is applied and the PATH state is installed at the edge router and the message is sent towards the DiffServ region. In DiffServ network the PATH message is processed as normal IP packets until it reaches the IntServ region and the receiving host that will generate an RSVP RESV message. The RESV message is carried back towards the DiffServ region and the sending host. At the edge router the RESV message triggers admission control processing. If it is accepted then the message is forwarded through DiffServ region to the sending host until it reaches the local base station. When the local base station receives the RESV message it initiates a special admission control process.

Hence, all the processing involved in this connection setup are the standard IntServ/DiffServ operations except the admission control process at the base stations.

IV. Scheduling Algorithm

The unified scheduling algorithm of [16] is used in the IntServ region. In this scheme guaranteed service is provided by weighted fair queuing algorithm [5]. Weighted fair queuing assigns a portion of link capacity to each active flow. The scheduling discipline for predictive service is a priority queue. The flows within each predictive class are scheduled by FIFO algorithm. Best effort flows have the lowest priority in the scheduling. The satisfaction of end-to-end delay requirements is the responsibility of end systems. An end system could use any QoS routing mechanism to select a route that satisfies its end-to-end requirements.

V. Conclusion

In this paper, we propose an all-IP wireless network architecture. It is based on the cooperation of IntServ and DiffServ models. The access network operates IntServ while the DiffServ is used in the core network. We take advantage of both worlds to develop a dynamic and scalable architecture for all-IP wireless networks. The standard RSVP protocol is used for signaling and reservation. The next step is to design a distributed admission control that accommodates both packet-level and connection-level QoS requirements.

References

[1] B. Braden *et al.*, "Integrated services in the internet architecture: An overview." RFC 1633, IETF, June 1994.

[2] S. Blake *et al.*, "An architecture for differentiated services." RFC 2475, IETF, December 1998.

[3] S. Jamin, *A Measurement-Based Admission Control Algorithm for Integrated Services Packet Networks*. Ph.d. dissert., Dept. Computer Science, University of Southern California, Los Angeles, USA, 1992.

[4] S. Jamin, S. Shenker, and P. Danzig, "Comparison of measurement-based admission control algorithms for controlled-load service," in *Proc. INFOCOM'97*, vol. 3, (Kobe, Japan), pp. 973–980, April 1997.

[5] A. K. Parekh, *A Generalized Processor Sharing Approach to Flow Control in Integrated Services Network*. Ph.d. dissert., Dept. Electrical Engineering and Computer Science, MIT, Cambridge, USA, 1996.

[6] A. K. Talukdar, B. Badrinath, and A. Acharya, "Integrated services packet networks with mobile hosts: Architecture and performance," *ACM/Baltzer Wireless Networks*, vol. 5, pp. 111–124, 1999.

[7] A. K. Talukdar, B. Badrinath, and A. Acharya, "Mrsvp: A resource reservation protocol for an integrated services with mobile hosts," *ACM/Baltzer Wireless Networks*, vol. 7, pp. 5–19, 2001.

[8] B. Braden *et al.*, "Resource reservation protocol (rsvp): Version 1 functional specification." RFC 2205, IETF, September 1997.

[9] L. Zhang *et al.*, "Rsvp: A new resource reservation protocol," *IEEE Network*, vol. 7, pp. 8–18, September 1993.

[10] I. Mahadevan and K. M. Sivalingam, "Architecture and experimental framework for supporting qos in wireless networks using differentiated services," *ACM/Kluwer Mobile Networks and Applications*, vol. 6, pp. 385–395, 2001.

[11] S. Floyd and V. Jacobson, "Link-sharing and resource management models for packet networks," *IEEE/ACM Trans. Networking*, vol. 3, pp. 365–386, August 1995.

[12] Y. Bernet *et al.*, "A framework for integrated services operation over diffserv networks." RFC 2998, IETF, November 2000.

[13] J. Harju and P. Kivimaki, "Co-operation and comparison of diffserv and intserv: Performance measurements," in *Proc. IEEE LCN 2000*, (Tampa, USA), pp. 177–186, November 2000.

[14] B. Budiardjo, B. Nazief, and D. Hartanto, "Integrated sservices to differentiated services packet forwarding: Guaranteed service to expedited forwarding phb," in *Proc. IEEE LCN 2000*, (Tampa, USA), pp. 324–325, November 2000.

[15] T. Chahed *et al.*, "On mapping of qos between integrated services and differentiated services," in *Proc. IWQoS 2000*, (Pittsburgh, USA), pp. 173–175, June 2000.

[16] D. Clark, S. Shenker, and L. Zhang, "Supporting real-time applications in an integrated services packet network: Architecture and mechanism," in *Proc. SIGCOMM'92*, (Baltimore, USA), pp. 14–26, October 1992.