Network Support for Multimedia Content in Mobile Networks

Major Area Examination Report

Kimaya Sanzgiri
Department of Computer Science
University of California, Santa Barbara
kimaya@cs.ucsb.edu

1 Introduction

The increasing support for multimedia content in wireless computing devices, such as laptops, cellular phones and PDAs, has opened up a new, rich application area for mobile ad hoc networks. These sophisticated devices enable mobile network users to engage in various multimedia applications, such as streaming music and videos, and on-line media-rich collaboration with other users. This creates a need for network support of multimedia applications in mobile networks.

Multimedia applications that involve streaming, or real-time continuous transfer, of multimedia data across the network are sensitive to end-to-end delay and jitter. To effectively support these applications, the network needs to ensure sufficient resource availability so that the applications receive the desired quality of service (QoS). This problem has been studied in great detail for wired networks and many solutions have been proposed. However, the problem is significantly more difficult in mobile networks. Due to the shared nature of the wireless medium, the resources at each node are affected by the activities of others in its neighborhood. Also, mobility and dynamic topology cause the neighborhood of a node to continually change. These network characteristics make the support of multimedia applications a challenging task.

In my major area examination, I will focus on the problem of providing network support to multimedia applications in mobile networks. I will present an overview of various solutions that have been proposed so far, and highlight the open issues.

2 Wired Network Solutions

Before investigating how QoS support may be enabled in wireless networks, it is useful to examine how the problem has been addressed in wired networks. Although wired network solutions are often not directly applicable to wireless networks due to the inherently different network characteristics, they provide insight into the problem and are a good starting point for addressing the problem in the wireless environment.

The need for providing different qualities of service to different applications was recognized from the early days of the Internet. For example, bulk data transfer applications, such as FTP, have very different service requirements as compared to real-time media applications. While the former require reliable packet delivery and cannot tolerate packet loss, the latter place constraints on end-to-end delay of data packets. In order to enable the provision of different qualities of service, the IP Precedence and Type of Service (TOS) field was included in the IP header [1, 3]. The purpose of this field was to enable applications to give a hint to the network about the type of service desired. However, the implementation of the different service levels was not defined clearly. As a result, the TOS field remained largely unused and best-effort packet delivery became the only service type offered in the Internet.

In the early 90s, the Internet community recognized the need to expand the Internet model to support the requirements of diverse applications, and the Integrated Services (IntServ) architecture was proposed [6]. In this expanded model, each data flow that desires better than best-effort quality of service reserves resources at routers along its path in order to ensure the desired level of service. RSVP [7] is the recommended resource reservation protocol. If insufficient resources are available, the flow is denied admission into the network. Routers maintain reservation state for each flow and monitor the flow to ensure that it does not consume more than the reserved resources. Although this architecture enables fine-grained QoS provisioning, the requirement for maintaining per-flow state and monitoring flow behavior at all routers greatly reduces the scalability and efficiency of this approach.

A more scalable solution to the problem was proposed in the form of Differentiated Services (DiffServ) [5, 16]. This solution achieves scalability by moving the tasks of flow monitoring and admission control to the edge of the network. Routers at the network boundary classify packets and mark them to receive a particular type of service in the network. Routers in the interior of the network recognize a finite set of service types. Each forwarded packet receives a particular type of service based on the marking by the edge router. The DiffServ model enables better-than-best-effort packet delivery. While it cannot provide the same per-flow guarantees as the IntServ model, it also avoids the overhead of per-flow state at routers and is therefore more scalable.

3 Wireless Network Solutions

The proposed solutions for wired networks, which were reviewed in the previous section, are not directly applicable to wireless networks for various reasons. Due to the shared nature of the medium, available resources at a wireless node are dependent on the activities of other nodes in the neighborhood, and can constantly change with node mobility. As a result, the effectiveness of resource reservations, as proposed by IntServ, is questionable. The DiffServ approach may be more applicable in the wireless environment. However, mechanisms are necessary to discover QoS routes and control flow admission. Also, since access to the wireless medium is shared, the Medium Access Control (MAC) protocol needs to be QoS-aware as well. In the following sections, we briefly examine how these issues have been addressed and what problems still remain open.

3.1 QoS-Aware Medium Access Control

The wireless medium has an inherent shared nature. As a result, medium access needs to be co-ordinated among nodes. IEEE 802.11 is currently the most popular Medium Access Control (MAC) protocol for wireless networks. This protocol provides fully distributed medium access control based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

To enable QoS support in ad hoc networks, packets belonging to high priority flows must be given prioritized access to the medium. Since the medium is shared among multiple nodes, it is not enough for each node to independently prioritize its own transmissions, and a co-ordinated prioritization across nodes is necessary. For this purpose, the MAC protocol needs to be QoS-aware. Several researchers have proposed solutions for enabling prioritized medium access in IEEE 802.11 networks [4, 11, 21, 22, 23]. IEEE 802.11e [15] enhances the 802.11 MAC protocol to provide QoS support. Prioritized medium access is enabled by varying the inter-frame spacing intervals and the maximum contention window, such that high priority packet transmissions get faster access to the medium.

3.2 Bandwidth Availability Determination

Many multimedia applications place constraints on the minimum bandwidth required along a path. In order to determine the amount of free bandwidth along a path, each node must first know its local bandwidth availability. As mentioned earlier, determining available bandwidth at a wireless node is a complex task. Since the medium is shared among multiple nodes, bandwidth availability at each node is affected by the activities of others in the neighborhood. Due to mobility, the neighborhood of a node may change continuously. Bandwidth availability determination is therefore very challenging. Several researchers have proposed solutions to this problem [8, 24, 25]. These solutions present different trade-offs between accuracy, complexity and overhead. It still remains to be determined which approach, if any, provides an effective solution to the problem.

3.3 QoS Routing

Routing in mobile networks is a challenging task due to mobility and dynamically changing topology. Even more challenging is the task of finding routes that satisfy QoS constraints. Several solutions for QoS routing in ad hoc networks have been proposed [2, 9, 10, 14, 19, 20, 24, 26]. Each of these QoS routing protocols exhibits one or more of the following features:

- The QoS routing protocol is based on either a proactive routing protocol, such as DSDV [17], or a reactive routing protocol such as AODV [18] or DSR [12].
- The protocol finds multiple paths between the source and destination.
- Admission control is integrated with route discovery, i.e., if a route with sufficient resources cannot be found, the application is denied a route to the destination.
- The protocol establishes resource reservations along the route in the process of route discovery.

The proposed protocols represent different trade-offs between effectiveness and efficiency. No single protocol is clearly superior to the others, and there is still significant room for improvement and innovation in this area.

3.4 Admission Control

Admission control is the process of ensuring resource availability before admitting a data flow into the network. The complexity of this task is increased in mobile ad hoc networks owing to the interference between multiple hops along a single path. Multiple nodes along a route may contend with each other for bandwidth access if they lie within carrier-sensing range, and may not be able to transmit simultaneously. As a result, the required bandwidth along the path becomes a multiple of the bandwidth requested by the application. Determining the number of contending nodes at each hop is difficult, since it depends on the exact topology of the route. Some admission control solutions attempt to solve this problem [8, 25]; however, they require knowledge of all nodes within carrier-sensing range and all nodes that lie on any given route. Acquiring this knowledge incurs considerable overhead. It is not clear how this problem could be effectively solved without this knowledge, and there is scope for further research in this area.

3.5 QoS Monitoring

Once a QoS flow has been established, it is necessary to monitor the quality received by the flow and take action if the quality drops below acceptable limits. This is especially needed due to the dynamically changing topology and resource availability in mobile ad hoc networks. QoS monitoring could be accomplished in different ways, and could be exercised at various levels of the network stack. INSIGNIA [13] is a proposed QoS framework that attempts to solve this problem through in-band signalling between the source and destination. SWAN [2] uses explicit congestion notification to regulate the flow of real-time sessions, while AQOR [24] requires the destination to monitor the received QoS and inform the source if any action is necessary. The various approaches used by the proposed solutions are by no means exhaustive, and other solutions are possible. Further investigation is necessary to evaluate the approaches, and determine how they may be used, either independently or in combination, to provide an effective solution to the problem.

4 Conclusion

Multimedia applications require network support for different qualities of service. In this report, we briefly reviewed the current state of the art for QoS support in mobile networks. Although several solutions have been proposed, the problem is far from being solved completely and effectively. There is a need to evaluate the proposed approaches, not just in simulation but also in real-world deployments, and determine how they can be improved. In addition to MAC layer and network layer solutions, application layer protocols for multimedia streaming need to be examined to determine whether they are effective in the wireless environment, and if not, then how they may be improved. It is important to ensure that solutions deployed at different levels of the network stack interact properly and do not hinder each other. Finally, it will be interesting to see how special characteristics of wireless networks, such as mobility and flexible connectivity, can be leveraged to improve quality of service.

References

[1] Internet Protocol. *RFC 1633*, September 1981.

[2] G. Ahn, A. Campbell, A. Veres, and L. Sun. SWAN: Service Differentiation in Stateless Wireless Ad Hoc Networks. In *IEEE Infocom*, 2002.

[3] P. Almquist. Type of Service in the Internet Protocol Suite. *RFC 1349*, July 1992.

[4] M. Barry, A. Campbell, and A. Veres. Distributed Control Algorithms for Service Differentiation in Wireless Packet Networks. In *IEEE Infocom*, 2001.

[5] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, and W. Weiss. An Architecture for Differentiated Services. *RFC 2475*, December 1998.

[6] R. Braden, D. Clark, and S. Shenker. Integrated Services in the Internet Architecture: an Overview. *RFC 1633*, June 1994.

[7] R. Braden, L. Zhang, S. Berson, S. Herzog, and S. Jamin. Resource ReSerVation Protocol (RSVP) - Version 1 Functional Specification. *RFC 2205*, September 1997.

[8] I. Chakeres and E. Belding-Royer. PAC: Perceptive Admission Control for Mobile Wireless Networks. Submitted for publication.

[9] S. Chen and K. Nahrstedt. Distributed Quality-of-Service Routing in Ad-hoc Networks. *IEEE Journal of Selected Areas in Communication*, 17(8), August 1999.

[10] T. Chen, J. Tsai, and M. Gerla. QoS Routing Performance in Multihop Multimedia Wireless Networks. In *IEEE ICUPC*, 1997.

[11] C. Coutras, S. Gupta, and N. Shroff. Scheduling of Real-time Traffic in IEEE 802.11 Wireless LANs. *Wireless Networks*, 6(6):457–466, 2000.

[12] D. Johnson and D. Maltz. Dynamic Source Routing in Ad hoc Wireless Networks. *Mobile Computing.*

[13] S-B. Lee, G-S. Ahn, X. Zhang, and A. Campbell. INSIGNIA: An IP-based Quality of Service Framework for Mobile Ad hoc Networks. *Journal of Parallel and Distributed Computing*, 60(4):374–406, 2000.

[14] C. Lin. On-Demand QoS Routing in Multihop Mobile Networks. In *IEEE Infocom*, 2001.

[15] S. Mangold, S. Choi, P. May, O. Klein, G. Hiertz, and L. Stibor. IEEE802.11e Wireless LAN for Quality of Service. In *European Wireless*, 2002.

[16] K. Nichols, S. Blake, F. Baker, and D. Black. Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers. *RFC 2474*, December 1998.

[17] C. Perkins and P. Bhagwat. Highly Dynamic Destination-Sequenced Distance Vector Routing (DSDV) for Mobile Computers. In *ACM SIGCOMM*, 1994.

[18] C. Perkins and E. Royer. Ad-hoc On-Demand Distance Vector Routing. In *IEEE WMCSA*, 1999.

[19] C. Perkins and E. Royer. Quality of Service for Ad-hoc On-demand Distance Vector Routing. *IETF Internet Draft, draft-perkins-manet-aodvqos-02.txt*, October 2003. (Work in progress).

[20] K. Sanzgiri and E. Belding-Royer. Leveraging Mobility to Improve Quality of Service in Mobile Networks. Submitted for publication.

[21] J. Sobrinho and A. Krishnakumar. Real-time Traffic over the IEEE 802.11 Medium Access Control Layer. *Bell Labs Technical Journal*, pages 172–187, 1996.

[22] N. Vaidya, P. Bahl, and S. Gupta. Distributed Fair Scheduling in a Wireless LAN. In *ACM Mobicom*, 2000.

[23] M. Visser and M. El Zarki. Voice and Data Transmission over an 802.11 Wireless Network. In *PIMRC*, 1995.

[24] Q. Xue and A. Ganz. Ad hoc QoS On-demand Routing (AQOR) in Mobile Ad hoc Networks. *Journal of Parallel and Distributed Computing*, 63:154–165, 2003.

[25] Y. Yang and R. Kravets. Contention-Aware Admission Control for Ad Hoc Networks. Technical Report 2003-2337, University of Illinois at Urbana-Champaign, April 2003.

[26] C. Zhu and S. Corson. Qos Routing for Mobile Ad Hoc Networks. In *IEEE Infocom*, 2002.