A Performance Comparision for Adaptive-based Distributed Call Flow for Multi-hop MANET

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Abstract— **MANET (Mobile Ad hoc networks) or simply Ad-hoc Networks have been proposed for a variety of applications where support for real time, multimedia services may be necessary. This requires that the network is able to offer service differentiation and quality of service (QoS) appropriate for the latency and jitter bounds needed to meet the real time constraint. This paper describes a design for realistic QoS support using a system approach that involves coordinated changes at the MAC and IP layers. At the MAC layer, we propose a priority-based scheduling mechanism to provide service differentiation based on current channel status. We develop a priority-based delay model for the adaptive back off scheme. The delay model allows each node to make local admission decisions. At the IP layer, the network resource availability distribution and flow admission in multi-hop ad hoc networks is achieved through a proposed call admission protocol, so that each node has the correct view of the shared channel usage, and the correct flow admission decision is made based on the estimated flow quality (accumulated delay of the path). Analytical and simulation results show that our approach can provide bounded latency and low jitter for real-time traffic, such as VoIP. The results also demonstrate that the aggregated network throughput is significantly improved given the quality requirements.**

Keywords- **Distribution call, Mobile ad-hoc network, MAC & IP Layer, QoS.**

I. INTRODUCTION

Wireless networking and multimedia content are two rapidly emerging technological trends. Among types of wireless networks, multi-hop wireless ad hoc networks provide a flexible means of communication when there is little or no infrastructure or the existing infrastructure is inconvenient or expensive to use. With the development of ad hoc networks, we can anticipate that multimedia applications will be popular in personal networks or other collaborative scenarios.

An important requirement for providing multimedia services in multi-hop ad hoc networks is that certain quality of service (QoS) metrics can be satisfied. There has been significant research on providing QoS in wired networks. For instance, Intserv and Diffserv are two well-known approaches. These approaches rely on the availability of precise resource utilization information of wired links. However, because of the shared nature of wireless communication channels and node movement, these techniques cannot be directly applied to wireless networks. For infrastructure wireless networks, the base station can act as a central coordination point, thereby enabling the use of centralized quality of service approaches. For example, the base station can simply deny the admission request of a new flow if the traffic load in the network is already saturated. An approach like the IEEE 802.11 Point Coordination Function (PCF) can be used by the base station to give priority to delay sensitive traffic. In ad hoc networks, however, there is no centralized point that can provide resource coordination for the network; every node is responsible for its own traffic and is unaware of other traffic flows in the network. Furthermore, a flow must often traverse multiple hops to reach the destination; multiple nodes must coordinate to route traffic. Hence, an approach that provides QoS must support multi-hop communication.

Service differentiation is another important aspect of providing QoS. In many ad hoc network applications, such as disaster rescue, communication terminals may have different priority ranks. For example, the messages sent by the commander should supersede traffic sent out by other rescue team members so that urgent information can be delivered. Many applications that are deployable in ad hoc networks, such as multimedia applications, may have different delivery requirements, i.e., low delay and jitter, and high throughput. For instance, a typical Voice over IP (VoIP) traffic session has the requirement of very low transmission delay. While multimedia streaming traffic is more tolerant to latency than VoIP traffic, it requires more bandwidth.

The contribution of this paper is three-fold. First we propose a priority-based scheduling mechanism to provide service differentiation based on current network status. Specifically, the collision rate is considered in the back off scheme for different priority flows. Second, we present an analytical model for the adaptive back off scheme and derive a priority based delay model. Third, we propose an admission control protocol in multi-hop ad hoc networks so that each node has the correct view of its shared channel usage, and correct admission decisions are made based on the estimated quality (delay) of a flow calculated using the delay model.

II. RELATED PREVIOUS WORK

The existing related work can be categorized into two groups: QoS routing for ad hoc networks, and MAC protocol enhancement to provide QoS. Many routing schemes/frameworks have been proposed to provide QoS support for ad hoc networks [2]. Among them, INSIGNIA uses an in-band signaling protocol for distribution of QoS information. The information is included in the IP headers of the data packets, and the available resources are calculated at each station the packet traverses so that a QoS decision can be made. SWAN [2] improves INSIGNIA by introducing an Additive Increase Multiplicative Decrease (AIMD)-based rate control algorithm. Specifically, Explicit Congestion Notification (ECN) is used to dynamically regulate admitted real-time sessions. Both [9] and [10] utilize a distance-vector protocol to collect end-to end QoS information via either flooding or hop-by-hop propagation. Once collected, the receiver selects the path that can satisfy the QoS requirement. CEDAR [3] proposes a coreextraction distributed routing algorithm that maintains a selforganizing routing infrastructure, called the "core". The core nodes establish a route that satisfies the QoS constraints on behalf of other nodes. None of these approaches significantly diverge from QoS approaches for wired networks, and they do not significantly address the differences between wired and wireless networks.

Recently, there has been other work that proposes to improve the performance of MAC protocols and to provide service differentiation. Many of these approaches specifically target IEEE 802.11. For example, studies in [1, 8, 16, 20] propose to tune the contention windows sizes or the interframe spacing values to improve network throughput. Among these solutions, MFS [20] proposes estimation techniques for the current network status and each node determines an extra scheduling delay so as to improve the network utilization. Recent studies in [23, 24, 33] investigate the problem of achieving fairness at MAC layer. Studies in [1, 3, 19, 28, 34], on the other hand, propose priority-based scheduling to provide service differentiation. Most of these studies utilize different backoff mechanisms, different DIFS lengths, or different maximum frame lengths, based on the priority of the traffic/node.

Among the discussed solutions, our approach is most closely related to the work in [19], which uses piggybacked information on control and data packets to know neighbor nodes' head-of-line packets. This information allows nodes to determine their relative priority. Subsequently, priority-based scheduling can be achieved. The solution utilizes multi-hop coordination so that a next-hop node can increase a packet's relative priority in order to meet the delay guarantee, thereby achieving the quality requirement along a multi-hop path. Our work is similar to [19] in that we also utilize priority scheduling by varying the back off behavior of different priority flows. We utilize multi-hop coordination along the data delivery path to accomplish a call setup. However, there are also significant differences between the approaches. First, our work uses a traffic-class based priority, and differentiation is based on per-flow traffic, while [19] provides relative priority on a per-packet basis. Second, our priority scheduling takes the current network status into consideration so that we can adapt to varying network conditions, while [19] uses static adjustment of the contention window. Third, our work does not rely on MAC protocol control packets to collect QoS information. Instead, we utilize the on-demand routing protocols to disseminate a node's load information to its neighbors. Piggybacking information on data and control packets on a per-frame basis, as recommended in [19], adds extra overhead, consequently reducing the good put of the channel. For example, given a 120 Byte VoIP packet, the overhead will be 48 Bytes (20 Bytes for the RTS, plus 14 Bytes each for the CTS and ACK), and the extra overhead for piggybacking priority information is 24 Bytes according to the algorithm described in [19]. Furthermore, RTS/CTS is optional for the IEEE 802.11 MAC protocol, especially when small packet sizes are used (such as for a VoIP packet). Hence the approach will result in less channel efficiency. Finally, [19] does not provide an admission control mechanism, resulting in performance degradation as the traffic load increases.

III. ADAPTIVE PRIORITY SCHEDULING

We describe our proposed priority scheduling solution and derive an analytical model of the back off operation, as well as a delay model with the priority scheduling.

A. Priority Based Scheduling

In the context of 802.11e, service differentiation at the MAC layer can be achieved by different schemes [1]. Possibilities include scaling the contention window according to the priority of each flow, assigning different inter-frame spacing's, and using different maximum frame sizes. Here we primarily focus on the adaptive back off schemes because typically the frame sizes cannot be controlled by the MAC layer. Specifically, by assigning a different set of CWmax and CWmin values to different traffic classes, we can achieve an initial service differentiation.

However, predefined static CWmin and CWmax values may not achieve optimal performance given different real traffic composition. To achieve better service differentiation, one approach is to change the back off rate. In addition, the faster back off rate will result in channel waste since the channel is idle for a longer time while all the stations back off, especially when all the traffic has low priority.

B. Adaptive Backoff Scheme

As stated in the IEEE 802.11e standard, different traffic class priorities are assigned different CW values. Typically, these values are predefined and hence do not adapt to the network state. However, because the state of ad hoc networks can vary greatly due to mobility and channel interference, it is advantageous to adjust the values according to the current channel condition. Specifically, mechanisms for avoiding collisions can be considered. Given a high traffic load in the network, the number of retransmissions significantly affects the throughput and subsequently packet delivery latency [20].

Hence, it is beneficial to consider the collision rate in the back off scheme.

C. Analytical Model for Backoff Schemes

We now develop an analytical model for our priority based adaptive back off scheme with consideration of the collision rate, as indicated in Eq. Our assumptions are the same as in other previous work, the channel attempt rate is exponentially distributed with average rate, and the collision rate, given in an empty slot, is constant and only relates to the current traffic load.

$$\lambda_c = \sum_{i=1}^{s} \sum_{j=1}^{a_i} \frac{1}{b_{i,j}} = \sum_{i=1}^{s} \frac{a_i}{\bar{b}_i} = \sum_{i=1}^{s} \frac{a_i}{L(a_i)}$$

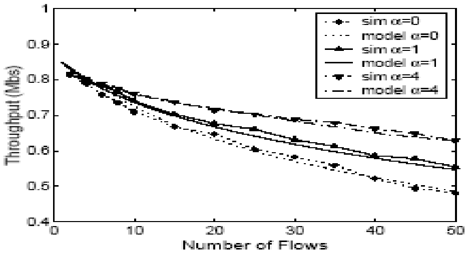

Figure 1: Comparision between Analytical and Simulation Results(CWmin=32)

D. Delay Analysis of Adaptive Backoff Scheme

Given the current traffic rate, collision possibility , and the average back off window size, as calculated in previous section, we now derive the delay model for priority.

Following the same analysis in previous section, let $d_j(a_i)$ denote the total deferred time during the d^{th} back off for priority i . Because the backoff timer only decreases when the channel is idle, we have

$$d_j(a_i) = \begin{cases} \bar{F}' + k_j \bar{F} + b_j & j = 1, \\ k_j \bar{F} + b_j + \bar{F} & j > 1 \end{cases}$$

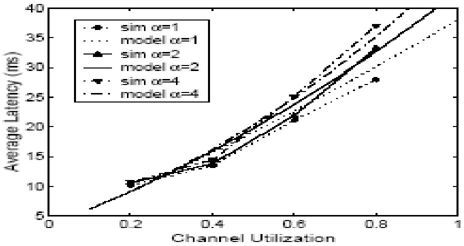

Figure 2: Comparision between Annlytical and Simulation Results(CWmin=32)

IV. THE MULTI-HOP CALL SETUP

we propose to utilize the route set up and maintenance process in ad hoc routing protocols to perform call admission and resource management. Many of the current routing protocols in ad hoc networks can be divided into two general categories: proactive and reactive routing protocols [27]. We consider the utilization of reactive routing protocols in this paper, in which routing activities are initiated in an "on demand" basis, and hence have the advantage of reduced routing load given low bandwidth wireless links, as described in [6]. Specifically, during call setup, the source node disseminates the flow's priority information along with the Route Discovery process of the routing protocol. Each node on the path decides whether the flow can be admitted based on its local information, i.e., its active neighbors and their associated load. The goal of admission is to admit as many flows as the channel permits, while not causing significant performance degradation to ongoing high priority traffic.

A. Call Setup

When a new flow is issued, the call setup process determines whether the flow can be admitted with the needed service level while the requirements of current sessions are still satisfied. We apply the proposed mechanism and the analysis as described in previous sections in a multi-hop ad hoc network and combine it with a reactive ad hoc routing protocol to provide call admission control. Before a flow can be admitted, a Route Discovery process is needed to setup a route from the source to the destination. This is typically accomplished through multi-hop forwarding. Route discovery works by flooding the network with a route request (RREQ) packet. Upon reception of a RREQ, each node rebroadcasts it to its neighbors, unless it is the destination or has a route to the destination. Such a node replies to the RREQ with a route reply (RREP) packet. The RREP is propagated hop-by-hop back to the source node. Once received by the source, data packets can be routed to the destination. Details of two well-known on-demand routing protocols can be found in [12].

B. Call Setup Request

Call setup is integrated with route discovery to find paths that can satisfy the QoS requirement. Specifically, through the request process, routes from the source node to the destination are obtained, and every node has the correct view of the traffic load in the shared channel. In addition to the routing table locally stored at each station, each node also keeps a set of neighbors, called a neighbor set. The neighbor set maintains information about the node's neighbors, i.e., nodes that are within its transmission range. Here we assume bi-directional link connectivity. Each record in the neighbor set contains the neighbor node's address, as well as its load information, in terms of the current number of service flows and their respective priority level. Load information has an associated state, confirmed or pending, or unknown, indicating whether the load has been admitted or is in the process of call admission. An unknown state indicates an inactive neighbor of a node.

C. Call Setup Request

As described above, when a destination node receives a RREQ destined to itself, it unicasts a RREP packet along the reverse path. Note, RREP generation by intermediate nodes, while utilized by many routing protocols [18, 26], is disabled here because the intermediate node may not have correct load information for the succeeding nodes along the path. Subsequently, it cannot make an admission decision. Upon the reception of the RREP packet, each intermediate node adds a record for the sender of the RREP (the previous hop) if there is no existing entry for that node in its neighbor set (the destination node should be excluded because it does not transmit packets for this session). The RREP is dropped. The forwarding node also updates the accumulated delay in the forwarded RREP. Finally, the RREP reaches the source node. After a re-examination of its neighbor set, the source node decides whether to admit the flow, and it uses the path indicated in RREP if it is admissible. After a successful call setup, the source node updates its neighbor set and sets the pending state of itself, as well as the next hop node, as confirmed. The source node also deletes the pending record for this flow associated with the nodes that are not on the selected next hop path. Note that to make an admission decision, the source node compares the sum of the estimated delay to a total threshold value. If a source node receives multiple RREPs, it chooses the route that best meets the service requirements.

D. Resource Management

As described in the call setup request process, each node that rebroadcasts the RREQ creates a pending record to be admitted flow from the RREQ source. Hence, there must be a mechanism to pass this information on to these off-path nodes. We achieve this objective by marking the very first packet of the flow. Each node along the communication path knows the flow is admitted through this marked packet, and as a result, updates its local load. It confirms the pending information of itself and its downstream neighbors. Then, each node along the path broadcasts a NREP packet to inform its neighbors of the change. Upon reception of the NREP, the nodes that are not on the delivery path of the flow update the load change for their neighbor nodes that are on the path and delete the pending record about this service load from the neighbor set. If the pending record expires and a node has not received a NREP message about the update, the node deletes the pending record.

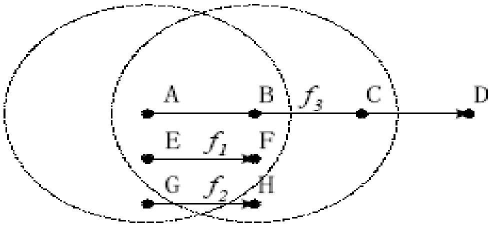

Figure 3: An Example topology

E. Optimization

Message Loss: The correct admission decision is based on an accurate view of a node's neighbor set. The update of the neighbor set is triggered by a message reception. Message loss due to collisions and node movement can be frequent in wireless networks. If a RREQ packet from node is not received at a neighbor node will not update potential load. This is likely to impact future admission decisions.

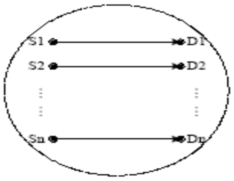

figure 4: Network topology for the first simulation set

Interference from Carrier Sensing Range: Our described protocol does not explicitly consider the interference from nodes within the carrier sensing range but outside of transmission range. Because the measured collision rate used in our delay analysis already takes the interference of carrier sensing into consideration, the problem is mitigated. However, to improve the accuracy of neighbor information, we can utilize current power control techniques so that control packets are transmitted at a higher power. This enables all neighbors within the carrier sensing range to be reached.

V. PERFORMANCE EVALUATION

The performance of our adaptive priority based scheduling algorithm, as well as the call setup protocol, is evaluated in the following simulations. Our approach is implemented in the NS-2 [14] simulator with the Monarch mobility extensions [6].

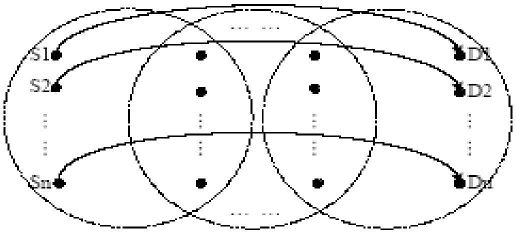

Figure 5: Network topology for the second simulation set

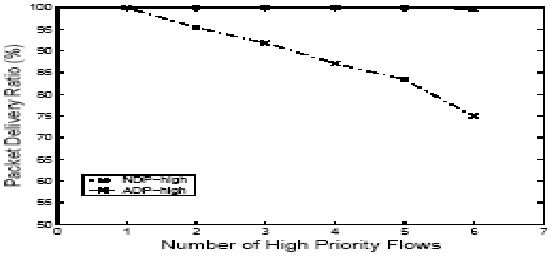

Figure 6: Packet Delivery Ratio of High Priority Flows.

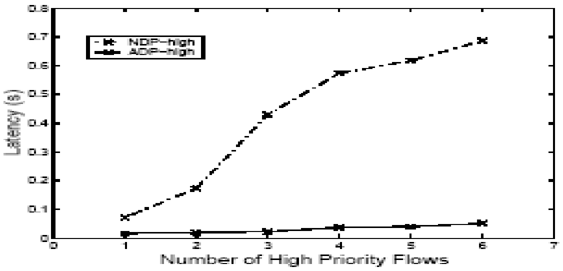

Figure 7: Packet Delivery Latency of High Priority Flows.

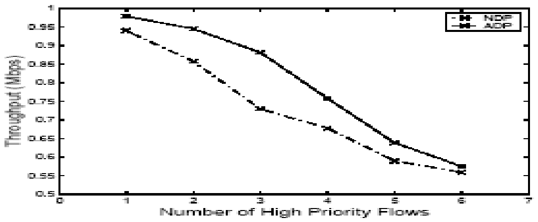

Figure 8: Aggregated Data Throughput of the Network

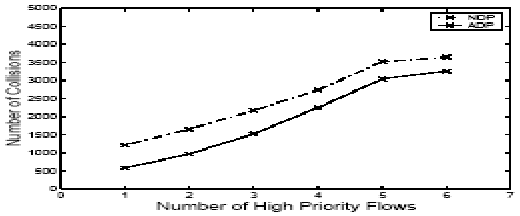

Figure 9: Total Collision of the Network.

Fig. 6,7,8,9 Performance Comparison between Adaptive Backoff and Non-adaptive Backoff without RTS/CTS

VI. EXPERIMENTAL SETUP

- *Packet delivery fraction*: The number of data packets received by the destination compared with the number of data packets generated by the source for each priority class.
- *End-to-end packet delivery latency*: The average delivery delay of the data packets from the source to the destination.
- *Aggregated throughput*: The sum of the throughput for active flows in the network, including flows of different priority classes.
- *Number of collisions*: The total number of collisions that occur in the network during the simulation.
- *Control overhead*: The number of control packets transmitted during the call setup.

VII. RESULTS

Adaptive Backoff Scheme

Figure 6-9 shows the effect of using our adaptive back off mechanism (denoted as ADP) with and without RTS/CTS control packets. For comparison, we also show the results of a non-adaptive scheme (denoted as NDP), which does not take the collision rate into consideration and only varies the CW_{min} values of different priorities.

Multi-hop Call Admission

Figure 14 shows the protocol performance in a multi-hop scenario when RTS/CTS is not employed. The solid lines represent the results for our adaptive back off scheme. The non-adaptive back off scheme is shown in dotted lines for comparison. Given our traffic model and network topology, our admission control process can admit up to four multi-hop high priority flows.

In summary, through the usage of multi-hop call admission, the service quality of existing high priority flows is maintained when new flows are requested. At the same time, by using the adaptive back off scheme, the aggregated network throughput is increased so that as many flows as possible are admitted, while service differentiation is still provided.

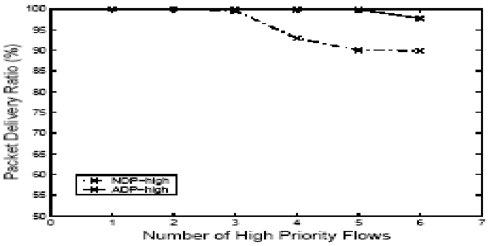

Figure 6: Packet Delivery Ratio of High Priority Flows

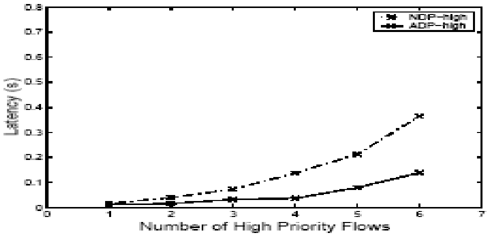

Figure 7: Packet Delivery Latency of High Priority Flows.

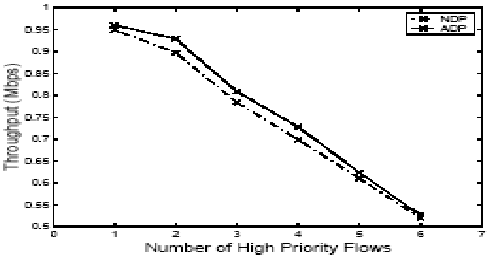

Figure 8: Aggregated Data Throughput of the Network

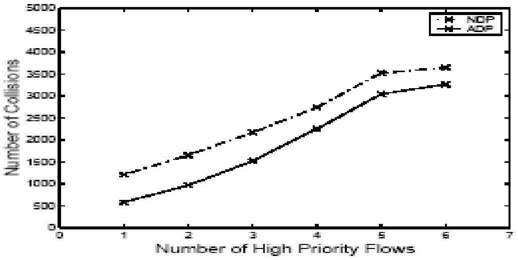

Figure 9: Total Collision of the Network.

VIII. OPTIMIZATION AND DISCUSSION

Our model provides a statistically "soft" quality assurance, where the average quality of a class of traffic flows is guaranteed. Other schemes, such as [19], aim to provide hard guarantees. The techniques in [19] can further be applied to our approach to provide a more fine-grained quality guarantee.

IX. CONCLUSION

This paper proposes an adaptive priority-based scheduling mechanism to provide better service differentiation. An analytical model of the mechanism is given, based on which we derive a delay model to predict average traffic latency given the current network load. Multi-hop coordination for admission control, integrated with reactive routing protocols, was studied. Specifically, during a call setup, each node along the propagation path estimates delay for the traffic using the derived delay model and uses this information to make an admission decision. Analytical and simulation results show that our approach provides service differentiation and quality of service support through the adaptive scheduling scheme and the admission control process. This is beneficial to the deployment of multi-hop ad hoc networks where a variety of applications, such as multimedia and VoIP, will be utilized, and the admission of as many flows as possible is desired as long as the needed service requirements are still met.

X. REFERENCES

[1]. I. Ada and C. Castelluccia. Differentiation Mechanisms for IEEE 802.11. In Proceedings of the IEEE Conference on Computer Communications (INFOCOM), Anchorage, Alaska, April 2001.

[2]. G.-S. Ahn, A. Campbell, A. Veres, and L.-H. Sun. Supporting Service Differentiation for Real-Time and Best-Effort Traffic in Stateless Wireless Ad Hoc Networks (SWAN). IEEE Transactions on Mobile Computing, 1(3):192–207, July-Septemeber 2002.

[3]. A. Banchs, X. Perez-Costa, and D. Qiao. Providing Throughput Guarantees in IEEE 802.11e Wireless LANs. In Proceedings of the 18Q$R International Teletraffic Congress (ITC-18), Berlin, Germany, September 2003.

[4]. O. Bertsekas and R. Gallager. . In Data Networks, 2nd Edition. Prentice -Hall, 1992.

[5]. G. Bianchi. Performance Analysis of the IEEE 802.11 Distributed Coordination Function. IEEE Journal on Selected Areas in Communications, 18(3):535–547, March 2000.

[6]. J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva. A Performance Comparison of Multihop Wireless Ad Hoc Network Routing Protocols. In Proceedings of the _ Q$R ACM/IEEE International Conference on Mobile Computing and Networking (MobiCOM'98), pages 85–97, Dallas, TX, October 1998.

[7]. J. Byers, M. Luby, M. Mitzenmacher, and A. Rege. Digital Fountain Approach to Reliable Distribution of Bulk Data. In ACM SIGCOMM Conference on Communications Architectures, Protocols and Applications, pages 56–67, Vancouver, September 1998.

[8]. F. Cal´ı, M. Conti, and E. Gregori. Tuning of the IEEE 802.11 Protocol to Achieve a Theoretical Throughput Limit. IEEE/ACM Transactions on Networking, 8(6), December 2000.

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

[10]. T. Chen, M. Gerla, and J. Tsai. QoS Routing Performance in a Multihop, Wireless Network. In Proceedings of the IEEE ICUPC'97, 1997.

[11]. R. R. Choudhury, X. Yang, R. Ramanathan, and N. Vaidya. Using Directional Antennas for Medium Access Control in Ad Hoc Networks. In Proceedings The Eighth Annual International Conference on Mobile Computing and Networking (MobiCOM'02), Atlanta, GA, Septemper 2002.

[12]. S. R. Das, C. E. Perkins, and E. M. Royer. Performance Comparison of Two On-demand Routing Protocols for Ad Hoc Networks. In Proceedings of the IEEE Conference on Computer Communications (INFOCOM), pages 3–12, Tel-Aviv, Isarel, March 2000.

[13]. D.Grossman. New Terminology and Clarifications for Diffserv. Request For Comments (Draft Stardard) 3260, Internet Engineering Task Force, April 2002.

[14]. K. Fall and K. Varadhan. ns Manual. http://www.isi.edu/nsnam/ns/doc/. The VINT Project.

[15]. J. Goodman and A. Greenberg. Stability of Binary Exponential Backoff. Journal of the ACM, 35(3), March 1998.

[16]. T. S. Ho and K. C. Chen. Performance Evaluation and Enhancement of CSMA/CA MAC Protocol for 802.11 Wireless LANs. In Proceedings of the IEEE PIMRC, October 1996.

[17]. IEEE. 802.11e Draft 3.1, May 2002.

[18]. D. B. Johnson and D. A. Maltz. Dynamic Source Routing in Ad Hoc Wireless Networks. In T. Imielinski and H. Korth, editors, Mobile Computing, pages 153–181. Kluwer Academic Publishers, 1996.

[19]. V. Kanodia, C. Li, A. Sabharwal, B. Sadeghi, and E. Knightly. Distributed Multi-Hop Scheduling and Medium Access with Delay and Throughput Constraints. In Proceedings of the Seventh Annual Internationa l Conference on Mobile Computing and Networking (Mobi-COM'01), Rome, Italy, July 2001.

[20]. H. Kim and J. C. Hou. Improving Protocol Capacity with Model-based Frame Scheduling in IEEE 802.11-operated WLANs. In Proceedings of the Ninth Annual International Conference on Mobile Computing and Networking (MobiCOM'03), pages 190–204, San Diego, CA, September 2003.

[21]. S. Lee, G.-S. Ahn, X. Zhang, and A. T. Campbell. INSIGNIA: An IP-Based Quality of Service Framework for Mobile Ad Hoc Networks. Journal of Parallel and Distributed Computing, Special issue on Wireless and Mobile Computing and Communications, 60:374–406, 2000.

[22]. J. Li, Z. Haas, M. Sheng, and Y. Chen. Performance Evaluation of Modified IEEE 802.11 MAC for Multi-channel Multi-hop Ad Hoc Networks. Journal of Interconnection Networks, 4(3), 2003.

[23]. H. Luo, S. Lu, and V. Bharghavan. A New Model for Packet Scheduling in Multihop Wireless Networks. In Proceedings of the Sixth Annual International Conference on Mobile Computing and Networking (MobiCOM' 00), Boston, MA, August 2000.

[24]. T. Nandagopal, T. Kim, X. Gao, and V. Bharghavan. Achieving MAC Layer Fairness in Wireless Packet Networks. In Proceedings of the Sisth Annual International Conference on Mobile Computing and Networking (MobiCOM'00), Boston, MA, August 2000.

[25]. K. Nichols and B. Carpenter. Definition of Differentiated Services Per Domain Behaviors and Rules for Their Specification. Request For Comments (Draft Stardard) 3086, Internet Engineering Task Force, April 2001.

[26]. C. E. Perkins and E. M. Royer. Ad-hoc On-Demand Distance Vector Routing. In Proceedings of the ___ V IEEE Workshop on

Mobile Computing Systems and Applications, pages 90–100, New Orleans, LA, February 1999.

[27]. E. M. Royer and C.-K. Toh. A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks. IEEE Personal Communications Magazine, 6(2):46–55, April 1999.

[28]. R. Rozovsky and P. Kumar. ”SEEDEX: A MAC Protocol for Ad Hoc Networks. In Proceedings of the ___ V ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc’01), Long Beach, CA, October 2001.

[29]. S. Shenker, C.Partridge, and R. Guerin. Specification of Guaranteed Quality of Service. Request For Comments (Draft Stardard) 2212, Internet Engineering Task Force, September 1997.

[30]. P. Sinha, R. Sivakumar, and V. Bharghavan. CEDAR: A Core Extraction Distributed Ad Hoc Routing Algorithm. In Proceedings of the IEEE Conference on Computer Communications (INFOCOM), pages 202–209, 1999.

[31]. I. C. Society. IEEE Standard for Wireless LAN-Medium Access Control and Physical Layer Specification, Novermber 1999.

[32]. S. Sundaramurthy and E. M. Belding-Royer. The AD-MIX Protocol for Encouraging Participation in Mobile Ad hoc Networks. In Proceedings of the International Conference on Network Protocols (ICNP), Atlanta, GA, November 2003.

[33]. N. Vaidya, P. Bahl, and S. Gupta. Distributed Fair Scheduling in a Wireless LAN. In Proceedings of the Sixth Annual International *Conference on Mobile Computing and Networking (MobiCOM’00)*, Boston, MA, August 2000.

[34]. A. Veres, A. T. Campbell, M. Barry, and L.-H. Sun. Supporting Service Differentiation in Wireless Packet Networks Using Distributed Control. *IEEE Journal of Selected Areas in Communications*, 19(10), October 2001.

[35]. X. Yang and N. Vaidya. Priority Scheduling in Wireless Ad Hoc Networks. In *Proceedings of the* _ _ V *ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc’02)*, Lausanne, Switzerland, June 2002.