A STUDY ON DISTRIBUTED PRIORITY SCHEDULING AND MEDIUM ACCESS CONTROL IN AD HOC NETWORKS

A.Raja,
Assistant Professor,
Department of Comnputer Science,
Kavitha's College of Arts and Science,
Vaiyappamalai, Namakkal,India.

Abstract: Ad hoc wireless network has been a most active research area for its flexibility in network construction. In ad hoc networks, contention-based MAC protocols, such as IEEE 802.11, are popular since they are easy to implement. However, these contention-based MAC protocols do not coordinate between nodes at different hops within a multi-hop flow. It has been pointed out that the 802.11 MAC cannot discover the optimum schedule of multi-hop transmissions. Distributed priority scheduling, a technique that piggybacks the priority tag of a node's head-of-line packet onto handshake and data packets; e.g., RTS/DATA packets in IEEE 802.11. By monitoring transmitted packets, each node maintains a scheduling table which is used to assess the node's priority level relative to other nodes. It incorporates this scheduling table into existing IEEE 802.11 priority back-off schemes to approximate the idealized schedule. In this paper we discussed medium access control and distributed priority scheduling concepts.

Keywords: Distributed Priority scheduling, Ad hoc network, Medium Access Control, contention based MAC Protocol

I. INTRODUCTION

The simplicity in deployment makes mobile ad hoc networks (which do not require any infrastructure) suitable for a variety of applications such as collaborative computing, disaster recovery, and battlefield communication. With the proliferation of communications and computing devices such as mobile phones, laptops, or Personal Digital Assistants (PDAs), Personal Area Networking (PAN), which is an ad hoc networking-based technology, has recently gained much interest. In ad hoc networks, transmitters use radio signals for communication. Generally, each node can only be a transmitter (TX) or a receiver (RX) at a time. Communication among mobile nodes is limited within a certain transmission range. And nodes share the same frequency domain to communicate. So, within such a range, only one transmission channel is used, covering the entire bandwidth. Unlike wired networks, packet delay is caused by not only the traffic load at the node, but also the traffic load at the neighboring nodes, which is called "traffic interference."

Medium Access Control (MAC) protocols play an important role in the performance of the Mobile Ad hoc Networks (MANETs) [1]. A MAC protocol defines how each mobile unit can share the limited wireless bandwidth resource in an efficient manner. The source and destination could be far away, and each time packets need to be relayed from one node to another in multihop fashion, a medium has to be accessed. Accessing a medium properly requires only informing the nodes within the vicinity of transmission. MAC protocols control access to the transmission medium. Their aim is to provide an orderly and efficient use of the common spectrum. These protocols are responsible for per-link connection establishment (i.e., acquiring the medium) and per-link connection cancellation (i.e., releasing the medium). One of the fundamental challenges in MANET research is how to increase the overall network throughput while maintaining low energy consumption for packet processing and communications. The low throughput is attributed to the harsh characteristics of the radio channel combined with the contention-based nature of MAC protocols commonly used in MANETs. Regarding the MAC protocol for a wireless MANET, the following performance measures should be considered [2]:

- **Throughput and delay:** Throughput is generally measured as the percentage of successfully transmitted radio-link level frames per unit time. Transmission delay is defined as the interval between the frame arrival time at the MAC layer of a transmitter and the time at which the transmitter realizes that the transmitted frame has been successfully received by the receiver.
- **Fairness:** Generally, fairness measures how fair the channel allocation is among the flows in the different mobile nodes. The node mobility and the unreliability of radio channels are the two main factors that impact fairness.
- **Energy efficiency:** Generally, energy efficiency is measured as the fraction of the useful energy consumption (for successful frame transmission) to the total energy spent.
- **Multimedia support:** This is the ability of a MAC protocol to accommodate traffic with different service requirements, such as throughput, delay, and frame loss rate.

Need for Medium Access Control (MAC) Protocols: There are several important issues in ad hoc wireless networks. Most ad hoc wireless network applications use the Industrial, Scientific and Medical (ISM) band that is free from licensing formalities [3,4]. Because wireless is a tightly controlled medium, it has a limited channel bandwidth that is typically much smaller than that of wired networks. Besides, the wireless medium is inherently error prone. Even though a radio may have sufficient channel bandwidth, factors such as multiple accesses, signal fading, and noise and interference can cause the effective throughput in wireless networks to be significantly lower. Because wireless nodes may be mobile, the network topology can change frequently without any predictable pattern.

Usually the links between nodes would be bidirectional, but there may be cases when differences in transmission power give rise to unidirectional links, which necessitate special treatment by the MAC protocols. Ad hoc network nodes must conserve energy as they mostly rely on batteries as their power source. Security issues should be considered in the overall network design, as it is relatively easy to eavesdrop on wireless transmission. Routing protocols require information about the current topology, so that a route from a source to a destination may be found. However, the existing routing schemes, such as distance-vector and link-state-based protocols, lead to poor route convergence and low throughput for dynamic topology. Therefore, a new set of routing schemes is needed in the ad hoc wireless context. The MAC layer, sometimes also referred to as a sub layer of the data-link layer, involves the functions and procedures necessary to transfer data between two or more nodes of the network. It is the responsibility of the MAC layer to perform error correction for anomalies occurring in the physical layer. The layer performs specific activities for framing, physical addressing, and flow and error controls. It is responsible for resolving conflicts among different nodes for channel access. Because the MAC layer has a direct bearing on how reliably and efficiently data can be transmitted between two nodes along the routing path in the network, it affects the quality of service (QoS) of the network. The design of a MAC protocol should also address issues caused by mobility of nodes and an unreliable time-varying channel.

II. CLASSIFICATION OF MAC PROTOCOLS

MAC protocols for ad hoc wireless networks can be classified into several categories based on various criteria such as initiation approach, time synchronization, and reservation approaches [6, 7]. Ad hoc network MAC protocols can be classified into three basic types [5].

- Contention-based protocols
- Contention-based protocols with reservation mechanisms
- Contention-based protocols with scheduling mechanisms

A) Contention-based protocols: These protocols follow a contention-based channel access policy. A node does not make any resource reservation a *priori*. Whenever it receives a packet to be transmitted, it contends with its neighbor nodes for access to the shared channel. Contention-based protocols cannot provide QOS guarantees to sessions since nodes are not guaranteed regular access to the channel. Random access protocols can be further divided into two types.

- **Sender-initiated protocols:** packet transmissions are initiated by the sender node.
- **Receiver-initiated protocols:** The receiver node initiates the contention resolution protocol

Sender-initiated protocols can be further divided into two types.

- **Single-channel sender-initiated protocols:** In these protocols, the total available bandwidth is used as it is, without being divided .A node that wins the contention to the channel can make use of the entire bandwidth.
- **Multichannel sender-initiated protocols:** In multichannel protocols, the available bandwidth is divided into multiple channels. This enables several nodes to simultaneously transmit data, each using a separate channel. Some protocols dedicate a frequency channel exclusively for transmitting control information.

B) Contention-based protocols with reservation mechanisms: Ad hoc wireless networks sometimes may need to support real-time traffic, which requires QOS guarantees to be provided. In contention-based protocols, nodes are not guaranteed periodic access to the channel. Hence they cannot support real-time traffic. In order to support such traffic, certain protocols have mechanisms for reserving bandwidth a *priori*. Such protocols can provide QOS support to time sensitive traffic sessions. These protocols can be further classified into two types.

- **Synchronous protocols:** Synchronous protocols require time synchronization among all nodes in the network, so that reservation made by a node is known to other nodes in its neighborhood. Global time synchronization is generally difficult to achieve.
- **Asynchronous protocols:** They do not require any global synchronization among nodes in the network. These protocols usually use relative time information for effecting reservations.

C) Contention-based protocols with scheduling mechanisms: These protocols focus on packet scheduling at nodes, and also scheduling nodes for access to the channel. Node scheduling is done in a manner so that all nodes are treated fairly and no node is started of bandwidth. Scheduling based schemes are also used for enforcing priorities among flows whose packets are queued at nodes. Some scheduling schemes also take into consideration battery characteristics, such as remaining battery power, while scheduling nodes for access to the channel.

Protocols in this category focus on packet scheduling at the nodes and transmission scheduling of the nodes. The factors that affects scheduling decisions

- Delay targets of packets
- Traffic load at nodes
- Battery power

In this section, some protocols are described.

1. DPS (Distributed priority scheduling and medium access in Ad Hoc Networks)

It presents two mechanisms for providing quality of service (QOS) for connections in ad hoc wireless networks.

- Distributed priority scheduling (DPS) – piggy-backs the priority tag of a node's current and head-of-line packets o the control and data packets The packets information are transmitted to its neighborhood, a node build a table (scheduling table) which maintains rank of position or priority of the packets and compare to the neighbor nodes. This rank is considered for back-off calculation and build schedule table with rank.
- Multi-hop coordination – extends the DPS scheme to carry out scheduling over multi-hop paths. The excessive delay incurred by a packet at the upstream nodes is compensated for at the downstream nodes.

Both schemes are fully distributed. They can be utilized for carrying time-sensitive traffic on ad hoc wireless network.

2. DWOP (Distributed Wireless Ordering Protocol)

A media access scheme along with a scheduling mechanism. It is based on the distributed priority scheduling scheme. It ensures the packet access medium in order specified by ideal reference scheduler like FIFO, virtual clock, or earliest deadline first.

3. DLPS (Distributed Laxity-based Priority Scheduling Scheme)

Scheduling decisions are made based on

- The states of neighboring nodes and
- feedback from destination nodes regarding packet losses

Packets are recorded based on their uniform laxity budgets (ULBs) and the packet delivery ratios of the flows. The laxity of a packet is the time remaining before its deadline. It maintains Scheduler Table (ST) and Packet Delivery Ratio Table (PDT). ST maintains sorted information of the packets with priority index. PDT maintains count of the packets transmitted and ACK is received for every flow passing through the nodes.

III. DISTRIBUTED PRIORITY SCHEDULING (DPS)

A protocol that falls under this category focus on packet scheduling at the nodes and transmission scheduling of the nodes. Scheduling decisions may take into consideration various factors such as delay targets of packets, laxities of packets, traffic load at nodes, and remaining battery power at nodes. In this section, scheduling based protocols (distributed priority scheduling (DPS)) is described.

A) Distributed Priority Scheduling and Medium Access in Ad Hoc Networks: This work, proposed in [18], presents two mechanisms for providing quality of service (QOS) support for connections in ad hoc wireless networks. The first technique called distributed priority scheduling (DPS), piggy-backs the priority tag of a node's current and head-of-line packets on the control and data packets. By retrieving information from such packets transmitted in its neighborhood, a node builds a scheduling table from which it determines its rank (information regarding its position as per the priority of the packet to be transmitted next) compared to other nodes in its neighborhood. This rank is incorporated into this back-off calculation mechanism in order to provide an approximate schedule based on the ranks of the nodes. The second scheme, called multi-hop coordination, extends the DPS scheme to carry out scheduling over multi-hop paths. The downstream nodes in the path to the destination increase the relative priority of a packet in order to compensate for the excessive delays incurred by the packet at the upstream nodes.

B) Distributed Priority Scheduling: The distributed priority scheduling scheme (DPS) is based on the IEEE 802.11 distributed coordination function[10]. DPS uses the same basic RTS-CTS-DATA-ACK packet exchange mechanism [8]. The RTS packet transmitted by a ready node carries the priority tag/priority index for the current DATA packet to be transmitted. The priority tag can be the delay target for the DATA packet. On receiving the RTS packet, the intended receiver node responds with a CTS packet. The receiver node copies the priority tag from the received RTS packet and piggy-backs it along with the source node id, on the CTS packet. Neighbor nodes receiving the RTS or CTS packets (including the hidden nodes) retrieve the piggy-backed priority tag information and make a corresponding entry for the packet to be transmitted, in their scheduling tables (STs). Each node maintains as ST holding information about packets, which were originally piggy-backed on control and data packets. The entries in the ST are ordered according to their priority tag values. When the source node transmits a DATA packet, its head-of-life packet information (consisting of the destination and source ids along with the priority tag) is piggy-backed on the DATA packet (head-of-line packet of a node refers to the packet to be transmitted next by the node) . This information is copied by the receiver onto the ACK packet it sends in response to the received DATA packet. Neighbor nodes receiving the DATA or ACK packets retrieve the piggy-backed information and update their STs accordingly. When a node hears an ACK packet, it removes from its ST any entry made earlier for the corresponding DATA packet. Figure 1 illustrate the piggy-backing and table update mechanism. Node I need to transmit a DATA packet (with priority index value 9) to node 2. It first transmits RTS packet carrying piggy-backed information about this DATA packet. The initial state of the ST of node 4 which is a neighbor of nodes 1 and 2 is shown in ST (a). Node 4, on hearing this RTS packet, retrieves the piggy-backed priority information and makes a corresponding entry in its ST, as shown in ST(b). The destination node 2 responds by sending a CTS packet. The actual DATA packet is sent by the source node once it receives the CTS packet. This DATA packet carries piggy-backed priority information regarding the head-of-line packet at node 1. On hearing this DATA packet, neighbor node 4 makes a corresponding entry for the head-of-line packet of node 1, in its ST. ST (c) shows the new updated status of the ST at node 4. Finally, the receiver node sends an ACK packet to node 1.

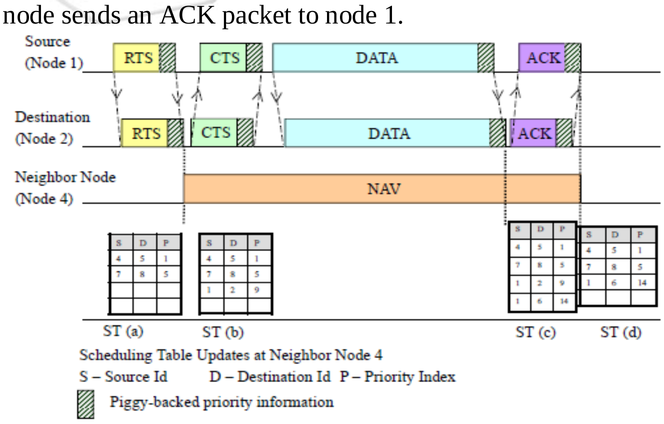

Figure 1: Piggy-backing and scheduling table update mechanism in DPS

When this packet is heard by node 4, it removes the entry made for the corresponding DATA packet from its ST. The state of the scheduling table at the end of this data transfer session is depicted in ST (d). In essence, each node's scheduling table gives the rank of the node with respect to other nodes in its neighborhood. This rank information is used to determine the back-off period to be taken by the node. The back-off distribution is given by

$$\text{Back-off} = \begin{cases} \mathrm{Unif}[0, 2^l \mathrm{CW_{min}} - 1], & r_j = 1, l < m \\ \alpha \mathrm{CW_{min}} + \mathrm{Unif}[0, \gamma \mathrm{CW_{min}} - 1], & r_j > 1, l = 0 \\ \mathrm{Unif}[0, 2^l \gamma \mathrm{CW_{min}} - 1], & r_j > 1, l \geq 1 \end{cases}$$

Where CW_{min} is the minimum size of the contention window. *r* is the rank in the scheduling table of the node's highest priority packet; *n* is the current number of transmission attempts made by the node; *nmax* is the maximum number of retransmissions permitted; α is a constant; and ϒ is a constant that is used to control the congestion in the second attempt for the highest ranked nodes.

Multi-Hop Coordination : By means of the multi-hop coordination mechanism, the excess delay incurred by a packet at the upstream nodes is compensated for at the downstream nodes[9]. When a node receives a packet, it would have already received the priority index of the packet piggy-backed on the previous RTS packet. In case the node is an intermediate node which has to further forward the packet, the node calculates the new priority index of the DATA packet in a recursive fashion, based on the received value of the priority index. If $d_{i,j}{}^k$ is the priority index assigned to the k^{th} packet of flow *i* with size l_i^k at its j^{th} hop, and if t_i^k is the time at which the k^{th} packet of flow *i* arrives at its first hop (the next hop node to the source node on the path to the destination), then the new priority index assigned to the received packet at intermediate node *j* is given as

$$d_{i,j}^k = \begin{cases} t_i^k + \delta_{i,1}^k, & j = 1 \\ d_{i,j-1}^k + \delta_{i,j}^k, & j > 1 \end{cases}$$

Where the increment of the priority index $\delta_{i,j}{}^k$ is a non-negative function of i,j,l_i^k, and t_i^k. Because of this mechanism, if a packet suffers due to excess delay at the upstream nodes, the downstream nodes increase the priority of the packet so that the packet is able to meet its end-to-end delay target. Similarly, if a packet arrives very early due to lack of contention at the upstream nodes, then the priority of that packet would be reduced at the downstream nodes. Any suitable scheme can be used for obtaining the values for $\delta_{i,j}{}^k$. One simple scheme, called uniform delay budget allocation, works as follows. For a flow I with an end-to-end delay target of D, the increment in priority index value for a packet belonging to that flow, at hop *j*, is given as , $\delta_{i,j}{}^k$ = DR , where K is the length of the flow's path. The distributed priority scheduling and multi-hop coordination schemes described above are fully distributed schemes. They can be utilized for carrying time-sensitive traffic on ad hoc wireless networks.

IV. CONCLUSION

As described in this paper, a centralized scheduler with knowledge of all packet priority indexes can in principle schedule packets in exact order of the ideal schedule. However, due to the distributed nature of *ad hoc* wireless networks, each node is equipped with its own buffer state, and at best partial information about other nodes. Thus, it is immediate that if the scheduler is distributed, with incomplete system information, the ideal schedule cannot be met exactly. To better approximate the ideal schedule, we propose to exploit the broadcast nature of the medium and piggyback priority indexes of the current and HOL packets. The piggyback mechanism allows for efficient exchange of information while imposing minimal overhead. Each node then maintains a local scheduling table and on hearing newly announced priority indices, adds them to the local table. This local table is then adaptively used to control the channel access policy used by the node. We emphasize that all policies are completely distributed with information exchange relying solely on existing broadcasts by each node. Using analytical and simulation based studies, we show that the piggybacked information can yield significant gains in the probability of transmitting packets in order of the ideal schedule, and corresponding reductions in packet delay.

REFERENCES

[1]. C. Siva Ram Murthy and B. S. Manoj: "Ad Hoc Wireless Networks: Architectures and Protocols".

[2]. Marek Natkaniec,., Szymon Szott., 2013 ―A Survey of Medium Access Mechanisms for Providing QoS in Ad-Hoc Networks‖.

[3]. S. Chakrabarti and A Mishra, 2001 ―QoS Issues in Ad Hoc Wireless Networks,‖ IEEE Commun. Mag.

[4]. A. Abbas and O. Kure, 2010 ―Quality of Service in mobile ad hoc networks: a survey,‖ International Journal of Ad Hoc and Ubiquitous Computing,vol. 6.

[5]. Amjad Ali, Wang Huiqiang, Lv Hongwu, and Xiaoming Chen 2014 ‖A Survey of MAC Protocols Design Strategies and Techniques in Wireless Ad Hoc Networks‖.

[6]. S. Van den Heuvel-Romaszko and C. Blondia, 2004 ―A survey of MAC protocols for ad hoc networks and IEEE 802.11‖.

[7]. R. Jurdak, C. Videria Lopes, and P. Baldi, "A Survey, Classification and Comparative Analysis of Medium Access Control Protocols for Ad Hoc Networks," *IEEE Commun. Surveys*, 2004.

[8]. M A Khan, Tazeem Ahmad Khan, M T Beg 2012 " RTS/CTS Mechanism of MAC Layer IEEE 802.11 WLAN in Presence of Hidden Nodes ", IJEIT.

[9]. 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 ACM MOBICOM '01*, Rome, Italy, July 2001.

[10]. I. Aad and C. Castelluccia. Differentiation mechanisms for IEEE 802.11. In *Proceedings of IEEE INFOCOM'01*, Anchorage, Alaska, April 2001.