A Survey on MAC Protocols for Provisioning QOS in Ad-Hoc Wireless Networks

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Abstract— Past few years, research has increased on quality of service (QOS) provisioning in wireless ad hoc networks. They do not require any fixed infrastructure. Nodes are themselves to solve topology changes due to mobility. Such a network needs to support the applications that generate multimedia and real-time traffic. In this regard, we have to provide QOS support for multimedia traffic in Ad hoc wireless networks, and need solutions that not only address the issue of minimizing the end-to-end delay and increase robustness to packet losses but also lower the overhead involved in transmission of high frame rate multimedia traffic. A lot of research has been conducted on MAC protocols and QOS provisioning in wireless ad-hoc networks. In this paper, we discuss the issues and challenges in the same and review some of the MAC QOS solutions are proposed.

Keywords—QOS, MAC, collision, RTS, CTS, ACK.

I. INTRODUCTION

Ad hoc networks are autonomous and self-organized networks. They do not require any fixed infrastructure and nodes themselves to solve topology changes due to mobility. This lack of centralized infrastructure and applications such as real-time or multimedia application require the network to provide guarantees on the Quality of Service (QOS) of the connection. Because, the boundary between the service provider (network) and the user (host) is not defined clearly, thus making it essential to have better coordination among the hosts to achieve QOS guarantees. QOS[2] defines communication requirements, such as bandwidth, delay, jitter, and packet loss. Voice, data, image, and video have different bandwidth requirements. Some classes of traffic, like voice, are also much more sensitive to delays than other classes, such as data.

A. Challenges and issues for QOS Provisioning in Ad-Hoc Wireless Network

The major issues are [9-12]:

- **Dynamically varying network topology** - The topology of the network varies dynamically. Therefore, it is difficult to design a scheme or a protocol that is able to provide hard guarantees about the QOS desired by an application.

- **Limited availability of resources such as bandwidth and battery power** - The resources of the devices used are limited; therefore, any such scheme or a protocol should be a light-weight scheme. In other words, the protocol should not consume a significant amount of energy or should not incur a large amount of computational or communication overheads.

- **Lack of central coordination, imprecise network state information, unrestricted mobility of hosts, error prone shared radio channel.**

B. QOS Provision Scheme

QOS provides level of Services and attain more deterministic network behavior by better delivery of information and resources are better utilized. It can be done through several ways, viz., per flow, per link, or per node. QOS provisions are provided the following network operation incorporated with the functionalities:

- Traffic classifier
- Resource reservation
- Scheduling
- Admission control.
C. QOS Parameters

Some level of guarantee or assurance should be provided to an application depends on level of services are required. The following QOS parameter [1] to be considered depends upon specific requirements of an application.

- Delay: Multimedia and real-time application traffics are delay-sensitive may require the QOS in terms of delay guarantees. On-Demand and live audio-video communication accept end-to-end delay with maximum 400 ms of.
- PDR: Certain application may require a guarantee that the packets are delivered from a given source to destination reliably. Improving Packet Delivery Ratio, we can reduce end-to-end delay. That is, the proportion of packets that reaches the destination within the deadline.
- Packet Loss: Multimedia applications can tolerate packet losses up to 5%. The packet cannot reach the destination within specified deadline, it becomes useless.
- Bandwidth: The one of the most important parameter of QOS Provisioning in ad-hoc wireless network for multimedia or real time application. Some applications may require that the packets should flow at certain minimum bandwidth. But Multimedia not likes to send raw information without compressing it due to huge bandwidth requirements.

D. Designing Options

The solution can avail at various layer of network protocol stack that support multimedia traffic and fulfill the challenges of QOS Provisioning in Ad-Hoc Wireless networks. Hereby, we need solutions that not only address the issue of minimizing the end-to-end delay requiring increase robustness to packet losses and lower the overhead involved in transmission of high frame rate multimedia traffic. This involves the design of suitable Medium Access Control (MAC) algorithms, resource reservation schemes, priority scheduling algorithms, and routing and multicasting mechanisms that take into account peculiar characteristics of multimedia traffic and unique characteristics of Ad hoc wireless networks. In this paper, we discuss MAC protocols that support QOS Provision for Multimedia application.

E. Necessity of MAC

MAC layer is sub layer of Data Link Layer involves the functions and procedures necessary to transfer data between two or more nodes of the network.

It is responsible for error correction of anomalies occurring in the physical layer, framing, physical addressing, and resolving conflicts occurring in number of nodes to access the channel. Due to Mobility of nodes, in Ad-hoc wireless network, we may face the huge challenges of ad-hoc such as the lack of centralized control may get loss of connectivity, network partitioning, and bit errors. This involves bandwidth inefficiency utilization, not supported real–time traffic, and hidden/exposed terminal problem express collisions. The design of a MAC protocol has to address on how reliably and efficiently data can be transmitted in this type of network.

The primary responsibility of a MAC protocol [3] in Ad-hoc Wireless Network is to control the access to the medium that is shared by several network nodes. It deals with QOS that allow fair access to the shared radio medium, operation of the protocol should be distributed, should support real-time traffic, the access delay must be minimized, available bandwidth must be utilized efficiently, fair bandwidth allocation to competing nodes, control overhead must be minimized, the effects of hidden/exposed terminals must be minimized, scalable, minimize power consumption, provide synchronization between nodes.

F. Classification of MAC QOS

Polling, Token Based, TDMA, FDMA, and CDMA are contention free protocol that avoid contention and don’t have reservation, scheduling mechanism. It is designed to approach static networks and not in aware of collision.

Contention based scheme make contention [5] among node for acquiring resources. Winning nodes are access the channel for utilizing the resources as content basis.
It is suitable for networks with centralized control or distributed networks and uses RTS/CTS control packets to prevent collision. I.e., the nodes to transmit data if both sender and receiver make assurance to involve transmission without interruption of other nodes. Contention based-scheme such as sender-initiated and receiver-initiated, single or multiple channels, power-aware, directional, and MAC QOS discussed in Section II, Conclusion and Future Work given in Section III.

II. MAC QOS PROTOCOL

In this section, we discuss above mentioned in figure 2 MAC classification protocols and their features.

A. Contention Based Scheme

- Contention based scheme contention for reservation initiated by sender or receiver. Before sending data, sender initiate/make prior reservation for transmission, is called “Sender-initiated”. The “receiver-initiated” protocol requesting to receive the data has sent by sender. The receiver polls sender node and it has some data for the receiver, it is allowed to transmit after confirming polled.
- Transmission may involve single or multiple channels. Single channel protocol set up reservation for a particular channel to transmit data in the same channel with same frequency. Multiple channel protocols use more than one channel in order to coordinate connection sessions among the transmitter and receiver nodes
- Power-aware protocol is important in the context of low power devices, to have energy efficient protocols at all layers of the network model.
- Directional or unidirectional antenna protocol directing the signal for sensing the nodes to make transmission by single or bi-direction.
- QOS-aware protocol provides expected level of QOS what demands from users. It is responsible for MAC layer has a direct bearing on how reliably and efficiently data can be transmitted from one node to the next along the routing path in the network.

A.1 MACA (Multiple Access Collision avoidance)

It is used to overcome the Hidden/Exposed Terminal problems caused by CSMA [13]. The idea behind this protocol is that any neighboring node that overhears an RTS packet has to defer its own transmissions until sometime after the associated CTS packet would have finished, and that any node overhearing a CTS packet would defer for the length of the expected data transmission. MACA is effective because RTS and CTS packets are significantly shorter than the actual data packets, and therefore collisions among them are less expensive compared to collisions among the longer data packets. However, the RTS-CTS approach does not always solve the hidden terminal problem completely, and collisions can occur when different nodes send the RTS and the CTS packets. Problems and solution are given the below:

- Starvation of flows :
  Use field of back-off value, counter, and minimize the size of contention window after successful transmission.
- Fast adjustment of CW:
  Multiplicative increase when collision, linear decrease when success.
- An exposed node is free to transmit:
  Node receive data from s1, receive CTS from R2 may collide, CW increase at S2 unnecessarily. We solve this by use of small data sending packet (DS) to update information.
- Neighbor receivers’ problem: Node receives two RTS from different sender node. It can solve by use of RRTS.

A.2 DBTMA (Busy Tone Multiple Access Protocol)

DBMTA sends RTS packets on data channel to set up transmission requests by using two different busy tones. The sender of the RTS sets up a transmit-busy tone (BTt). Correspondingly, the receiver sets up a receive-busy tone (BTr) in order to acknowledge the RTS, without using any CTS packet. The DBTMA scheme [20] uses out-of-band signalling to effectively solve the hidden and the exposed terminal problems.
A.3 MACA-BI (Multiple Access Collision Avoidance-By Invitation)

MACA-BI [3] is a receiver-initiated protocol and it reduces the number of such control packet exchanges. Instead of a sender waiting to gain access to the channel, MACA-BI requires a receiver to request the sender to send the data, by using a “Ready-To-Receive” (RTR) packet instead of the RTS and the CTS packets. Therefore, it is a two-way exchange (RTR-DATA) as against the three-way exchange (RTS-CTS-DATA) of MACA [13]. Since the transmitter cannot send any data before being asked by the receiver, there has to be a traffic prediction algorithm built into the receiver so it can know when to request data from the sender.

A.4. MARCH (Media access with reduced handshake)

Nodes know about packet arrival at neighboring node listening to CTS signals and relay packet, if it sends a CTS packet to the concerned node. It carries MAC address of sender and receiver, route identification number that reduces control overhead and increase throughput.

B. Contention Based Scheme with Reservation Scheme

- Use bandwidth reservation technique and provide QOS.
- The contention takes place only during the bandwidth reservation phase. Nodes who make contention to reserve its bandwidth, they gets an exclusive to access the media.

B.1 D-PRMA (Distributed Packet Reservation Multiple Access)

D-PRMA is a TDMA [7] based scheme where the channel is divided into frames. Each minislot contains two control fields, RTS/BI – Request To Send / Busy Indication and CTS/BI – Request To Send / Busy Indication. The competition for slots is a certain period from the beginning of every slot and it is reserved for carrier-sensing. The nodes compete for the first minislot in each slot. The winning one transmits a RTS packet through the RTS/BI part of the first minislot. The receiver responds by sending a CTS packet through the CTS/BI field. Thus, the node is granted all the subsequent minislots [1]. In addition to that, this very same slot in the subsequent frames is reserved for the same node, until it ends its transmission. Within a time slot, communication between the source and destination nodes is done either by Time Division Duplexing (TDD), or by Frequency Division Duplexing (FDD). There are two rules for the reservation, which prioritize voice traffic:

- Contention for the first minislot is done with probability 1 for voice traffic, and a smaller probability for other traffic.
- The reservation of a minislot brings reservation of the subsequent slots only if the winning node is a voice one.

B.2 CATA (Collision avoidance time allocation Protocol)

CATA provides support for collision-free broadcast and multicast traffic. The first four minislots are control ones, CMS, only the fifth is used for data transmission, the receiver of a flow must inform other potential source nodes about the reservation of the slot on which it is currently receiving packets, and also inform them about interferences in the slot. Nodes contend for and reserve time slots by means of a distributed reservation and handshake mechanism. Negative acknowledgements are used at the beginning of each slot for distributing slot reservation information to senders of broadcast or multicast sessions. Nodes contend for and reserve time slots by means of a distributed reservation and handshake mechanism

B.3 HRMA (Hop-Reservation Multiple Access)

HRMA uses a reservation and handshake mechanism to enable a pair of communicating nodes to reserve a frequency hop, thereby guaranteeing collision-free data transmission. A frequency hop is reserved by contention through a request-to-send/clear-to-send exchange between a sender and a receiver. A common frequency hop is used to permit nodes to synchronize with one another.

HRMA [8] can be treated as a TDMA scheme, where each time slot is assigned a specific frequency and subdivided into four parts - synchronizing, HR, RTS and CTS periods. One of the N available frequencies in the network is reserved specifically for synchronization. The remaining N-1 frequencies are divided into M = floor ((N-1)/2) pairs of frequencies. For each pair, the first frequency is used for Hop Reservation (HR), RTS, CTS and data packets, while the second frequency is used for ACK packets.

A successful exchange leads to a reservation of a frequency hop, and each reserved hop can remain reserved with a reservation packet from the receiver to the sender, which prevents those nodes that can cause interference from attempting to use the reserved frequency hop. After a hop is reserved, a sender is able to transmit data beyond the normal frequency-hop dwell time on the reserved frequency hop.
Distributed priority scheduling and medium for transmitting best effort packets are asynchronous with various lengths. At nodes are asynchronous with varying lengths, at the same time maximizing the statistical multiplexing gain. Nodes use a collision-handshake mechanism and soft reservation mechanism in order to contend for and effect reservation of time slots. It allows any urgent node transmitting packets generated by real-time applications, to take the radio resources from another node of non-real time application on-demand basis.

The main features of this protocol:
- Unique frame structure
- SR capable for distributed and dynamic scheduling, and priority assignment
- Update policies
- Time-constrained back-off algorithm.

B.5 FPPR (Five-Phase Reservation Protocol)

It is a single-channel time division multiple access (TDMA)-based broadcast scheduling protocol. Nodes use a contention mechanism in order to acquire time slots. This protocol is fully distributed, so it offers multiple reservations at simultaneously. And it assumes the availability of global time at all nodes. The reservation takes five phases: reservation, collision report, reservation confirmation, reservation acknowledgement, and packing and elimination phase. It has two frames: Reservation (RS) and Information Phase (IS). In order to reserve an IS, a node needs to contend during the corresponding RS where it composed by M reservation Cycle (RC). Nodes don’t need to distribute the information other than one-hop neighbor nodes before reservation becomes successful.

B.6 MACA/PR (MACA with Piggy-Backed Reservation)

It provides real-time traffic support in multi-hop wireless networks. This MAC protocol is based on MACAW with the provisioning of non-persistent CSMA. The main components of MACA/PR are:
- A MAC Protocol
- Reservation Protocol
- QOS Routing Protocol

While providing guaranteed bandwidth support for real-time packets, at the same time it provides reliable transmission of best-effort packets. The reservations made at nodes are asynchronous with varying lengths.

And Each node maintains a reservation table (RT) which record all the reserved transmit/receive slots/windows within its transmission range.

B.7 RTMAC (Real-Time Medium Access Control Protocol)

It provides a bandwidth reservation mechanism for supporting real-time traffic in ad hoc wireless networks. RTMAC consists of two components:
- A MAC layer protocol is a real-time extension of the IEEE 802.11 DCF.
- A medium-access protocol for best-effort traffic
- A reservation protocol for real-time traffic
- A QOS routing protocol is responsible for end-to-end reservation and release of bandwidth resources.

A separate set of control packets has used
- ResvRTS, ResvCTS, ResvACK: used for effective bandwidth reservation for real-time packets.
- RTS, CTS, ACK: used for transmitting best-effort packets.

In Order to give high priority for real-time packets and waiting time for transmitting ResvRTS is reduced half to DCF inter-frame Space for best-effort packets.

C. Contention Based Protocol with Scheduling Mechanism

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.

C.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.
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- 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.

C.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.

C.3 DLPS (Distributed Laxity-based Priority Scheduling Scheme)
Scheduling decisions are made based on
- The states of neighbouring 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. CONCLUSION
This literature survey made an overview for the research work on QOS provisioning for MAC Protocol in Ad-Hoc Wireless Networks. Here, we are known the characteristic, and issues of Ad-hoc wireless network, why we aware of QOS provision in such a network, and how can be solvable by MAC Scheme. Hence, we have discussed many MAC protocols and identified their features.

Most of the protocols have described in this survey are major significance of QOS related research. This area of study is prominent challenging in the context of Ad-Hoc wireless networks because of their frequently changing network topology, not stable in channel conditions, mobility of nodes, limited battery and computational power, etc. All these schemes are identified and observed from this survey.

REFERENCES