IEICE TRANS. INF. & SYST., VOL.E95–D, NO.2 FEBRUARY 2012

PAPER *Special Section on Architectures, Protocols, and Applications for the Future Internet*

Two Phase Admission Control for QoS Mobile Ad Hoc Networks

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SUMMARY In this paper a novel and effective two phase admission control (TPAC) for QoS mobile ad hoc networks is proposed that satisfies the real-time traffic requirements in mobile ad hoc networks. With a limited amount of extra overhead, TPAC can avoid network congestions by a simple and precise admission control which blocks most of the overloading flow-requests in the route discovery process. When compared with previous QoS routing schemes such as QoS-aware routing protocol and CACP protocols, it is shown from system simulations that the proposed scheme can increase the system throughput and reduce both the dropping rate and the end-to-end delay. Therefore, TPAC is surely an effective QoS-guarantee protocol to provide for real-time traffic.
key words: *quality of service (QoS), ad hoc on-demand distance vector (AODV), contention-aware admission control protocol (CACP)*

1. Introduction

A mobile ad hoc network is a collection of mobile nodes that can communicate with each other via multi-hop wireless links without any centralized management. Each node in the network acts as a host and a switch simultaneously and must cooperate with each other to provide a message-transmission path from source to destination. A multi-hop route needs to be established before message transmission begins.

The goal of any quality of service (QoS) supports in a communication network is usually to provide services with guarantee in terms of bandwidth, delay, or jitter. To provide such guarantee, the media control (MAC) layer is responsible for the transmission scheduling at individual node, while the network layer must consider resource allocation along the end-to-end route of a message flow. The main problem originates from the shared nature of the wireless medium, that is, all communications between nodes will contend with each other for the same channel resource. Hence, it is necessary to have a mechanism to prevent any flow from consuming too much resource and disrupting the QoS guarantee to other flows.

Usually, in traditional on-demand routing protocols such as ad hoc on-demand distance vector (AODV) [1], [2] and dynamic source routing (DSR) [3], [4] algorithms, the flooding method is used to find the possible routes to the destination without considering the capability of network resource, e.g. available bandwidth, to support the new traffic. These strategies may end up with huge permitted message transmissions become very large and result in network congestion, longer delay, and possible loss of packets. In order to avoid this problem, some kinds of network traffic control or admission control must be employed on route establishment process, especially when services with real-time QoS requirement are necessary to the system. These controls are based on the flow's bandwidth requirement and nodes' available bandwidth.

Many protocols [5]–[12] have been proposed to provide QoS services for the ad hoc networks. One of these proposals is QoS-aware routing protocol [5] based on the AODV protocol, which makes use of neighbors' available BWs and incorporates an admission control to meet the QoS requirements of real-time applications. Another QoS-routing protocol is contention-aware admission control protocol (CACP) [6] based on the DSR protocol, which carries out admission control by using the knowledge of local resources and the route information through a complex reply process. Both these protocols support QoS services for real-time applications, however, they either add extra overhead to the network or require a complex process to reach a precise admission control.

For providing a better performance, QoS admission control routing protocol (QACRP) based on the AODV protocol was proposed in [7] which discussion focuses mainly on the admission control and route establishment for QoS-flow. QACRP consider neither route-setup for many QoS-flows, nor the possible modification of the routing table at each node. In other word, the QACRP is still source-destination pair based, which can not work well for QoS-service. The QoS route-establishment must be for each individual data flow, not for each source-destination pair. This is the key factor on which the QoS routing protocols are different from the conventional ones. To deal with this issue, a novel two phase admission control (TPAC) protocol for QoS mobile ad hoc networks based on AODV and QACRP is proposed in this paper. The TPAC protocol is truly per flow based and with a limited amount of extra overhead, TPAC can avoid network congestions by a simple and pre-

Manuscript received May 10, 2011.
Manuscript revised September 20, 2011.
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DOI: 10.1587/transinf.E95.D.442

cise admission control which blocks most of the overloading flow-requests in the route discovery process.

The content of this paper is organized as follows: Section 2 describes the related routing protocols. The proposed TPAC design is presented in Sect. 3. Section 4 compares the system performances of TPAC with those of CACP, QoS-aware routing protocol and basic AODV. Finally, a conclusion is given in Sect. 5.

2. Related Work

Due to its wide availability, IEEE 802.11 is adopted as the MAC protocol for the considered mobile multihop ad hoc networks. The 802.11 MAC protocol and some QoS-routing protocols will be introduced briefly in this section.

2.1 IEEE 802.11 MAC

IEEE 802.11 standard defines the physical layer (PHY) specification and MAC protocol for wireless local area networks (WLAN). The working modes of MAC layer include distribution coordination function (DCF) and point coordination function (PCF). Since PCF mode is optional and only usable on the infrastructure network configurations, we will concentrate on DCF mode for ad hoc networks without access point (AP) or coordinator.

In DCF mode, carrier-sense multiple access (CSMA) protocol is adopted to minimize collision problem between neighboring stations (STAs) or nodes. Besides, this standard also makes use of an RTS-CTS mechanism (i.e. CSMA/CA protocol) to avoid hidden node problems. However, since the RTS/CTS exchange requests much overhead, it is inefficient to use this protocol for short data packet transmissions.

2.2 Routing Algorithms with QoS Consideration

AODV protocol and DSR protocol are popular routing schemes used in the ad hoc networks. Both schemes set up a new route for a source-destination pair by using route request (RREQ) and route reply (RREP) if it is necessary. The primary difference is that, in DSR scheme the full route information is carried in each data packet, while in AODV scheme the data packets are routed to the destination by using the information stored in the routing table at each relay node. Besides, every node will broadcast "Hello" packets to its neighbors periodically to declare its health in AODV scheme, but it won't in DSR scheme. Conventionally, both protocols do not have any QoS-consideration. Hence, the QoS-aware routing protocol [5] based on AODV and the contention-aware admission control protocol (CACP) [6] based on DSR were proposed to provide QoS services.

Two key processes are usually needed in the QoS routing schemes: one is the available bandwidth estimation and the other is the admission control. In the QoS-aware routing protocol, two schemes are proposed for available BW estimation: "Listen" bandwidth estimation and "Hello" bandwidth estimation.

1) "Listen" Bandwidth Estimation: Each node directly listens to and traces the channel state to determine the available bandwidth during a particular time interval. The IEEE 802.11 MAC can utilize both physical and virtual carrier sense (via the network allocation vector (NAV)) to distinguish the free and busy time interval. Hence, the "Listen" method to estimate the residual bandwidth (RBW) is straightforward for IEEE 802.11.

2) "Hello" Bandwidth Estimation: Each node determines its own consumed bandwidth by monitoring the transmitted packets. Then, this value is updated, 'piggybacked on the "Hello" packet, and broadcasted to all neighbors periodically. In particular, extra fields of <self-ID, consumed bandwidth, timestamp> and <neighbors i's ID, neighbors i's consumed bandwidth, timestamp> ($i = 1 \ldots n$, n is the number of neighbor nodes) are added to "Hello" packets and broadcasted to all neighbors. By this way, every node can learn the bandwidth consumption of its first-tier neighbors' and second-tier neighbors', and then can estimate the available bandwidth or RBW for itself. In general, the "Hello" scheme can get a more accurate estimation of local RBW than the "Listen" scheme. However, it requests much extra overhead in Hello packets.

The QoS-aware routing algorithm decides to accept or reject an incoming flow in the route-request (RREQ broadcast) based on the estimated local RBW. However, it is noted that an admitted incoming flow will affect not only the local node but also the nodes within the interference (carrier-sense) range of the route. Because the RREQ packet doesn't carry enough information about the nodes within the interference range of the route the QoS-aware routing protocol with either bandwidth estimation scheme can not provide a precise admission control in the route-discovery process.

In the CACP routing algorithm [6] which is based on DSR routing protocol, the "Listen" scheme for the RBW estimation is employed. The CACP performs two processes for admission control, the partial admission control in the route-request phase and the full admission control in the route-reply phase. For example, when Node A receives an RREQ packet of a new flow with bandwidth request W, it will calculate the possible bandwidth consumption B_c. $B_c = N_{ct} \times W$, where N_{ct} is the contention count defined as the number of nodes on the route, whose transmission may interfere with the message transmission from Node A. Then Node A will decide to discard the RREQ packet (i.e., reject to be a relay node of this flow) if the local RBW is less than B_c.

Since RREQ packets only contain the information of partial route, the value of N_{ct} may not be correct in the calculation of B_c. Hence, in the route-reply phase, when a node, for example Node B, receives an RREP packet, which contains the whole information of the complete route, it will recalculate the bandwidth consumption B_c for the flow more precisely. If the local RBW is larger than B_c, Node B will broadcast an admission request packet to its c-neighbors (the neighbors which are within the carrier-sensing range, but not on the route). When a c-neighbor receives this admission request packet, it will feedback a rejection message if it can not tolerate the impact of this flow. If Node B does not receive any rejection message for a certain period, it will assume the full admission control is successful and forward the RREP packet to the next upstream hop on the route.

The admission control of CACP is more precise than that of QoS-aware routing protocol because the impacts on the c-neighbors have been considered. However, the full admission control process in the route-reply phase is complex and requests a large amount of overhead.

3. Two Phase Admission Control Protocol

A novel routing protocol called two phase admission control (TPAC) for QoS mobile ad hoc networks based on the AODV protocol is proposed in this paper. The TPAC protocol offers less precision on admission control but with much less complexity when compared with the CACP protocol, and offers more precision on admission control with less overhead when compared with QoS-ware routing protocol with "Hello" bandwidth estimation. Like the QoS-aware routing protocol and the CACP protocol, the TPAC routing protocol also contains two major processes: bandwidth estimation and route-discovery with admission control.

3.1 Bandwidth Estimation

The values of the bandwidth requirement (BWQ) of the incoming flow local RBW and the neighbors' RBWs are essential for the proposed TPAC routing protocol to support QoS routing process. The BWQ should be determined by the source node and conveyed in the RREQ packet. The possible scheme to determine the local RBW and neighbors' RBWs based on IEEE 802.11 MAC/PHY specifications are depicted in the following subsections.

3.1.1 Estimation of Local Residual Bandwidth (RBW)

The local RBW is defined as the unoccupied bandwidth at a given node. Each node can estimate its own local RBW by periodically monitoring the network activities. In the TPAC protocol, the simple "listen" bandwidth estimation scheme in the QoS-aware routing protocol can be used to estimate the local RBW as

$$\mathrm{RBW} = (\mathrm{T}_{\mathrm{idle}}/\mathrm{T}_{\mathrm{period}}) \times \mathrm{C}, \quad (1)$$

where $\mathrm{T}_{\mathrm{idle}}$ is the amount of idle channel time during a period of $\mathrm{T}_{\mathrm{period}}$ and C is the transmission data rate defined in the physical layer.

3.1.2 Acquisition of Neighbors' Residual Bandwidths

In the TPAC protocol, the "Hello" packets of AODV are modified to include the local RBW of the transmitted node. It is similar to the "Hello" scheme of the QoS-aware routing protocol, but different in two aspects. One difference is that local RBW instead of local consumed bandwidth is conveyed. Another difference is that only local RBW is disseminated. Hence, the added overhead is much less because it does not contain the neighbors' RBWs. However, every node can only get the information of one-hop neighbors' RBWs.

3.2 Route-Discovery with Admission Control

Since the QoS guarantee is per data flow based, the QoS route-establishment must be for each individual data flow, not for each source-destination pair. This is the key factor on which the QoS routing protocols are different from the conventional ones. Hence, a complete routing protocol must consider not only the establishment of the QoS routes, but also the modification of essential protocol components such as routing table and packet formats. To deal with such issue, hence the route-discovery process of the AODV protocol is modified in this proposed TPAC protocol on several aspects.

One modification is that the routing table at each node must indicate the next-hop node for each data flow, not for each destination. Hence, as shown in Fig. 1, the destination IP address and destination sequence number in the original format are replaced by flow-ID, which is identified by the fields of source IP address and source sequence number conveyed in the RREQ of the flow. Another modification is that the RREQ packet (shown in Fig. 2) needs to contain the bandwidth requirement (BWQ) of the data flow and the minimal RBW of local and neighbors' RBW of node and previously two hops on the route. The original and new formats of the RREQ packet are shown in Fig. 2 in which Min_RBWn-1 is defined as Min(local RBW, neighbors' RBW) for the previously node of Node n. Note that the fields of original (source) IP address and original (source) sequence number are used to identify this data flow.

For the QoS-route discovery, the TPAC protocol performs two bandwidth-check phases as the CACP scheme does. The first phase is the partial bandwidth check process and the second phase is the full bandwidth check process.

Destination IP Address
Next Hop IP Address
Destination Sequence Number
Hop Count
Lifetime

(a)

Flow ID {Source IP Address, Source Sequence Number}
Next Hop IP Address
Hop Count
Lifetime

(b)

Fig. 1 Modification of routing table: (a) Original format. (b) New format.

Type	J	R	G	D	U	Reserved	Hop Count
RREQ ID							
Destination IP Address							
Destination Sequence Number							
Original IP Address							
Original Sequence Number							

(a)

Type	J	R	G	D	U	BWQ	Hop Count
RREQ ID							
Destination IP Address							
Destination Sequence Number							
Flow-ID{Original IP Address, Original Sequence Number}							
$\mathrm{Min\_RBW}_{n-2}$	$\mathrm{Min\_RBW}_{n-1}$						

(b)

Fig. 2 Modification of RREQ packet: (a) Original format. (b) New format.

However, instead of a complex process of the route-reply phase in the CACP scheme, the full bandwidth check in the TPAC protocol is done by the destination node only. The two bandwidth-check processes are described individually in the following subsections.

3.2.1 Partial Bandwidth Check Process

Once the source node receives a data flow request from its application layer, it will determine the BWQ of this data flow first. The BWQ value can either come from the application layer or be calculated (estimated) with the knowledge of data type and transmission information of the data flow. For example, for a constant-bit-rate (CBR) flow, the BWQ can be easy determined if the packet generating rate and packet length are known. Then the source node starts the partial bandwidth check process to establish the virtual connection from the source node to the destination node.

In a practical system, the interference range is usually greater than the communication range (i.e., one-hop range). Here, we assume that the interference range can reach two-hop neighbors. For example, as shown in Fig. 3 the nodes A, C and F are in the B's communication range and the nodes A, C, D, F and S are in the B's interference range. This means that the transmission of any two-hop neighbors should be taken into account in the bandwidth usage of a node.

Hence, to support a data flow, each node has to estimate the bandwidth requirement not only for it own transmission but also for the possible occupancy of the interference from the one-hop and two-hop neighbors. Based on this consideration and similar to that of the CACP protocol, a contention count N_{ct} for each node is defined as the number of nodes which will occupy the local RBW due to the setup of a new data flow. When it receives an RREQ packet during the route-discovery phase, each node determines its N_{ct} by

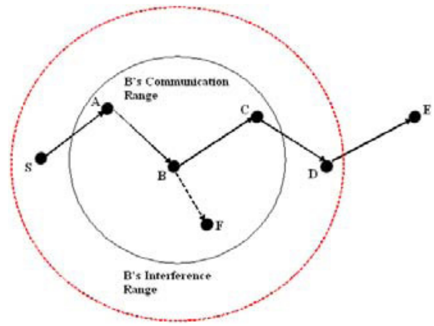


Fig. 3 Node B's communication and interference range.

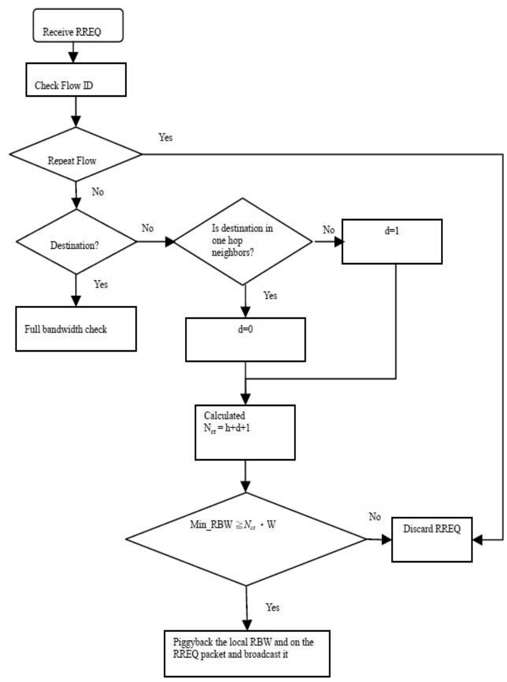


Fig. 4 Process of partial bandwidth check.

$$N_{ct} = \mathrm{h} + \mathrm{d} + 1 \tag{2}$$

In (2), h = hop count (the number of hop from the source node) if hop count > 2, h = 2 if hop count < 2; d = 0 if the destination node is a neighbor, d = 1 if not. It is obvious the values of Nct may not be correct due to the lack of knowledge of full route information.

In the proposed TPAC protocol, any node (including the source and destination nodes) cannot admit the route for a data flow with BWQ = W unless the following two conditions are satisfied:

$$\mathrm{Min\_RBW} \geqq N_{ct} \cdot \mathrm{W} \tag{3}$$

If the node does grant the route, it will piggyback its Min_RBW on the RREQ packet and broadcast it to all neighbors. The whole procedure of partial bandwidth check phase is show in Fig. 4.

Figure 5 is an example of the partial bandwidth check process for the routing-discovery in which Node S is the

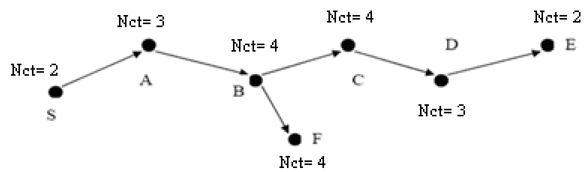


Fig. 5 The partial bandwidth check for the routing-discovery.

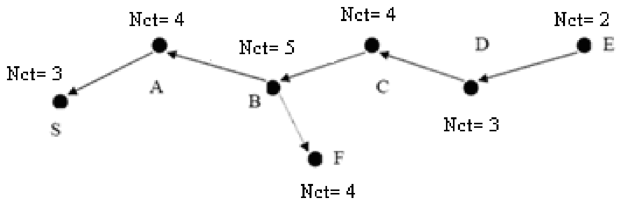


Fig. 6 The full bandwidth check for the routing-discovery.

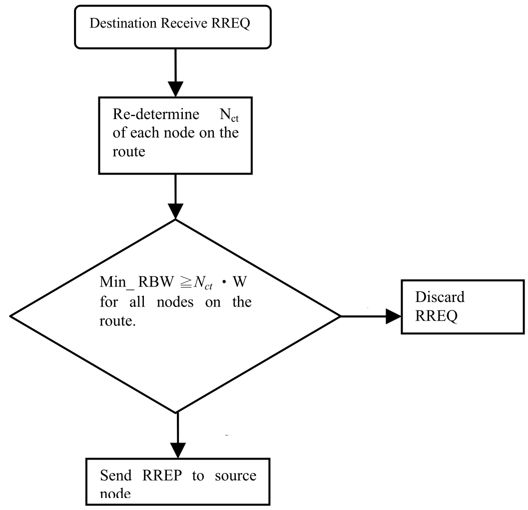


Fig. 7 Process of full bandwidth check.

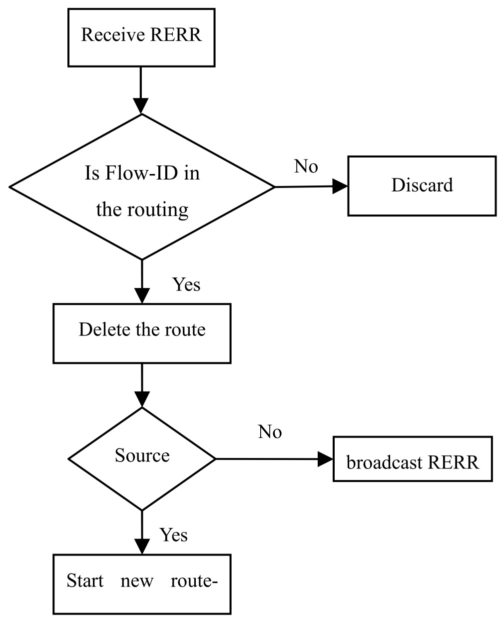


Fig. 8 RERR route maintenance process.

source and Node E is the intended destination. The data flow with BWQ=W may go through route S-A-B-C-D-E. Therefore, to support the route, Node S and E must have min (RBW, N_RBW) ≧ 2W Node A must have RBW ≧ 3W, Node B and C must have RBW ≧ 4W, and Node D must have RBW ≧ 3W.

3.2.2 Full Bandwidth Check Process

When the destination node receives an RREQ which includes BWQ of the data flow, RBWs and N_RBWs of the full route, it can determine accurate value of N_{ct} for each node on the route. For example, Fig. 6 shows the new N_{ct}s for each node on the same network example of Fig. 5; it seen that N_{ct} for source node S is 3 because the transmission of Nodes S, A and B will occupy its RBW; N_{ct} for destination node E is 2 because only the transmissions of Node C and D will occupy it RBW; ect. After the re-calculation of N_{ct}s, the destination node can then check the two conditions of Eq. (3) for each node to decide whether this RREQ or route can be granted. The whole procedure of this phase is shown in Fig. 7.

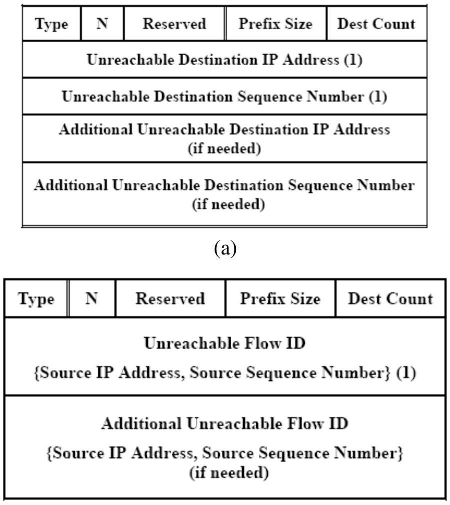
3.3 Route Maintenance

Similar to the AODV protocol, the TPAC protocol is able to detect a broken route by monitoring the packet retransmission error and the reception of the Hello packets as shown in Fig. 8. Since the QoS-route is per data flow based, the route-maintenance must be for each individual data flow, not for each source-destination pair. Hence, the unreachable destination IP address and unreachable destination sequence number in the original format of AODV are replaced by flow-ID in the TPAC protocol. The original and new formats of the RRER packets are shown in Fig. 7 and the process is shown in Fig. 9.

4. System Simulations

The system simulation performed to compare the performances of the proposed TPAC protocol, the AODV protocol, the QoS-aware routing protocols with Listen (donated by "Listen") and the QoS-aware routing protocols with Hello scheme (donated by "Hello"), and the CACP protocol. The MAC/PHY process is assumed to be on IEEE 802.11 specification, and the necessary parameters used in the simulations are listed in Table 1.

During simulations, there are 50 nodes randomly allocated in an area of 1000 m × 1000 m WLAN. Each simulation runs for 300 seconds. The first data flow is generated at the beginning and the other data flows are generated one after another with two seconds separation. The RTS, CTS, and ACK frames are transmitted at a basic rate of 12 Mb/s for CBR/VBR data flow (note that RTS and CTS packets do not apply for the for the data packet with size less than



(b)

Fig. 9 Modification of RRER packet: (a) Original format. (b) New format.

Table 1 Parameters of PHY layer.

PHY layer	802.11g
PHY preamble length	144 bits
PHY Physical Layer Convergence Protocol (PLCP) header length	48 bits
Data transmission rate for video/CBR flows	24Mbps
Data transmission rate for voice flows	11Mbps
Transmission rate of control signals # for video/CBR flows	12 Mbps
Transmission rate of control signals# for voice flows	2 Mpbs
Transmission range	250m
Interference range	500m
MAC layer	802.11 DCF
Contention windows	7~255
MAC service data units (MSDU)	1500 bytes
Interval of Hello packets	1 sec
Max. buffer size at each node	100 packets

512 bytes). DATA frames are transmitted at the channel rate of 11 Mb/s for voice data flow and 24 Mb/s for CBR/VBR data flow.

The comparisons of data flows for all schemes are including the end-to-end delay, the throughput, the overhead and the blocking rate. The throughput is the number of bits being received successfully at the destination. The blocking rate is the ratio of data flows have been blocked to the total data flows have to send. Any data packet of an admitted flow is dropped if the accumulated delay reaches the delay upper bound of 200 ms or a node doesn't receive the responding ACK packet or the CTS packet from the one-hop neighbor continuously for 6 times or does not receive the Hello message continuously for 3 times in the MAC contention process.

When the source node receives the data flow request from its application layer, it checks the data type then the BWQ was calculated as:

$$\mathrm{BWQ} = \mathrm{R} \times \mathrm{T}_{\mathrm{data}} \times \mathrm{C}, \tag{4}$$

where R is the packet generating rate of the CBR data flow, and T_{data} is the packet-transmit time needed for each data packet. The packet-transmit time must include the protocol overhead in the MAC layer. For the IEEE 802.11 MAC layer, each data-packet transmission was assumed to include an RTS-CTS-DATA-ACK handshake for data packet great than 512 bytes, and thus T_{data} can be expressed as

$$\begin{aligned} \mathrm{T}_{\mathrm{data}} &= \mathrm{T}_{\mathrm{handshake}} + \frac{\mathrm{H}+\mathrm{P}}{\mathrm{C}} \\ \mathrm{T}_{\mathrm{handshake}} &= \mathrm{T}_{\mathrm{DIFS}} + \mathrm{T}_{\mathrm{ave\_backoff}} + \mathrm{T}_{\mathrm{RTS}} + \mathrm{T}_{\mathrm{CTS}} \\ &\quad + \mathrm{T}_{\mathrm{ACK}} + 3\mathrm{T}_{\mathrm{SIFS}} + \mathrm{T}_{\mathrm{PHY}}, \end{aligned} \tag{5}$$

For data packet less than 512 bytes the $T_{handshake}$ can be expressed as

$$\mathrm{T}_{\mathrm{handshake}} = \mathrm{T}_{\mathrm{DIFS}} + \mathrm{T}_{\mathrm{ave\_backoff}} + \mathrm{T}_{\mathrm{SIFS}} + \mathrm{T}_{\mathrm{PHY}}, \tag{6}$$

where P is the size of data packet size and H is the length of packet header. T_{RTS}, T_{CTS}, and T_{ACK} are the duration times to transmit RTS, CTS, and ACK packets, respectively. $T_{ave\_backoff}$, T_{SIFS}, and T_{DIFS} denote the average contention back-off time (including retransmission) and the inter-frame spaces SIFS and DIFS.

4.1 CBR Flows

During simulations, there is 75 packets/s in CBR traffic with length of 1000 bytes for each CBR packet during the simulation.

The comparisons of CBR data flows for all schemes are including the end-to-end delay, the throughput, the overhead and the blocking rate as shown in Fig. 10–13. From these figures, the proposed TPAC clearly has the highest throughput, the lowest overhead and end-to-end delay in the QoS routing protocols. Obviously, the routing strategy with admission control of TPAC protocol performs the highest service quality, the more accurate QoS admission control, and much effective in blocking overloading flow in the CBR data flow. Since the CACP protocol performs a full admission control process during the route-replay phase and this control process is much complex and requires more control messages (overhead). Also, the CACP protocol blocks too much data flow in the CBR data flow and results in a lower performance of the throughput. The QoS-aware routing protocol with the "Listen" scheme has only the local residual bandwidth is available at each node in the route-discovery process and a precise admission control is impossible for this protocol. The QoS-aware routing with the "Hello" scheme has the same drawbacks as in the "Listen" scheme. In addition, there is a larger amount of extra overhead carried in the "Hello" packets due to it's contamination of the one-hop neighbors' consumed bandwidth.

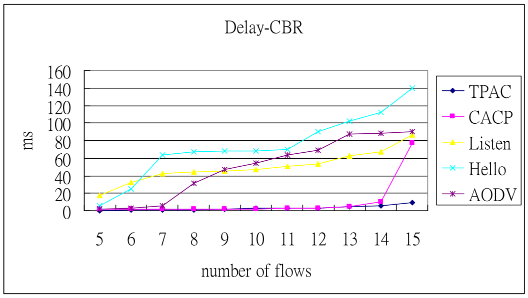


Fig. 10 Comparison of CBR delay.

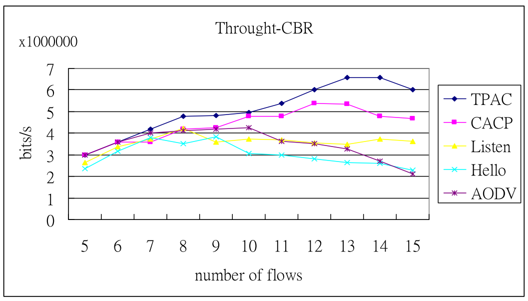


Fig. 11 Comparison of CBR throughput.

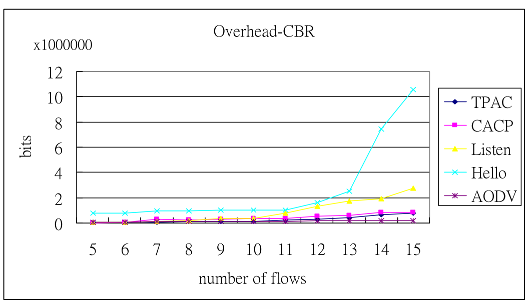


Fig. 12 Comparison of CBR model overhead.

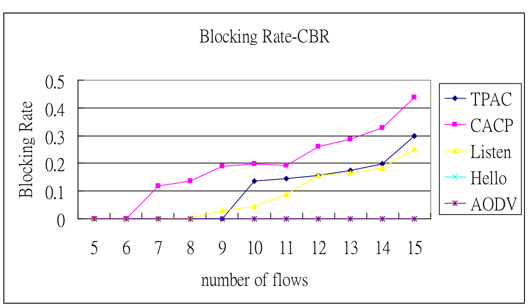


Fig. 13 Comparison of CBR model blocking rate.

4.2 VBR Flows-Video Message

When the source node receives the data flow request from its application layer, the choice the trace file of Jurassic Park I of MPEG-4 traffic models [14] was used, once the data type is VBR data flow has been confirmed. The parameters used in the simulation are show in Tables 2 and 3.

Table 2 Transmission times for the control signals.

T_{PHY} for video/CBR flows	(144 bits + 48 bits)/ 12 Mbps
T_{PHY} for voice flows	(144 bits + 48 bits)/ 2 Mbps
T_{RTS}	20 bytes/ 12 Mbps
T_{CTS}	14 bytes / 12 Mbps
T_{ACK}	14 bytes / 12 Mbps
T_{SIFS}	10 us
T_{DIFS}	50 us
$T_{ave\_backoff}$	300 us
Length of packet header, H	32 bytes

Table 3 Parameter of VBR Flow.

Frame Rate :	25frames/s
Frame-Size-Min:	72 Bytes
Frame-Size-Max:	16745 Bytes
Mean-Bit-Rate:	844094 bits/s
Peak-Bit-Rate:	3349000 bits/s

The BWQ for the VBR data flow was calculated as:

$$BWQ = \alpha R \times T_{data} \times C, \qquad (7)$$

where α is a factor to mitigate the impact by the larger variation of frame size and bit-rate (i.e., the Peak-Bit-Rate is around 4 times Mean-Bit-Rate) of the VBR data flow, the R is the mean packet generating rate of the VBR data flow, and T_{data} is calculated from Eq. (7) for the VBR data flow. In addition, if the frame size is lager then 1500 bytes, the frame will divide into several segments with maximum of 1500 bytes per packet. For instant, the Mean packet generating rate are divided the Mean-Bit-Rate into 64 packets per second as following, 844094/(1500*8) = 71 packet/s for Jurassic Park I, and α=1+(1−(C−RBW)/C). Hence, the BWQ was obtained with the value of α and the mean packet generating rate of 71 packet/s.

Figures 14–17 show the comparison of VBR data flows for all schemes. From these figures, the proposed TPAC has the highest throughput, the lowest overhead and the shortest end-to-end delay time in the QoS routing protocols. As for the CBR, the routing strategy with admission control of TPAC protocol is more accuracy (block most of the overloading flow requests in the VBR data flow) and has a higher service quality for VBR packets transmission. The admission control scheme in CACP protocol does not block the overloading VBR data flow requests accurately due to larger variation of frame size. The QoS-aware routing protocol with the "Listen" and "Hello" schemes are not sufficient in performing the effective blocking and minimizing the overheads and result in a lower performance.

4.3 Voice Flow

The on/off traffic model on [13] is adapted for voice data flow with the packets are generated with exponentially distributed arrive process. The average period is 1 second and 1.3 second for on and off respectively. During the off pe-

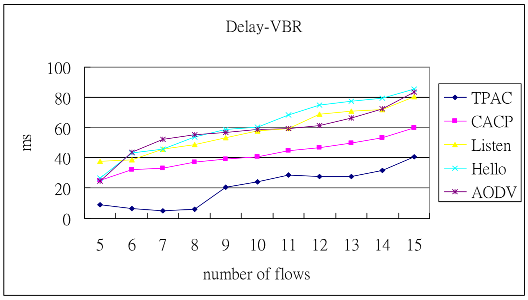


Fig. 14 Comparison of VBR flow delay.

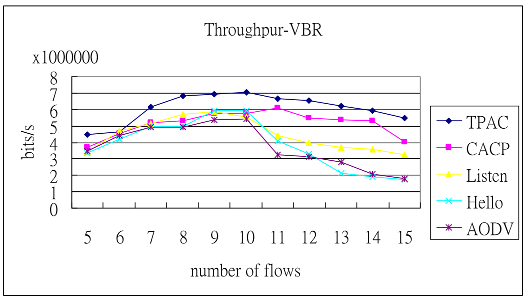


Fig. 15 Comparison of VBR flow throughput.

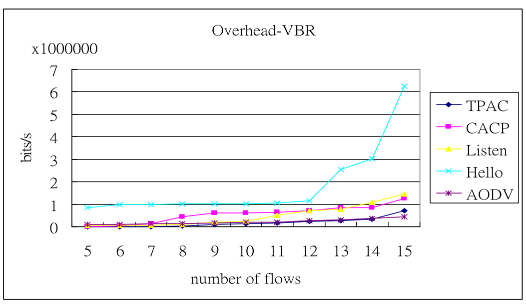


Fig. 16 Comparison of VBR flow overhead.

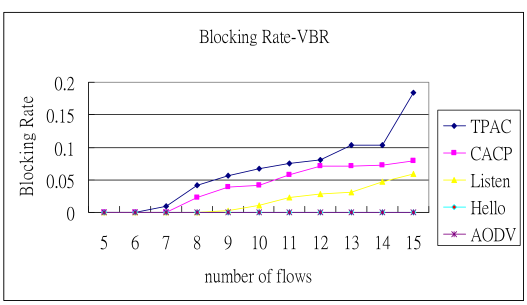


Fig. 17 Comparison of VBR flow blocking rate.

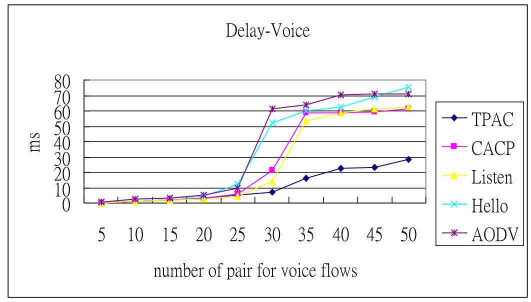


Fig. 18 Comparison of voice flow delay.

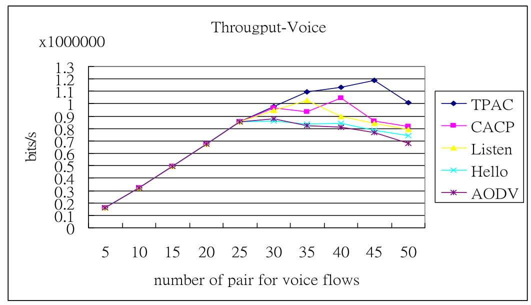


Fig. 19 Comparison of voice throughput.

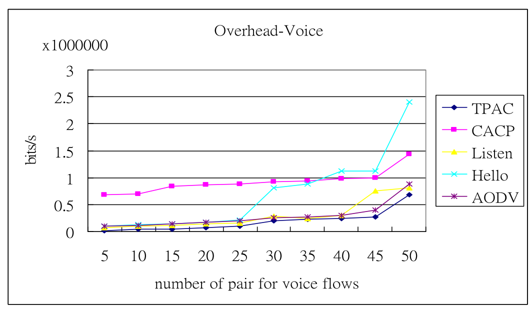


Fig. 20 Comparison of voice overhead.

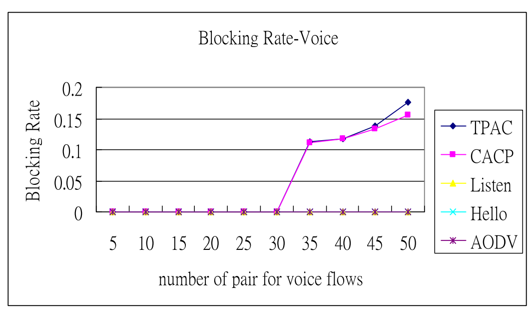


Fig. 21 Comparison of voice blocking rate.

riods, there are no voice packets generated. During the on periods, voice packets of each one-way voice data flow are generated at a rate of 32 kb/s with a packet size of 160 bytes and two ways voice data flow are generated at a rate of 64 kb/s with a packet size of 160 bytes. In addition, the two ways voice data flows are applied for the simulations. Hence, the packet generating rate for two ways voice data flow are divided the mean bit rate into 50 packets per second as following, 64000/(160*8)=50 packet/s.

The BWQ for the VBR flow was calculated as:

$$BWQ = R \times T_{data} \times C \qquad (8)$$

where the R is the packet generating rate of the voice data flow, and T_{data} is calculated from Eq. (7) for the voice data flow. Figures 18–21 show the comparison of voice data flows for all schemes. From these figures, the proposed

TPAC has the highest throughput, the lowest overhead and the shortest end-to-end delay time in the QoS routing protocols.

As to the CBR and VBR, the routing strategy with admission control of TPAC protocol is more accuracy (block most of the overloading flow requests in the voice data flow) and has a higher service quality for voice packets transmission.

5. Conclusions

In this paper a novel and effective Two Phase Admission Control for QoS mobile Ad Hoc networks (TPAC) is proposed. TPAC is based on AODV routing protocol with slight modifications on the RREQ and the Hello packets. With these modifications, TPAC can provide a precise admission control through a simple routing-discovery process, and the amount of extra overhead added on these packets is rather low. System simulations confirm that the proposed TPAC can greatly increase the system throughput, reduce the end-to-end delay by blocking most of the overloading flow requests. Obviously, it is outperforms the previous QoS routing schemes like the QoS-aware routing protocol and the CACP protocol.

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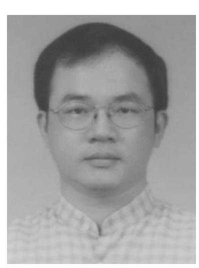

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