A Novel QoS-Aware Routing for Ad Hoc Networks

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Abstract

Most routing protocols focus on obtaining a workable route without considering network traffic condition for a mobile ad hoc network (MANET). Therefore, the quality of service (QoS) is not easily achieved by the real time or multimedia applications. To support QoS, this work proposes a QoS-aware routing protocol that incorporates an admission control scheme into route discovery and route setup. A dual-card dual-signal mechanism is adopted to increase system performance. Simulation results show the proposed protocol can more significantly improve packet delivery ratio, throughput (in heavy load), as well as reduce average end-to-end delay than routing protocols without QoS support can.

1. Introduction:

Support for QoS is becoming essential due to the expanding scope of MANET. QoS is usually defined as a set of service requirements that must be met by the network during data transmission. Due to the dynamic nature of MANET, the QoS provision cannot easily be perfectly fulfilled. Only a few QoS-aware routing protocols have so far been proposed. Chen et al. proposed flooding-based route discovery [3], Lin. Et al. proposed an available bandwidth calculation algorithm for ad hoc network based on TDMA [4]. A QoS routing protocol based on AODV is developed for TDMA-based MANET in [5]. Liao et al. proposed a multi-path routing protocol [6]. Chen et al. proposed a QoS-aware routing protocol based on bandwidth estimation for MANET in [7]. Yang et al. proposed contention-aware admission control for MANT in [8]. The Hierarchical Optimized Link Routing (HOLSR) [10] is based on the protocol specifications for the OLSR [9] algorithm. HOLSR dynamically organizes nodes into cluster levels, and these clusters are organized into a hierarchical architecture. The main improvements employed by HOLSR compared to OLSR are a reduction in the amount of TC (topology control) information that otherwise must be exchanged by different levels, and the efficient use of high capacity nodes which with multiple interfaces and high transmission range and data rate. The Core Extraction Distributed Ad Hoc Routing (CEDAR) algorithm is proposed as a QoS routing scheme for small to medium-sized ad hoc networks consisting of tens to hundreds of nodes [11]. Another approach to integrating QoS in the flooding-based route discovery process is proposed in [12]. The proposed positional attribute-based next-hop determination approach (PANDA) discriminates next-hop nodes based on their location or capabilities. Ge et al. [13] have proposed a proactive QoS routing, which is based on OSLR, for static networks. Another proactive QoS routing protocol is proposed in [14], called adaptive dispersity QoS routing (ADQR) based on SPAFAR [15], and chooses the longer-lived connection based on signal strength. The channel's idle time is used to measure available bandwidth. In an ad hoc network, when a node intends to transmit a flow, it consumes bandwidth at its neighboring nodes, and multiple nodes on the route may contend for bandwidth at a single location [8]. When a node sends a route request, it better knows the neighboring nodes' QoS parameter values as soon as possible and thus can derive the most accurate information by those parameters. Our proposed scheme uses a second card with a special signal to collect information at all the neighboring nodes. Additionally, an admission control scheme is combined with route discovery and route setup processes to find a QoS-suitable path. The rest of the study is organized as follows: Section 2 presents the proposed scheme. Section 3 considers the simulation results. Section 4 draws conclusions.

2. Proposed scheme:

Our scheme, which is named QUART (QUality of service with Admission control RouTing), is a QoS-aware routing in which an admission control is combines with route discovery and setup path in order to find a best workable route. Section 2.1 shows how to define clear and unclear neighboring nodes. Section 2.2 shows how to collect neighboring bandwidth information. Section 2.3 presents how to estimate local and interference range available bandwidth. Section 2.4 presents admission control during the route discovery and setup path.

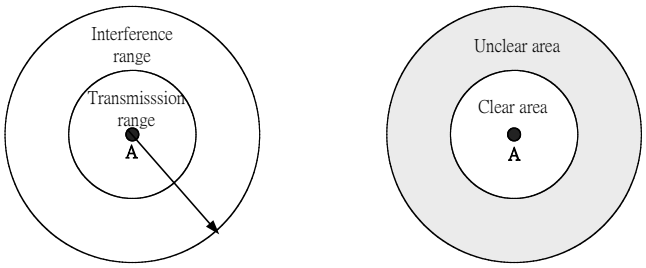

Fig. 1 (a) Transmission and Interference ranges (b) Clear and Unclear areas

2.1 Clear and Unclear neighboring nodes:

QoS is usually defined as a set of service requirements in terms of delay, bandwidth, probability of packet loss, and jitter. To avoid NP-complete problems, the bandwidth is selected as our only resource. The area within transmission range is defined as the clear area, and the area between transmission range and interference range is defined as the unclear area (see Fig.1 b). To achieve the goal of QoS, when a node wants to transmit data, it should consider not only clear range nodes' bandwidth but also unclear nodes' bandwidth because a node's communication consumes the bandwidth of neighboring nodes within the interference range. A signal sent by node A (see Fig. 1a) can be clearly heard by nearby nodes if it is greater than or equal to transmission range signal threshold α, and cannot be clearly heard by nearby nodes if it is less than α and greater than interference range signal β. The signal strengths sent by nodes within interference range of node A show how many nodes are in the clear and unclear areas. The total numbers of these two areas denotes the number of competitive nodes in node A. Therefore; each node maintains two tables, the clear and unclear area tables. Clear nodes are found from the first hop from node A. The nodes in the unclear area may be two or more hops from node A, or hidden nodes. (See section 2.3 in detail)

2.2 Collect neighboring nodes and bandwidth information:

Neighboring nodes' bandwidth can be obtained proactively or reactively. In proactive mode, every node issues a signal at its own defined interval, which can be coordinated with neighboring nodes in order to decrease collision, to delivery bandwidth information. In reactive mode, a signal is issued when a node receives a query asking for bandwidth information. Our proposed scheme chooses using proactive approach to obtain bandwidth information at neighboring nodes. In order to collect neighboring nodes, all neighboring nodes may send their own bandwidth data by multiple-hop with normal power, or one-hop with double power approach. The former approach will face hidden node problem or too many hops problems, therefore the bandwidth information cannot be obtained correctly. The approach by using double power can get the bandwidth information accurately, but the cost is higher than former. We proposed three versions of QUART, which are QUART-DD, QUART-SD, and QUART-SS. For achieving best performance QUART-DD is used. If the cost is an important concern, then QUART-SD or QUART-SS can be chosen, but comes at the price of performance.

2.2.1 Dual-cards Dual-powers (QUART-DD):

Dual cards provide dual signals with different powers. One channel, the special channel, has almost double the normal power and is used to send its own local bandwidth information to nodes within interference range, while the other channel called the common channel has normal power for finding a suitable QoS route and then sending data from the source node to destination node. This approach increases the accuracy of bandwidth estimation and QoS satisfaction over one card and one channel. Many benefits can be gained by using two signal channels including 1) Speedup: By separating special channel and common channel, the system can operate concurrently without collision and increase the efficiency of the entire network efficiency and cut down the delay time. 2) Accuracy: The hidden nodes are considered when estimating bandwidth consumption, thus increasing the package delivery ratio and throughput and decreasing average end-to-end delay. The only drawback is cost. If cost is an important concern, then we can change dual-cards dual-signals dual-powers to single-card single-signal dual-powers or just normal power. There is a strong reason to use two powers although single power is still working. As we stated previously, using single normal power multi-hop to collect neighboring nodes' bandwidth will face hidden nodes or too many hops problems and thus can not collect the hidden nodes' bandwidth precisely. As a result, the QoS quality will be diminished.

2.2.2 Single-card Dual-power (QUART-SD):

In this approach, each node needs to achieve time synchronization. The time is divided into two intervals, T1 and T2 (9 times T1), and switches between them. In the first interval T1, each node sends its own bandwidth to neighboring nodes with double power and in second interval T2, each node can sends control message or data to destination node with normal power level. By using this method, the end-to-end delay of QUART-SD will be longer than that of QUART-DD and the

package delivery ratio and end-to-end throughput of QUART-SD will be lower than those of QUART-DD.

2.2.3 Single-card Single-power (QUART-SS):

In this approach, each node use two hops to send its own bandwidth after a period of time, and send data when it needs. This approach does not need extra card and power, therefore is most inexpensive way to implement. It is also incorporated into an admission control mechanism; therefore its packet delivery ratio is higher than AODV.

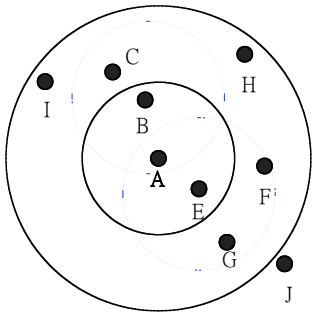

Fig. 2 multi-hop and hidden nodes

2.3 Bandwidth estimation:

In Fig.2, the outside circle denotes node A's interference range and the inside circle denotes node A's transmission range. Node A's first neighbor set is {B, E}. Node A's second neighbor set is {C, G, F}, but not including H and I which are hidden nodes for A, but in A's interference range. As previously stated, if node H has a data to transfer or forward, then it will consume node A's bandwidth due to it is within A node's interference range. Similarity, node A also consumes node H and I's bandwidth. Therefore, any node in A's interference node's neighbor infects each other. The proposed scheme must guarantee that each node within the interference range has enough bandwidth to transfer data without causing congestion. Therefore, the local and the neighboring nodes within the interference range must be identified as precisely as possible. A node wishing to transfer data should not only consider its local bandwidth but also all nodes within the interference range nodes. A distance of two hops is insufficient because the nodes within the interference range may be hidden or more than three hop away. In our proposed system, each node sends out a special signal with double power at a predefined interval, and collects all the signals from its neighboring nodes and updates its clear and unclear tables. The local bandwidth and neighboring nodes' bandwidth are predicted as below.

1) Local bandwidth measurement:

Since bandwidth is shared among neighboring nodes, a node listens to the channel and estimates bandwidth based on the ratio of idle and busy times for a predefined interval. The factors cause busy if the nodes are in any of the following states: transmitting or receiving a node, in RTS/CTS or network allocation vector (NAV), or sensing busy carrier with signal strength above β and below α. The local bandwidth B_{local} is estimated as follows:

$$B_{local} = B_{channel} \times \frac{T_{idle}}{T_{interval}} \qquad (1)$$

Where $B_{channel}$ denotes the channel capacity and T_{idle} denotes the idle time in a predefined interval $T_{interval}$

2) Interference range bandwidth measurement:

Because the information about neighboring nodes has already been collected, the minimum bandwidth $B_{neighbor\text{-}min}$ of all nodes within the interference range is known. The difference between $B_{neighbor\text{-}min}$ and the local bandwidth B_{local} is called the residual bandwidth saved in residual bandwidth register, which can be applied to an admission control scheme.

2.4 Admission scheme:

In order to support QoS, an admission control absolutely is a key factor to reach that goal. Once each node can get the most accurate neighboring nodes' bandwidth, an admission control then can be easily incorporated to route discovery and route setup process.

2.4.1 Route discovery:

An admission control is presented to discovery and setup routes. We apply our scheme to AODV, and the proposed scheme can be applied to other on-demand routing protocols such as DSR [16]. A source code sends a RREQ packet whose header is changed to {AODV RREQ header, request bandwidth, <Xs,i,d> <Cs,i,d>}. Denote the vector <Xs,i,d> as the union of the addresses of the nodes in the interference range source node s up to node i for the destination node d. < Cs,i,d> represents the corresponding count of members of vector <Xs,i,d>. Before a node sends a RREQ, it checks whether the node has no one-hop neighbor except itself (by checking the clear table), in which case it drops this route request. When an immediate node receives the RREQ packet, it checks whether the requested bandwidth is less than residual bandwidth from residual bandwidth register (RBR), if no, then discard RREQ, if yes, then it compares the intermediate node's neighboring nodes within its interference range with members of <Xs,i,d>, if a node is already a member of <Xs,i,d> then the count is incremented by

1, and otherwise the node address is appended to <Xs,i,d> as a new member, the corresponding < Cs,i,d> count is set to 1, and the route request is then broadcast. When reaching the destination node, the route setup procedure is then run. Figure 3 shows the route discovery procedure.

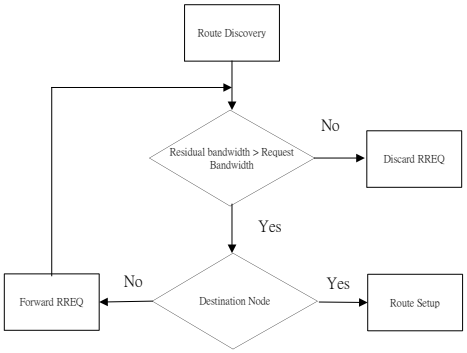

Fig.3 Route discovery procedure

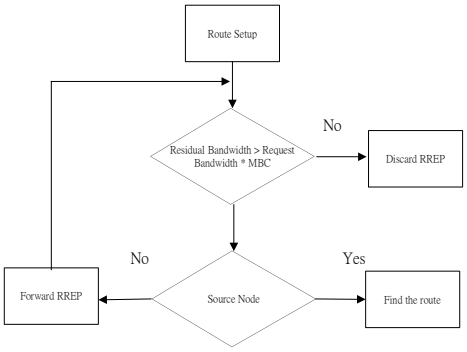

Fig.4 Route setup procedure

2.4.2 Route Setup:

The destination node sends a modified header {AODV RREP header, request bandwidth, minimum available bandwidth, <Xs,i,d>, < Cs,i,d>}, and the initial value of the minimum available bandwidth is set to 0. The maximum value of node which is around node i within interference range in <Cs,i,d> as the MBC (maximum bandwidth count). The intermediate node calculates the maximum need bandwidth at each node along reverse path to determine whether this residual bandwidth in RBR is less than the Request Bandwidth multiplied by the MBC in which case difference between residual bandwidth and (MBC* Request Bandwidth) is placed in the filed <minimum available bandwidth >, and RREP is sent to the previous node from which it received the modified header. Otherwise, a fail message is sent to the source node. After the source node receives the first RREP, it waits some time to see if another PREP arrives, if no other RREP arrives, then the only available RREP is selected, otherwise the RREP with the highest <minimum available bandwidth> is chosen. Example:

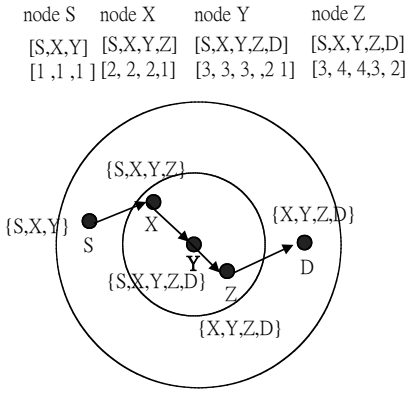

Fig. 5 An example of proposed scheme

In the route discovery process, as shown in Fig.5, <Xs,i,d> and <Cs,i,d> will be [S,X,Y] and [1,1,1] , before node S sends RREQ. Before node X sends the RREQ, <Xs,i,d> and <Cs,i,d> are [S,X,Y,Z] and [2,2,2,1]. Before node Y sends the RREQ, <Xs,i,d> and <Cs,i,d> are [S,X,Y,Z,D] and [3,3,3,2,1]. Before node Z sends the RREQ, <Xs,i,d> and <Cs,i,d> are [S,X,Y,Z,D] and [3,4,4,3,2]. In the route setup phase, the destination node receives the RREQ, then prepares the RREP, and is then sent back along the reverse path to the source node. After node Z receives RREP, it determines whether the residual bandwidth in RBR is less than (MBC * request bandwidth) in which case RREP is sent to previous node Y. Otherwise a fail message is sent back to the previous node. Finally, node S knows whether any route can satisfy QoS. If many RREPs, are available, then the source node adopts the route with the highest maximum minimum available bandwidth.

2.4.3 The effect of imprecisely estimated bandwidth:

The correctness of bandwidth estimation has a tremendous impact on system performance. If the estimation bandwidth is lower than that of network capacity, then the available bandwidth is under-estimated. If the estimation bandwidth is higher than that of network capacity, then the available bandwidth is over-estimated. In under-estimation case, the admission control will reject the flows which are below capacity of network. The system can get excellent packet delivery ratio, but also has a side effects of end-to-end delay and throughput. On the other hand, in over-estimation case, the admission control admits a flow whose bandwidth consumption is beyond the capacity of network. Therefore, those over-estimated flows' control messages or data will degrade the whole system performance.

To obtain the best result, we should minimize the difference of estimation bandwidth and capacity of the network, and collect

as accurate and updated data as possible just as our proposed schemes do.

3. Simulation results:

This study simulates and compares the three versions of QUART with AODV, which is on demand routing protocol [1-2] and has almost no support for QoS in ad hoc wireless networks, using a NS-2 version 2.26 simulation tool. The metrics of measured performances are throughput, average end-to-end delay and packet delivery ratio. The simulation parameters are 500 seconds for 50 nodes, in a 1000 m × 1000 m dimension field, 5 mps maximum moving speed with random way, 250m nominal communication range, 500m carrier sensing range, 2 Mbps channel bandwidth and 512 bytes in each frame payload. This simulation adopts five random source-destination pairs send packets at a requested rate between 0.1 and 0.6 Mbps. The simulation results are shown by average value of twenty different scenarios. As can be seen, the simulation results in figures 6, 7, and 8, show that the proposed system (QUART-DD) has better package delivery ratio, average end-to-end delay, and higher throughput after 0.2 Mbps when compared with AODV with the same requested rate. In figure 8, the throughput of QUART-DD is lower than AODV when sending data rate is 0.1M bps. In AODV, when sending rate is low, the chance of becoming a congested network is low, and the overhead of admission control is none since no admission control is performed. When more new data flows are joining to the network, the possibility of becoming a congested network is getting higher, therefore the throughput of AODV is lower than QUART-DD after 0.2Mbps. In figure 8, the throughput of QUART-SS is lower than AODV due to over-estimated bandwidth caused by hidden nodes problem and the collisions of messages for exchanging bandwidth information within interference range since it is single card single channel.

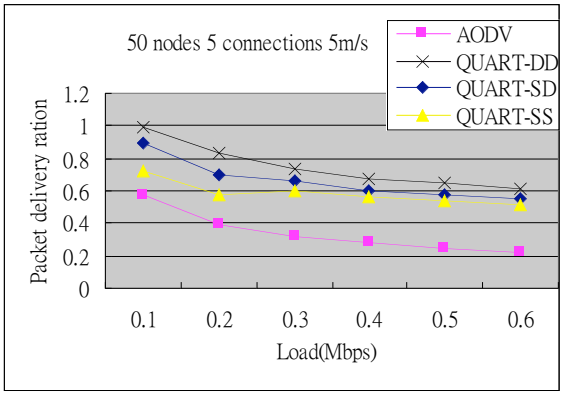

Figure 6 package delivery ratio comparisons

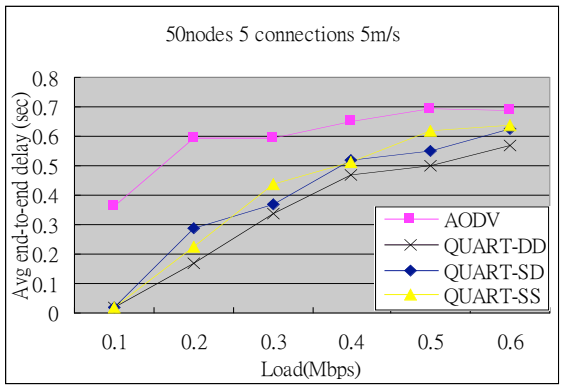

Figure 7 average end-to-end delay comparisons

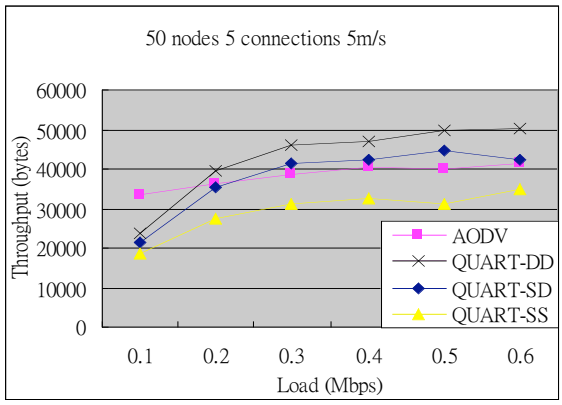

Figure 8 throughput comparisons

4. Conclusion:

This study proposes a novel QoS-aware routing protocol (QUART). When a node wishes to find a feasible route to a destination, it uses the related information that has already been collected from a card with second signal for QUART-DD. No matter what variant version (QUART-DD, QUART-SD, QUART-SS) it takes, an admission control system is incorporated into the route discovery and route setup processes. The system waits some time to obtain the best route, and then finally sends out the packages. Simulation results show the QUART-DD can achieve higher performance compared with other routing protocols.

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