Asian Journal of Information Technology 6 (6): 662-666, 2007

Differentiated Bandwidth Allocation in Mobile Ad Hoc Networks (MANET)-A Profile Based Approach

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Abstract: A major proliferating architecture, that extends its services globally in wireless networks, is Ad Hoc network, which endows more research areas to work with. In next generation networks, user can be accurately determined and maintained by the network on per-user basis. This study investigates the design of Ad Hoc network architecture that exploits user profiles to maximize network efficiency and promote better quality of service by differentiated bandwidth reservation and resource allocation to different classes of users. A model called High-Privileged and Low-Privileged Architecture (HPLP) for the forthcoming Ad Hoc network is proposed through which differentiated services can be achieved for different class of users. A new MAC protocol named as D-MACAW is also suggested for the proposed architecture. Among the various factors influencing the differentiated services, bandwidth reservation is only considered and different factors that can influence the efficiency of the bandwidth reservation are identified. Two classes of users are considered as high-privileged, a high-cost and efficient service users and low-privileged, low-cost and best effort service users. The differentiated service provided for the different classes of users is proved through simulation analysis. The results obtained using ns2 show that efficient quality of service is guaranteed to users who subscribe high-privileged profile.

Key words: Wireless Ad Hoc networks, quality of service, differentiated service, low-privileged, high-privileged users, bandwidth reservation

INTRODUCTION

Wireless Ad Hoc networks have received significant attention in recent years due to their potential applications in battlefield, disaster relief operations and so on. A wireless Ad Hoc network consists of a collection of mobile hosts dynamically forming a temporary network without the use of any existing network infrastructure. In such a network, each mobile host can serve as a router. On the other hand, there are wireless infrastructure networks which comprise of some exclusive devices performing certain centralized operations like routers. The lack of infrastructure, not relying on any centralized administration supports Ad Hoc network devices to achieve mobility as a whole. When trying to provide efficient mobility to the devices there are some hassles to be overcome like interference, lack of energy availability and topology changes.

Nowadays services provided are growing rapidly in different scenarios compared to earlier days where the end users are provided services according to their usage and the time they stick with the system. Presently the end users can avail differentiated quality of services as per their requirements. In Ad Hoc Networks several factors can influence the differentiated services like bandwidth reservation, security approaches and path utilized for routing and the routing algorithms used. Considering the complexity in handling all such factors, it is decided to consider bandwidth reservation (Chun and Kang, 2004) for determining the type of service to be provided as it plays a vital and remarkable role in determining the differentiated quality of service for users.

Medium Access Control (MAC) protocols are responsible for scheduling access among multiple stations contending for the common channel and they often introduce overhead that result in a suboptimal utilization of the channel capacity. For contention-based MAC protocols, the overheads typically include channel idle periods where all contending stations are waiting to transmit and packet collisions which occur when multiple stations attempt to transmit simultaneously. MAC overhead can be reduced by dynamically adjusting the channel access behavior of each contending station based on channel feedback information, which consequently improves the channel utilization (Murthy and Manoj, 2005).

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HIGH-PRIVILEGED AND LOW-PRIVILEGED (HPLP) ARCHITECTURE

A High-Privileged and Low-Privileged (HPLP) Architecture to describe how the users are opting the service, different combinations of high-privileged and low-privileged users, the entry towards the network cloud and scheduling the users is proposed as in Fig. 1. The 2 different user profiles considered are high-privileged, who are paying high cost opting for efficient quality of service and low-privileged, who are paying low cost opting for best-effort quality of service (Vijoy, 2004).

HPLP architecture: HPLP architecture defines the scenario how the user's requirements are satisfied as per their classification. Basically the users are of two categories namely High privileged and Low privileged users. High privileged users are provided with good quality of service like high data transfer rate, efficient bandwidth allocation, lower delay etc. low Privileged users can avail optimal data transfer rate, optimal bandwidth and reasonable delay etc. The entity in this architecture may be of low privileged user who is denoted as LP node or High privileged users denoted as HP node. The most important parameter considered here for forming the architecture is the number of HP users and the number of LP users availing the service at an instance, the different permissible scenarios can be designed by from the 5 sets of combinations having high privileged and low privileged nodes. The different combinations are 0:100 percentage of high privilege and low privileged users, 30:70 of high % privilege and low privileged users , 50:50 % of high privilege and low privileged users , 70:30 percentage of high privilege and low privileged users, 100:0% of high privilege and low privileged users.

A sample scenario is shown in the Fig. 1. Efficient bandwidth allocation can be done for these different scenarios through by Differentiated-Medium Access Protocol for Wireless LAN's.

DIFFERENTIATED BANDWIDTH RESERVATION AND SCHEDULING

The MAC protocol proposed for fulfilling the requirement of providing differentiated services to end users named as D-MACAW (Differntiated Medium Access Protocol for Wireless LAN's) .D-MACAW is the enhancement of MACAW protocol (Starvos, 2006) at the packet level. The protocol and the funtionalities are explained in 2 phases as follows.The first phase describes the reservation policy and associated problems of the MACAW protocol and the second phase exlpains the new protocol to provide service differentiation for the different classes of users.

Conventional reservation approach: The MACAW protocol is the extension of Media Access Control Protocol (MACA) for wireless networks with an additional field in the packet header carrying the current back-off counter value of transmitting node. A node receiving the packet copies this value into its own back-off counter. This mechanism allocates bandwidth in affair manner. In MACAW the BEB algorithm follows a multiplicative increase and linear decrease back-off mechanism. Upon each collision the back-off is increased by a multiplicative factor (1.5) and upon each successful transmission it is decremented by one. This eliminates contention and long contention periods after every successful transmission and at the same time provides a reasonably quick escalation in the back off process when the contention is high. MACAW implements per flow fairness by maintaining multiple queues at every node, one each for each data stream and running the back-off algorithm independently for each queue. A node that is ready to transmit packets first determines how long it needs to wait

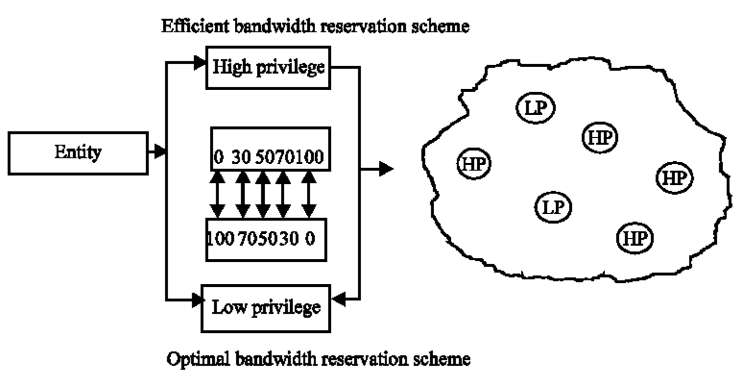

Fig. 1: HPLP architecture

Fig 2: Data transmission1 using MACAW

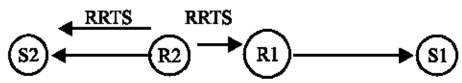

Fig 3: Data transmission 2 using MACAW

before it could transmit packet to each of the destination nodes corresponding to top most packets in the node's queues. It then selects the packet for which waiting time is minimal. MACAW uses the control packets called Acknowledgment (ACK) packet and Data-Sending (DS) packet. Before transmitting the actual data packet the source node transmits the DS packet as illustrated with the following scenario in Fig. 2.

When a transmission is going on between nodes S1 and R1, node S2 is free to transmit. RTS transmissions by node S2 is of no use, as it can proceed further only if it can receive CTS from R2. But this is not possible as CTS packets from R2 got collided at node S2 with packets transmitted by node S1.As a result, the back-off counter at node S2 builds up unnecessarily. So an exposed node should not be allowed to transmit. But an exposed node since it can hear only the RTS sent by the source node and not the CTS by the receiver, does not know for sure whether the RTS-CTS exchange was successful. This problem is overcome by Data-sending packet.

Assuming transmission is going on between nodes S1 and R1 and when node S2 wants to transmit to node R2., it receives CTS packets from node R1, since R2 and R1 are neighbor nodes and therefore it defers its own transmissions. Node S2 has no way to learn about the contention periods during which it can contend for the channel and so it keeps on trying, incrementing its back-off counter after each failed attempt. Hence the main reason for this problem is the lack of synchronization information at source S2. MACAW overcomes this problem by using the RRTS packet as shown in Fig. 3.

Receiver node R2 competes for the channel on behalf of source S2. If node R2 had received an RTS previously for which it was not able to respond immediately because of the on-going transmission between nodes S1 and R1, then node R2 waits for the next contention period and transmits the request-for-request-to-send RRTS packet. Neighbor nodes that hear the RRTS packet (including node R1) are made to wait for two successive slots (for the RTS-CTS exchange to take place).The source node S2 on receiving the RRTS from node R2 transmits the regular RTS packet to node R2 and the normal packet exchange (RTS-CTS-Data-ACK) continues thereupon.

Differentiated-Medium Access Protocol for Wireless LAN's (D-MACAW): The proposed protocol called as Differentiated-Medium Access Protocol for Wireless LAN's (D-MACAW) follows the functionalities of MACAW with service differentiation at user level incorporation. This is be achieved by introducing additional fields in the packet format. In our approach, the users are differentiated at the packet level itself and the data packets are segregated as high privileged packet and low privileged packet by introducing a field in the packets. In every buffer of a node separate queues for different users are maintained. The High Privileged (HP) packets are allowed to access the shared medium twice than that of Low Privileged (LP) users, subject to the situation when there is equal or more number of high privileged users and they are uniformly distributed and equal in data rate transmission. The request-to-send packets are replaced by Request-to-Send- High-Packet (RTSH) and Request-to-Send-Low-Packet (RTSL) and also the clear-to-send packets.

If one intermediate node receives both RTSH and RTSL simultaneously from high privileged and low privileged users respectively then it sends CTS only to the node with high privilege packet to transmit.

For the scenario in Fig. 4 among the 3 nodes, node A, a Low-Privileged user comprising LP packet acts as a sender and node B, a high-privileged user comprising HP packet also acts as a sender. When both of these nodes contend for the same node C, it sends CTSH to B, the back-off timer of A keeps on increasing multiplicatively, since it contains only LP packet so it does not get any CTSL so ultimately the node A is blocked from accessing C.

To overcome this situation a packet named as RTSLForce (RTSLF) is defined and when a RTSL packet did not get acknowledgement, before the LP packet's time to live counter expires, it sends RTSLForce (RTSLF) which overcomes the RTSH. By this signal a best effort service to the LP users can be achieved as assured earlier while providing an efficient service for high privileged users.

Justification for the assumptions: In order to achieve a good differentiated quality of service the users are classified at the lowest level instead of at application level. Though the process complexity slightly increases while taking to application level, an efficient differentiated service can be achieved from each level layers. In order to achieve the above mentioned differentiation, request and response signals are designed varying from normal Medium Access protocols for Wireless LAN's. As packet level segregation is done,

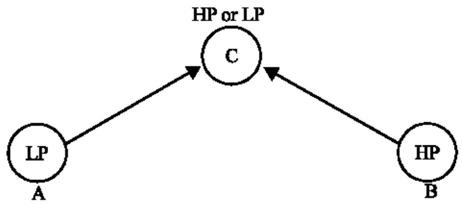

Fig. 4: Contention with privileged users in D-MACAW

separate queues are available at every node for high privileged and low privileged nodes for account maintenance.

DESIGN ISSUES

In this study two major issues of segregating the users and the allocation of buffer queues to the two classes of users is discussed.

Segregated users: As mentioned earlier, users who seeking services simultaneously may be of different types and hence different set of combinations of users are considered in order to demonstrate and account for the performance of the protocol. The aim is to achieve higher bandwidth to HP than LP users. This is achieved by defining an access ratio for the users packets as depicted in the Table 1.

The ratio of bandwidth allocated in the intermediate nodes is based on the different combinations of High-Privileged and Low-Privileged users (Yan, 2006). The access ration is defined as follows: Total no. of HP node packets from different sources ×2 and Total no. of LP node packets from different sources.

For example when a node receives packets comprising 90 % of HP packets and 10 % of LP packets then the shared medium is allocated according to the access ration.

In this regard the ratio between HP: LP is 18:1, so 18 HP packets are given first priority then succeeded by 1LP packet. It is found that the above formula holds good when number of HP user packets are more or equal to LP user packets. When LP packets are more than HP, it is assumed to be equal and hence the 2:1 ratio allocation to HP and LP user packets for the equality case is adopted to provide efficient quality of service to High-Privileged users as well as retaining the best effort service to the Low-Privileged users.

Buffer management: In every node separate buffer is maintained for HP and LP users. The buffers are accessed in the ratio shown in the Table 1.Let H^b and L^b be buffers for high-privileged users packets and low-privileged

Table 1: Access ratio allocation

% of HP users	% of LP users	Access ratio allocated
90	10	18:1
80	20	16:2
70	30	14:3
60	40	12:4
50	50	10:5
40	60	10:5
30	70	10:5
20	80	10:5
10	90	10:5

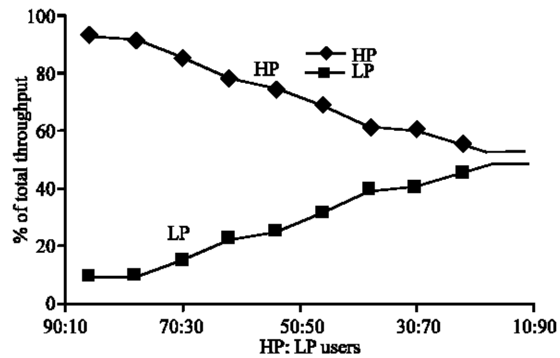

Fig. 5: User profile based bandwidth reservation

users packets respectively and, x and y be the number of packets in percentage in the queue for the buffers H^b and L^b, respectively. As per the ratio defined if $x> = 50$ and $y < = 50$, then 2x:1y ratio allocation is followed for buffer access, else assuming that $x = 50$ and $y = 50$, 2x:1y ratio allocation for buffer access is followed for achieving an efficient quality of service for high privileged users and optimal quality of service for low privileged users.

IMPLEMENTATION AND INFERENCES

In this study, performance evaluation results are resented for our MAC protocol. The performance evaluation is done with the ns-2 simulator (Team, 2000). The test network topology consists of 10 nodes and the transmission range of each node is defined as 250 m and the bandwidth of the channel is 2 Mbps. The Dynamic Source Routing (DSR) protocol is employed for routing. Ten different scenarios are considered with different percentage of HP and LP user packets and tested using the simulator. We demonstrated how the bandwidth distribution between HP and LP users is demonstrated in Fig. 5 based on the throughput for different types of packets HP and LP to achieve differential QoS for the 2 classes of users.

An analysis is made considering the delay in processing the bandwidth reservation by high privileged and low privileged users. The Fig. 6 represents that delay will be higher for the nodes in high privileged users and the delay gradually decreases for the count decreases.

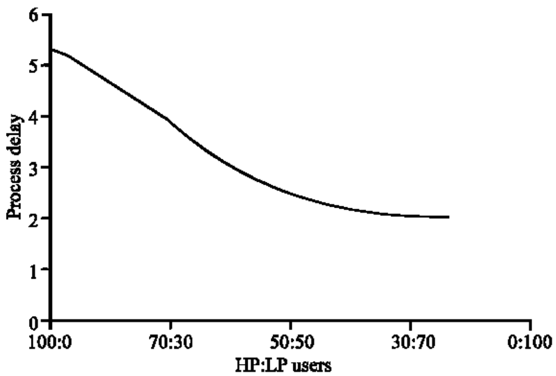

Fig. 6: Process delay for HP and LP users

CONCLUSION

The High-Privileged and Low-Privileged Architecture (HPLP) for Ad Hoc network is proposed for achieving optimal differentiated services for different classes of users. The new MAC protocol, D-MACAW, was implemented and tested using the network simulator. The results obtained for various test cases justify that differentiated quality of service is provided for different categories of users who are having different profiles based on cost.

As a future work it is planned to consider three major factors for the proposed protocol namely;

- Mobility of the nodes (dynamicity), considering the randomly changing topology.
- Diverse collection of data types like audio, video and multimedia data streams.
- Addressing the other performance and complexity issues like processing time, transaction time (latency), buffer management and memory utilization.

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