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Node Categorization Scheme (NCS) for Throughput Efficiency in Multi-rate Mobile Ad hoc Networks

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ABSTRACT
In multi-rate networks IEEE DCF 802.11 ensures long term equal channel access probability this in turn penalizes the faster stations in this networks. The maximum achievable throughput by any station gets bounded by the slowest transmitting peer. This leads towards the under utilization of the bandwidth. Another reason for bandwidth deficiency is overheads present at the nodes. In this paper, we present an analytical conclusion on the adjustment for the various transmission overhead in order to upgrade bandwidth efficiency. We call our proposal Node Categorization Scheme (NCS) which is a dynamic method for improving the performance of Ad hoc multi-rate networks in various transmission schemes. We consider aggregate throughput as the performance indicator. The network topology consider have a lone sender one or more intermediate nodes and one or multiple end receivers. The overall transmission scenario allows us to categorize nodes according to their transmission state. Here we improve the performance of different categories dynamically by adjusting the overheads of nodes which improves the overall transmission performance. We compare the performance of our proposed scheme (NCS) with the performance of existing standard (IEEE 802.11). Our comprehensive simulations validate the efficacy of our method towards providing high throughput and better bandwidth efficiency.

Categories and Subject Descriptors
C.2.1 [Advantage-Networks]

General Terms
Performance

Keywords
Distributed multihop wireless networks, ad hoc networking, medium access control, random ranks, mini slots, aggregate throughput, long-term fairness.

1. INTRODUCTION
AS wireless technologies advance and become more popular wireless protocols must evolve to meet the higher demands of these technologies. Ad hoc networks are new approach to network design. Ad hoc wireless networks utilize multi hop radio releasing and are capable of operating without the support of any fixed infrastructure. In an Ad hoc wireless network, the routing and resource management are done in a distributed manner in which all nodes coordinate to enable communication among them. Ad hoc wireless networks, due to their quick and economically less demanding deployment find applications in several areas like military applications collaborative and distributed computing, emergency operations, wireless mesh networks, wireless sensor networks etc.

If a Ad hoc network is transmitting a multimedia information it has to support a broad range of bit rates demanded by connections, not only because there are many communication medium may be encoded by algorithm with different bit rates. Thus we need a multi-rate network in which different stations may employ different transmission rates.

The IEEE standard 802.11 specifies the most famous family of wireless network in which many products are available. The standard specifies the physical and medium access layer adapted to the special requirements of wireless network. The issue considered at the MAC layer is aggregate throughput.

Distributed Co-ordination (DCF) is the essential medium access control method of IEEE 802.11. DCF uses CSMA/CA protocol which provides equal transmission opportunity for all participating stations. When all nodes experience similar channel conditions and equal frame sizes all nodes achieve equal throughput. This is called throughput based fairness. Because of different media 802.11 standards support multiple data rates, which are dynamically adapted by different stations to improve the performance. In this case time allotted to transmit the data by different stations depends on their data rates. For transmitting the data the time allotted to lower data rate stations is more as compared to higher data rate stations. This causes unfair allotment of time to different data rate stations. This unfairness reduces the throughput of the station with the highest bit rate. Further the aggregate throughput is reduced to a level much closer to what one gets when all competing stations are slow. This is called rate anomaly problem of IEEE 802.11 DCF.

In this paper the aggregate throughput of the multi-rate network is improved by reducing the overhead of the nodes. In multi-rate networks the performance of one node is heavily dependent on the node in its vicinity. We are here proposing a method which takes decision dynamically after assessing the data rates of the nodes in one transmission scenario and then accordingly it tries to minimize the overheads at different node so that the performance of the overall network can be improved .

2. Ad Hoc Multi-Rate Networks

Multi-rate network is the network in which different stations may employ different transmission data rates. The need of multi-rate network come for the desire to integrate multimedia transmission such as audio, data, image and video into one switching networks. As different media require a broad range of bandwidth, each request is associated with its required rate of bandwidth. Multi-rate can also be called K-rate if the number of distinct rates is specified to be k.

Under IEEE 802.11 DCF, if we consider multi-rate network than long term throughput of each station becomes largely independent of its own datarate; rather, it gets bounded by the lowest datarate peer. Thus multi-rate network penalizes faster stations, since they invariably need to wait for this slower peer to complete their transmissions or retransmissions. This in turn decreases the aggregate throughput.

This phenomenon is better explained by the example topology in figure 1. station 1 has a two-hop route to station 3, with station 2 being the intermediate forwarder. Both the links are assumed to be perfect in the sense that they can transmit at the highest data rate of 11 Mbps. Station 2 shares the channel with another link R (station 4 to 5). Figure 3.1 depicts the variation of the end-to-end throughput and the channel occupancy ratio (COR) for station 2 with the transmission rate of link R. The throughput decreases by 63 percent as the rate of link R varies from 11 to 1 Mbps. We notice that both the links have approximately the same throughput, even though station 2 always transmits qt 11 Mbps. This can be explained by the ratios of COR for the two competing stations, which is roughly proportional to their respective datarates.

It is clearly suggests that slower links occupy more channel airtime to ultimately transmit the same number of packets as faster links. This phenomenon has been quoted as the rate anomaly problem of IEEE Distributed Coordination Function (DCF) networks. It is caused by the fairness philosophy of 802.11, which ensures long-term equal channel access

probability [3].

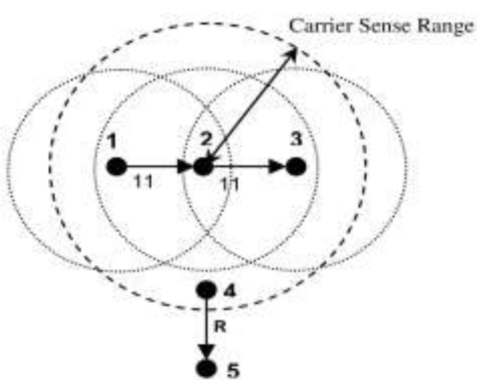

Figure 3.1 Example Topology [3]

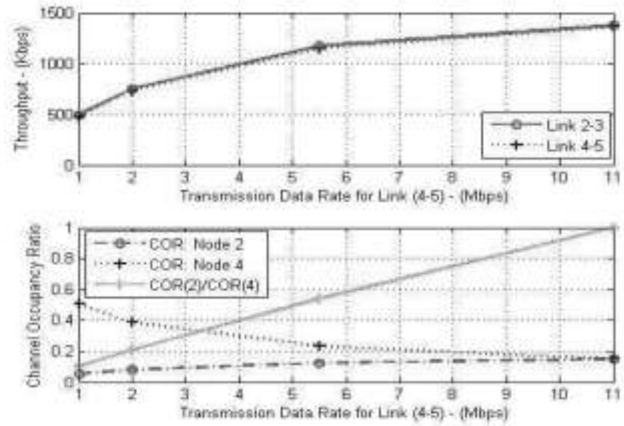

Figure 3.2 Throughput and COR versus data rate [3]

3. Related Work

3.1 Throughput Based fairness

Fairness philosophy of 802.11 ensures long term equal channel access probability [3]. If similar sized packets are used under similar channel conditions, then each station achieves roughly the same throughput., irrespective of its own transmission rate. Now, if all the competing station employs similar data rates, 802.11 automatically guarantees equal time share as well. However, in IEEE 802.11 DCF Multi-rate networks penalize the faster station.

This variant of the CSMA medium access protocol is designed to give approximately equal transmission opportunities to each competing node. This is to say each node will have approximately the same number of opportunities to send a data frame, irrespective of the amount of time required to transmit a packet. This scheme decreases the aggregate throughput in multi-rate networks because faster stations have to wait for their slower peers to complete the transmission.

3.2 Time Based Fairness

In time based fairness, each competing node receives an equal share of the wireless channel occupancy time. This notion of fairness leads to significant improvements in aggregate performance while still guaranteeing that no node receives worse channel access than it would in a single rate WLAN. The achieved throughput of the slower nodes is less under time based fairness than under throughput based fairness. Time based fairness provides an important in multi-rate WLANs that throughput based fairness does not. This property is known as Baseline property [1]. This property says that "The long term throughput of a node competing against any number of nodes running at different speeds is equal to the throughput that the nodes achieve in an existing single rate 802.11 WLAN in which all competing nodes were running at its rate". DCF's transmission opportunity based mechanism provides fair allocations of both throughput and channel occupancy time only if all contending nodes use

1) The same data rate
2) The same packet size
3) Experience very similar loss characteristics.

If only last two conditions hold, DCF achieves throughput based fairness but does not achieve time based fairness. For any other combination, DCF achieves neither time based fairness nor throughput based fairness.

We propose a method which improves the bandwidth utilization as well as increases the throughput of the multi-rate mobile Ad hoc networks in IEEE 802.11 DCF. This method does not need changes in the basic access mechanism of IEEE 802.11 for its implementation. Bandwidth and battery power are key constraints for efficient and continuous operation of mobile computers [2]. Bandwidth efficiency is the most important aspect. The channel utilization, also known as bandwidth utilization, is related to the net bit rate in bit/s of a digital communication channel. In general efficiency formula is:

Efficiency = data/(data + ∑overhead)

To achieve efficiency, we give different access priority to different hosts according to their transmission bit rate classes (11, 5.5, 2 or 1 Mbit/s) [4].

5. PROPOSED SOLUTION

In multirate networks the performance of one node is heavily dependent on the node in its vicinity. We are here proposing a method which takes decision dynamically after assessing the datarates of the nodes in one transmission scenario and then accordingly it tries to minimize the overheads at different node so that the performance of the overall network can be improved. NCS (Node Categorization Scheme) categorizes nodes into three main categories. Categorization will be done on the basis of transmission state.

In a network transmission whether it is unicast transmission or broadcast transmission their generally exists a lone sender and many intermediate nodes and a few end receivers. So at a particular time instant the node interested in sending the data, sends RTS which defines the sender in the transmission, and the destination address defines the receiver (if not broadcasted).

The Sender comprises the category A. The intermediate nodes will come under the category B and the receiver will comprise category C.

Table 5.1 Real Time Throughput of each category

Category A	Category B	Category C
38-40 %	25-30 %	15-20%

Now as we have simulated the basic IEEE-802.11b standard (DCF), the simulations depict the efficiency for different node categories. Now the efficient bandwidth utilization can be achieved by two means:

1. Minimizing overheads (i.e. upgrading the throughput) of category B and category C type nodes, when these nodes have the lower datarates.
2. The Second option, when sender is having the lower datarate then increase the efficiency of sender node by minimizing overheads at sender(category A).

Now the proposed scheme will reduce the overhead at different categories' nodes after assessing their datarates in multirate networks. This method is increasing the throughput of individual nodes as well as increasing the overall throughput of the network. Also, this method is improving utilization of the channel time.

6. PERFORMANCE EVALUATION.

Here we will analysis the proposed scheme, which takes into consideration the results taken from the simulation of the basic IEEE-802.11b protocol. We used NCTUns simulator and packet size is constant at 1500 bytes.

We have a chain network of five nodes as an example topology. Traffic is generated at the very first node of the chain, and is sent to last node of the network, through intermediate nodes. The results are firstly taken under the basic IEEE-802.11 standard protocol.

When we simulate this topology, NCS (Node Categorization Scheme) shows significant increase in the throughput of individual node than the IEEE 802.11b.

In Figure 6.1 Category 1 node (N1) has the lower datarates than the Category 3 and 4 nodes. Here, NCS (Node Categorization Scheme) minimize overheads at Category 1 node. As contention window is a prime overhead, we should minimize the contention window for the sender node. So we suggest a minimum contention window for the sender nodes, when sender is having lower datarate.

Figure 6.2 shows the results obtained by simulating the topology of Figure 6.1. Figure 6.2 depicts that NCS (Node Categorization Scheme) ameliorates the throughput than IEEE 802.11b.

In multirate networks, faster stations have to wait for their slower peers to complete the transmission. In Figure 6.3, Category 1 node has the higher datarates than Category 2 and Category 3 nodes. So, NCS (Node Categorization Scheme) suggests for minimizing overheads at Category 2 and Category 3 nodes. So, slower peers of the Category 1 node will start transmitting data faster because we will minimize the overhead at Category 2 and Category 3 nodes and Sender will not have to wait for their slower peers to complete the transmission.

Figure 6.4 demonstrates the results received by simulating the topology of Figure 6.3. Figure 6.4 pictures that NCS (Node Categorization Scheme) provides the increased throughput than IEEE 802.11b.

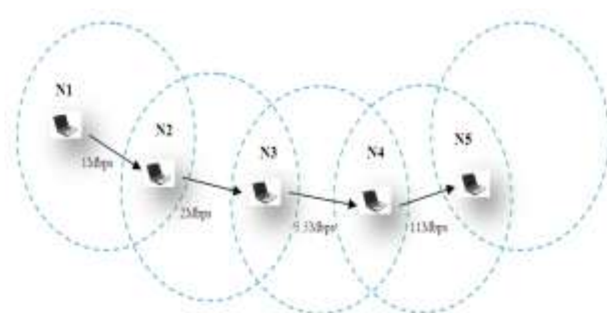

Figure 6.1 Example Topology1

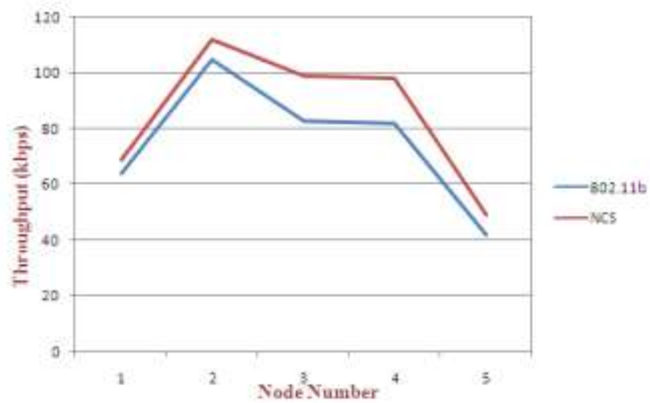

Figure 6.2 Throughput versus Node for Example Topology 1

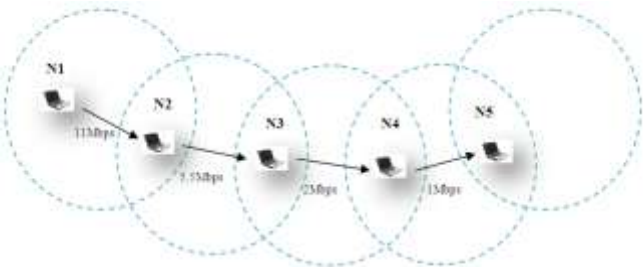

Figure 6.3 Example Topology 2

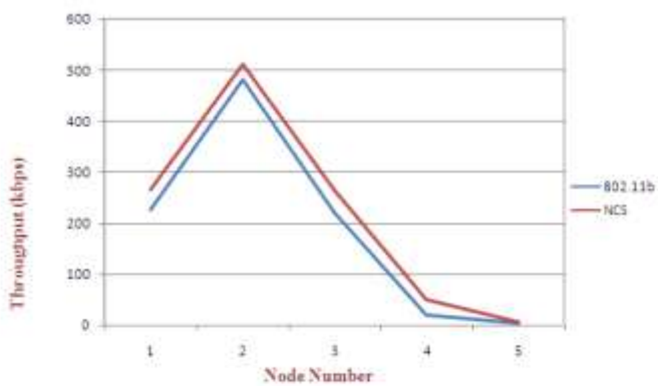

Figure 6.4. Throughput versus Node for Example Topology 2

7. CONCLUSION

We have presented Node Categorization Scheme (NCS) to improve multirate ad hoc network performance, by simply making use of the general scenarios and the basic distributed nature of the Distributed Coordination Function. We have verified our proposed solution with the help of simulations.NCS is dynamic method which does not require changes in basic access mechanism of IEEE 802.11b, also it is simple to implement.

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