LINK UTILITY BASED MULTIHOP RELAY PROTOCOL FOR WIMEDIA MEDIUM ACCESS CONTROL

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Abstract

Due to tremendous growth in wireless personal area network and home networking, high data rate supporting protocols has got wide range of opportunities. WiMedia Alliance emerges as a promising technology and enables high rate data transfer with low energy consumption. Thus it is essential to improve the performance of highly optimistic WiMedia medium access control protocol. Relay based communication may enrich the consistency of communication which might be deteriorate due to poor link conditions, interference and other well-known limitations of wireless networks. Hence, several contributions using on reservation based Multihop relay based MAC protocols were suggested. In this work, relay nodes were identified by using unreserved medium access slots with minimal queue length for data transmission to increase throughput. This article addresses these issues by two fold approach. First, we have developed a relay selection algorithm based on queue utilization factor. Second, we tested the performance of the algorithm by implementing the protocol to test the quality of outcomes. The numerical results demonstrate that the relay based transmissions assists efficient utilization of resources.
and improves the network life time under high data rate and throughput.

**Key Words:** WiMedia MAC, Multihop, Distributed Reservation Protocol, Delay.

## 1 Introduction to WiMedia Medium Access Control

Wireless personal area network is a growing technology in personal area network going through incredible changes in the last decade due to its fantastical properties and better quality of service. In fact, it has a high level of expectation amongst the high data rate users in order to support multimedia applications, building home networks, developing military applications, medical applications but suffers from coverage issues. Its operating frequency range from 2.4 GHz and extended till 10.6GHz. When devices come into close proximity, they can communicate with its neighbours which is synchronized in the network. WiMedia technology uses multiband orthogonal division modulation (MB-OFDM) to support short range high bandwidth communication at low energy levels using ultra-wide band physical layer [1]. When compared to the other personal area network protocols the success of WiMedia is capacity of providing maximum data rate of 480Mbps with low power consumption.

WiMedia Alliance provides simple, scalable, synchronized and distributed access. WiMedia MAC provides decentralized time division based medium access for both contention based and contention free access. The communication is grouped using a single frame structure, called Superframe Structure(Fig. 1) of duration 65535µs. The superframe is divided into 256 medium access slots 256µs. The Superframe structure consists of two phases namely: Beacon Period and Data Transfer Period. Beacon Period is used for synchronization and communicating Control as well as Device Information in order to provide device capacity and medium occupancy amongst communicating entities. The contention free access is provided by Distributed Reservation Protocol(DRP) and contention based access is provided by Prioritized Contention Access(PCA). As mentioned earlier, Networked devices uses Information Elements(IE) in Bea-
Figure 1: Superframe Structure

con Frames to inform device capacity and medium availability to their neighbours. Though many Information Elements are used by WiMedia MAC, we limit our discussion with Link Feedback IE, DRP IE and DRP Availability IE. Distributed Reservation Protocol provides various modes of reservation namely: Soft, Hard, Private. These modes have various medium access relaxation for the non-registration devices.

2 Related Work

WiMedia supports high speed, short range communication among the devices under close proximity preferably around 10 meters. Therefore if the distance between the communicating entities increase, there is a possibility of losing signal strength since the radio waves may propagate through the medium. Not only the distance, there were so many factors like signal interference, noise, data rate and so on may deteriorate the network performance. Therefore researchers showed interest in continuing communication using helper or intermediate to make a suitable communication (Table 1). They have considered various parameters for using a cooperative relay node. When the signal is more prone to interference then choosing an interference free path may be helpful to enhance the data rate as well as choosing a reliable path will reduce the rate of interference [2, 3]. As name specifies, personal area network is limited by its coverage region, increasing the distance between the nodes may lower the signal strength. During such worst condition, a relay node could be more beneficiary to enhance the data rate as well as addressing the faulty node[4]. Another notifiable factor leading to the same situation is nodes mobility addressed by kim et al., gives
Table 1: Researchers contributions on Relay based WiMedia MAC

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Issues addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Rosier et al.</td>
<td>Choice of interference free link could optimize channel utilization</td>
</tr>
<tr>
<td>2013</td>
<td>Hur et al.</td>
<td>To avoid bad channel conditions prefer better link quality</td>
</tr>
<tr>
<td>2013</td>
<td>Kim et al.</td>
<td>Relay selection procedure for better data rate to avoid signal strength due to mobility</td>
</tr>
<tr>
<td>2014</td>
<td>Lee et al.</td>
<td>Relay selection procedure for better data rate</td>
</tr>
</tbody>
</table>

the solution for the same using relay node [5].

We have analysed the requirement of using relay node, hence in the proposed work to present a reliable system a relay selection procedure based on queue length is used in addition to tradition approach i.e. link quality. The objective of this work is

- To identify a cooperative node based on the packet drop ratio
- To extend the network life time and minimizing delay

3 Cooperative Relay Selection Procedure

When the sender is trying to transmit the data, due to bad channel condition they may adopt the procedure for selecting the relay node [4]. Consider the relay node chosen is having good channel but the queue is full, then the possibility of packet drop is more (Fig. 2).

Every nodes communication is associated with a queue for the respective interface at the MAC level. The signal strength between
the sender and receiver may be too low. Therefore the sender will try to find a relay node and hence finds the node N1 and N2. Among N1 and N2, the node with comparatively lesser queue occupancy is chosen as the relay node (Fig. 3) and will be updated in the relay format (Fig. 4). The Fig. 5 depicts the flow of the relay selection and allocation.

4 Performance Analysis

We have evaluated the performance of a relay node selection using throughput for relay node representing the queue length [6, 7]. Initial state of the model represents the probability of having empty queue and defined as $P_{idle}$.

The probability of having a relay node $P_r$ and relay nodes with empty queue is denoted as $1 - (1 - P_{idle})^N$ and \( \binom{N}{1} P_{idle}^i (1 - P_{idle})^{N-i} \) respectively, where N represents cooperative neighbours of relay node.

Using Bernoullis process, the probability of j number of packets
arriving into the queue in a superframe is

\[ Q(j) = \begin{cases} \binom{M}{j} \sigma^j (1 - \sigma)^{M-j} & \text{if } 0 \leq j \leq M \\ 0 & \text{otherwise} \end{cases} \]

where \( \sigma \) represents the probability of producing new packet in a time slot and \( M \) is the total number of slots reserved within a superframe. Among the packets handled by the nodes, there is a possibility of processing non-relay packets that is generated by itself. So, to categorize the relay and non-relayed packets in equation (1) \( \sigma(r) \) and \( \sigma(nr) \) are used for representing relayed and non-relayed packets respectively. Similarly, to characterize the probabilities of having \( n \) relay packet and \( m \) non-relay packets in the queue \( Q_r(n) \) and \( Q_{nr}(m) \) are used.

Let \( k \) relay packets arrive the relay node within a superframe is represented by:

\[ Q_{nr}(k) = \sum_{(m=k)}^{M} Q_r(M) \binom{M}{k} (1 - P_r)^k P_r^1 (m - k) \quad (2) \]

Let \( T_l \) be the probability of number of packets increased by \( l \) in the relay nodes queue within a superframe is given by

\[ T_l = \begin{cases} P_{succ} Q_{nr}(0) & l = -1 \\ P_{err} \sum_{(n=l)}^{0 \leq m \leq M} Q_{nr}(m)Q_r(n) + P_{succ} \sum_{(n=l-m+1)}^{0 \leq m \leq M} Q_{nr}(m)Q_r(n) & 0 \leq l \leq 2M \\ 0 & \text{otherwise} \end{cases} \]
By using markovian model [6], let $T_h$ the throughput for a relay node in the proposed system as the average number of successfully processed packets per frame

$$T_h = P_{\text{succ}}[1 - (1 - \sigma_r(1 - P_r))^M(1 - \sigma_{nr}^M\pi_{r0})] + [1 - (1 - P_{\text{succ}}^N)]1 - (1 - \sigma_r P_r)^M\pi_{h0}$$

For various signal strength, we have analysed the throughput of the system (Fig. 6). The results depicts that the throughput can be maximized if the channel with good conditions is preferred.

5 Conclusion

In this work, we have developed and analysed a relay selection algorithm based on queue utilization ratio. The numerical results are used to validate the relay based transmissions. It actually promotes effective utilization of resources and increases throughput under high data rate. The possibilities of selecting relay nodes may further be explored using reliability and trust worthiness.

References


