Dynamic TDMA-MAC for Multi-Hop Wi-Fi Networks

Xingmin Zhuang 5110309433

June 21, 2014

1 Introduction

Most 802.11 networks use the DCF to arbitrate access to the shared wireless medium, which is designed for networks where stations are near each other. For very long distances the time required to wait for each frame to be acknowledged can dramatically affect performance. TDMA is a good way to handle media access in long distance networks. No arbitration is required once a slot is assigned to a station.

2 Background

2.1 TDMA

TDMA works with principle of dividing time frame in dedicated time slots, each node sends data in rapid succession one after the other in its own time slot. Synchronization is one of the key factors while applying TDMA. It uses full channel width, dividing it into two alternating time slots. TDMA uses less energy than others due to less collision and no idle listening. TDMA protocols are more power efficient than other multiple access protocols because nodes transmits only in allocated time slots and all the other time in inactive state. A packet generated by node suffer three type of delays as it reaches receiver.

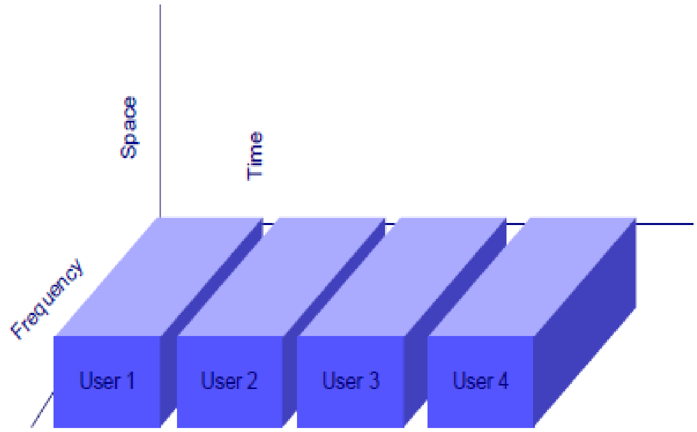

Figure 1: Timing diagram of TDMA

2.2 CSMA/CA

CSMA/CA is a extended version of CSMA. Collision avoidance is used to enhance performance of CSMA by not allowing node to send data if other nodes are transmitting. In normal CSMA nodes sense the medium if they find it free, then they transmits the packet without noticing that another node is already sending the packet, this results in collision. To improve the probability of collision CSMA/CA was proposed, CSMA/CA results in the improvement of collision probability.

It works with principle of node sensing medium, if it finds medium to be free, then it sends packet to receiver. If medium is busy then node goes to back-off time slot for a random period of time and wait for medium to get free. With improve CSMA/CA RTS/CTS exchange technique node send Request to send (RTS) to receiver after sensing the medium and finding it free. After sending RTS, node waits for Clear To Send (CTS) message from receiver. After message is received, it starts transmission of data, if node does not receive CTS message then it goes to back-off time and wait for medium to get free. CSMA/CA is a layer 2 access method. It is used in 802.11 wireless LAN and other wireless communication.

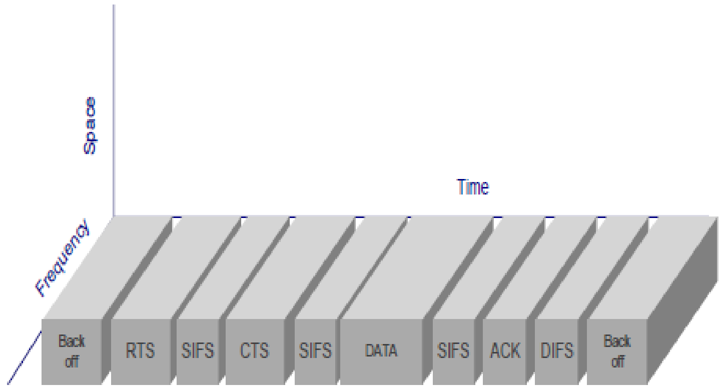

Figure 2: Timing diagram of CSMA/CA

3 Protocol Design

A proposed network design is showed in figure 3. The green node R in the middle is a root node of this network, acting as an access point. The blue nodes within R's range are called Hop-1 nodes, they connect with R directly. The yellow nodes are those nodes that are out of R's range but within Hop-1 nodes' range. These nodes are called Hop-2 nodes connect with Hop-1 nodes directly. Since the distance between R and Hop-2 nodes are far too long, Hop-1 nodes act as bridges to connect them. Then the whole network connect like this.

Since a multi-hop network have been designed, when a new node wants to get into this network, the dynamic access function follow these three steps.

Step 1: Listening for a while and choose a proper node to connect. The proper node needs to be choose by the new node, which should be in upper stage and have fewer children nodes.

Step 2: The root node assigns a proper time slot for the new node. In this step, the root node must considers both time slot reusing and collision avoiding.

Step 3: If a node disconnects from the network, the root node will retain the time slots for its children nodes, waiting to be reconnected.

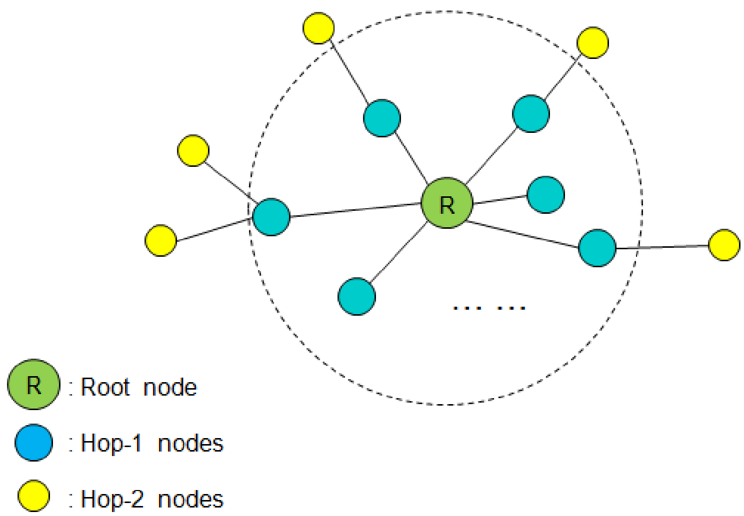

Figure 3: A proposed network

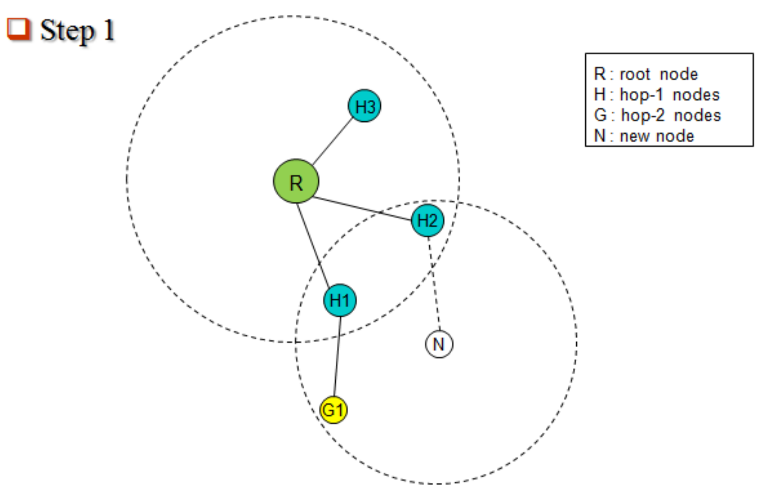

Figure 4: Step 1 situation

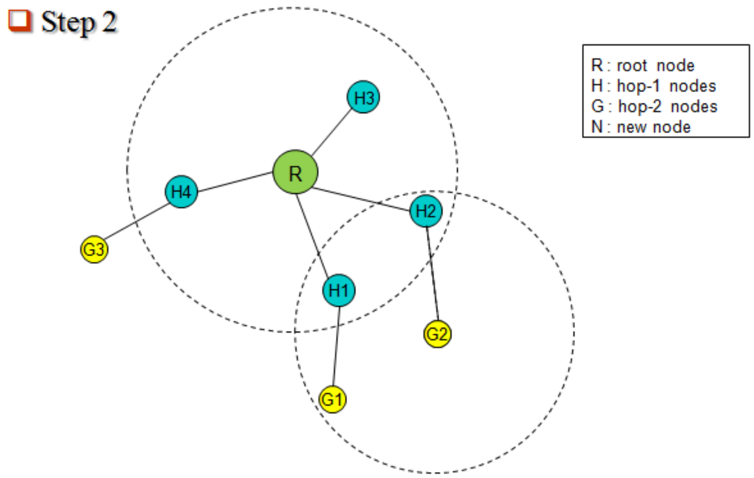

Figure 5: Step 2 situation

Take this simple network for an example. In step 1, when a new node N needs to connect to this network, it will listen for a while. Within its range, there are three nodes: hop-1 node H1, hop-1 node H2 and hop-2 node G1. H1 and H2 are in a same stage, they are in a upper stage than G1. Then compare H1 and H2, H1 has more children node than H2, so the new node will consider H2 as the proper node. If there are more than one proper node, then choose randomly. After choosing a proper node H2, N sends a message to H2 asks for connection. When H2 receives the message from N, it transmit the message to R in its own time slot.

Here comes the step 2. The root node notices the request from H2 and receives the information of the new node N. After assigning a proper time slot for N, it will transmit the data back to H2. When N receives the data from H2, it will become a new hop-2 node G2. In order to increase the throughput of the whole network, the time reuse technique is taken into consideration. When R transmits data to H1, H2 can communicates with G2 in the same time. But it may cause a problem. When H2 exchanges information with G2, it can also listen R and H1 because they and in its range. In this situation, H2 can receive information from G2 and R in the same time, which may cause collision. In order to solve this problem, R needs to know the nodes within G2's range, called G2's neighbour nodes. In the step 1

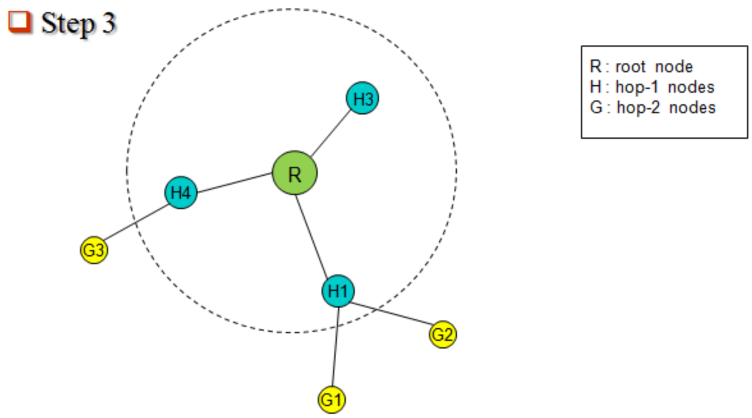

Figure 6: Step 3 situation

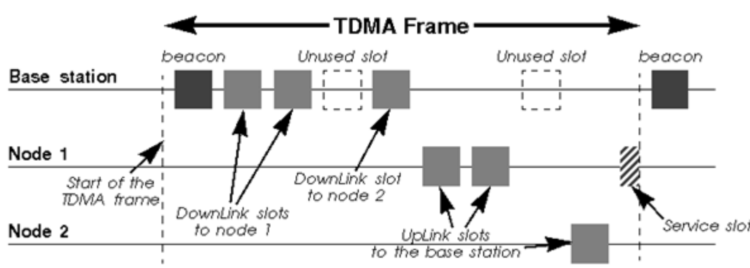

Figure 7: TDMA channel access mechanism

when G2 listen before asking for connection, it can gather neighbour nodes' information. The data can be sent to R when asking for connection, which will be add to a table listed neighbour information in R. With this table, R can assign a time slot for G2 avoid collision. Like figure 5 shows, H2 can communicate with G2 and H4 can communicate with G3 in the same time without collision situation.

In step 3, when node H2 disconnects from this network, R will probably delete H2's time slot. But G2's routine is cut because of H2' quiet. G2 needs to reconnect and R will not delete G2's time slot temporary, waiting for G2's reconnection.

As the protocol is a TDMA-base protocol, TDMA channel access mechanism is showed in figure 7, it is just a simple frame. In stage 1, the root node R acts as base station, it divides the frame for hop-1 nodes. The first time slot is for beacon and the last one is for service. In stage 2, the hop-1 nodes act as base station dividing their frame for hop-2 nodes. They also have their own beacon and service time slots. Actually, the frame can not be fully used in order to avoid collision between the neighbour stages. So there are still some unused slots in the frame.

4 Future Work

The protocol designed above may be a efficient protocol for Multi-Hop Wi-Fi Networks, but it is still a rough idea. Many details need to be considered fully, and a mathematical analysis is also necessary. Using MATLAB to run a simulation can connect some feedbacks whether the protocol design works or not. If it really works well, some implementation on test beds can be done in the future.