Strengthening Unlicensed Band Wireless Backhaul

Use TDD/TDMA Based Channel Access Mechanism

WHITE PAPER

Strengthening Unlicensed Band Wireless Backhaul: Use TDD/TDMA Based Channel Access Mechanism

WHITE PAPER

Lot of organizations use low cost standard Wi-Fi based solutions for outdoor wireless backhaul connectivity in ISM/License Free bands (i.e 2.4 GHz and 5.8 GHz). These standard Wi-Fi based solution meet the overall low cost CAPEX target, but with increase in interference levels in outdoor, links performance reduces to sub optimal level leading to lower or negative ROI. In this white paper we discuss the basic flaw in the MAC layer of IEEE 802.11 for outdoor wireless backhaul solution and suggest an alternative TDD/TDMA based MAC solution for wireless backhaul in ISM band.

omoco
be in charge

INTRODUCTION

Channel access method or multiple access method allows several terminals connected to the same multi-point transmission medium to share the medium and transmit over it. Examples of shared physical media are wireless networks, bus networks, ring networks, hub networks.

A channel-access scheme is based on a multiplexing method, which allows several data streams or signals to share the same communication channel or physical medium. A channel-access scheme is based on a multiple access protocol and control mechanism, also known as media access control (MAC). This protocol deals with issues such as addressing, assigning multiplex channels to different users, and avoiding collisions. The MAC-layer is a sub-layer in Layer 2 (Data Link Layer) of the OSI model and a component of the Link Layer of the TCP/IP model.

WI-FI IEEE 802.11 MEDIUM ACCESS CONTROL

Standard IEEE 802.11 protocol uses Carrier Sense Multiple Access (CSMA) with Collision Avoidance (CA) mechanism to access the channel. This is a probabilistic Media Access Control (MAC) protocol in which a node verifies the absence of other traffic before transmitting on a shared transmission medium. In CSMA, transmitter uses feedback from a receiver that detects a carrier wave before trying to send. That is, it tries to detect the presence of an encoded signal from another station before attempting to transmit. If a carrier is sensed, the station waits for the random backoff duration before retrying. Transmission is only started if the channel is found to be free. In other words, CSMA is based on the principle “sense before transmit” or “listen before talk”.

Wi-Fi systems are half duplex shared media configurations where all stations transmit and receive on the same radio channel. The fundamental problem this creates in a radio system is that a station cannot hear while it is sending, and hence it is impossible to detect a collision. Because of this, the developers of the 802.11 specifications came up with a collision avoidance mechanism called the Distributed Control Function (DCF).

According to DCF, Wi-Fi station will transmit only if it thinks the channel is clear. All transmissions are acknowledged, so if a station does not receive an acknowledgement, it assumes a collision occurred and retries after a random waiting interval.

These kinds of protocols are very effective when the medium is not used since it allows stations to transmit with minimum delay. The incidence of collisions (resulting in packet drop and increased latency) will increase as the traffic increases or in situations where mobile stations cannot hear each other.

TIME DIVISION MULTIPLE ACCESS

In TDMA a specific node, generally called the base station or master, has the responsibility to coordinate the transmission of all nodes in the network. The time on the channel is divided among the nodes and nodes are synchronized to ensure that each one of them transmit in their allocated time. Time Slots are usually organized in a frame, which is repeated on a regular basis. The frame is organized as downlink (base station to node) and uplink (node to base station) slots, and all the communications goes through the base station. TDMA suits for applications which have very predictable needs e.g. TDM traffic and is also suitable to provide guaranteed services for end users. TDMA is also very good to achieve low latency, low jitter and guarantee of bandwidth (where CSMA/CA is quite bad).

In CSMA collisions will occur, effectively lowering bandwidth and creating latency issues. With TDD/TDMA, everyone gets a turn without interruption. This decreases latency issues and improves bandwidth utilization.

LONG DISTANCE WIRELESS LINKS

Major problem in long distance ISM band wireless links is co-existence with other external omni-directional Wi-Fi transmitters. This causes hidden node problem to become worse. In long distance wireless links, directional transmission is used and due to highly directional nature of transmission, large number of interfering sources within range of receiver acts as hidden terminal since they cannot sense directional transmission.

As an optional feature, the 802.11 standard includes the RTS/CTS (Request to Send/Clear to Send) function to control station access to the medium. If RTS/CTS is enabled, node will not send data frame until it completes a RTS/CTS handshake with peer. A node initiates the process by sending a RTS frame. The peer node receives the RTS and responds with a CTS frame. The node must receive a CTS frame before sending the data frame. The CTS also contains a time value that alerts other stations to hold off from accessing the medium while the station initiating the RTS transmits its data.

The RTS/CTS handshaking provides positive control over the use of the shared medium. The primary reason for implementing RTS/CTS is to minimize collisions among hidden stations. However, use of RTS/CTS increases the overhead (caused by additional control frames that gets transmitted at lowest rate and wait times for acknowledgments) and hence reduces throughput.

In TDD/TDMA based access mechanism two communicating nodes are synchronized to each other and have fixed allocation of Tx and Rx time and operates without sensing the channel, so there is no need for additional control messages and hence gives better performance.

SYNCHRONIZING MULTIPLE LINKS

CSMA is a distributed random access protocol. Each transmitter chooses a random time instance to initiate its transmission, and it can only rely on its limited local knowledge to infer whether its transmission is compatible with other simultaneous transmission under various interference settings.

Since CSMA uses distributed random access, it is impossible to synchronize transmission and reception times for various nodes in the network. Synchronization of multiple radios on the same location is required to reduce self interference and to enable frequency re-use. In case of TDMA, since Tx and Rx times are centralized it is possible to achieve synchronization of Tx and Rx time of multiple collocated radios using TDMA based access.

Multiple collocated radios operating using CSMA/CA channel access will cause self interference. To understand this lets consider four wireless

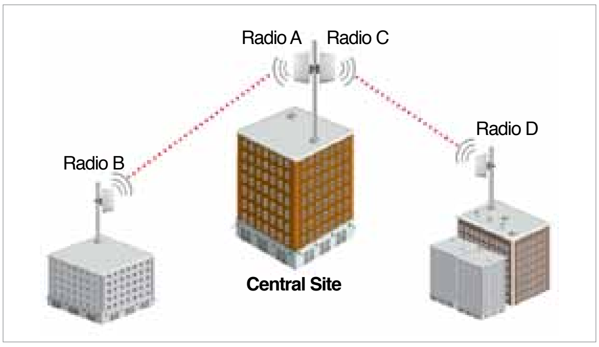

Figure 1: Synchronization of Multiple Collocated Radios

radios A, B, C and D, forming 2 point to point links AB and CD. When D is transmitting to C, A does not know of this communication and may try to communicate with B. This might interference with the communication at C if the transmit power of A is high as local side lobes are similar (or maybe better) in strength to the signal received from remote units. As soon as one radio starts transmitting after sensing the carrier to be idle, all other radios in the vicinity find the carrier to be busy and backoff. This backoff leads to suboptimal throughput. E.g. consider a scenario when there are N co-located links each with bandwidth support for X mpbs. In case of CSMA/CA based access mechanism there will be lot of collisions, so total throughput achieve will not exceed X mbps. However, in case of synchronized TDD/TDMA based radios, entire bandwidth of X mbps will be available to each link.

Figure 3 shows synchronized transmission between various master radio units installed at co-located tower. This synchronization helps in reduction of self interference and enables multiple radio links to operate at minimum frequency spacing and thus enables ease of deployment and reduces OPEX.

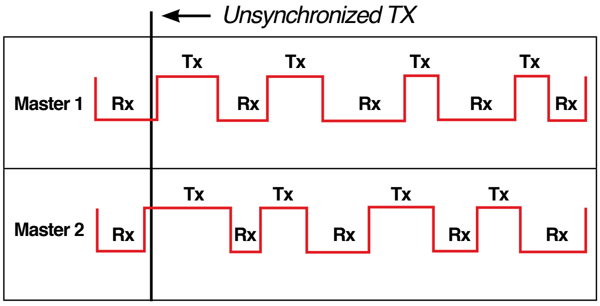

Figure 2: CSMA/CA based Non Sync transmission

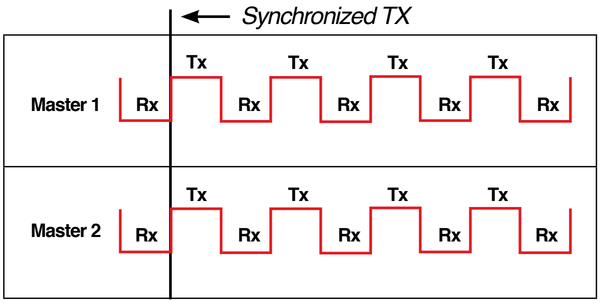

Figure 3: TDMA based Sync transmission

PERFORMANCE OVER MULTIPLE-HOPS

When using long distance wireless links using standard based Wi-Fi protocol (based on CSMA/CA), it is generally observed that due to unsyncronized nature of links, performance gets degraded as more number of hops are added. More hops results in more wireless nodes on the same tower/locations. Increased number of nodes on same location results in higher self-interference, collisions, backoffs and retransmissions and hence results in degraded performance.

With TDD/TDMA based wireless access mechanism, it is possible to synchronize transmission across multiple hops. This can be done by ensuring that slave unit on first hop provides sync pulses to master unit on the next hop. By doing this, slave and master units (at same tower) can synchronize their Rx and Tx resulting in zero mutual interference.

DELIVERING SECURED SLA USING CONTINUOUS TRANSMISSION

In IEEE 802.11-based systems, interference in a channel causes the radio to halt transmission until the channel is free for transmission again. This method of dealing with interference is not suitable for outdoor application where more interfering sources get added overtime.

This problem can be solved by using non-interrupted transmission based on TDD/TDMA channel access mechanism. TDD/TDMA access mechanism ensures that transmission and link stability is maintained even on encountering significant levels of interference. Radios continuously transmit even when encountering interference to ensure non-stop high quality wireless backhaul links in harshest conditions.

CONTENTION

When there are many nodes sending packets on the network, the probability of having two nodes choosing the same slot in the contention window increases. When two nodes choose the same slot (and they are first), their packets collide and are lost. This means that when the level of contention increases, the number of retry increases as well, so the performance of the network drops up to the point of congestion. With TDMA based channel access mechanism specific time slots are allocation for each slave, so increase in number of slaves doesn't result in increase of contention and collision.

TCP TRAFFIC

TCP adaptively adjusts its transmission rate according to the network condition. If the network condition does not vary, the TCP throughput should stay in some level.

Taken together, the protocol shortcomings of 802.11 and channel induced losses significantly lower end-to-end TCP performance. The use of stop-and-wait over long distances reduces channel utilization. Due to collision losses due to interference from unsynchronized transmissions as well as from external Wi-Fi sources TCP flows often timeout resulting in very poor performance. The only configurable parameter in the driver is the number of packet retries. Setting a higher value on the number of retries decreases the loss rate, but at the cost of lower throughput resulting from lower channel utilization.

For optimal performance of TCP traffic it is required to have a link with low latency, jitter and packet loss. Resource reservation is a well known technique widely used in TDMA schemes to achieve high throughput since channel access in the reserved slots ensures less network collisions. Usually TDMA are more appropriate for QoS-aware applications than contention-based CSMA protocols because of hidden node problem, huge Round Trip Time (RTT) and unnecessary contention. Due to these reasons TDMA based wireless backhaul links offer optimal performance for TCP traffic.

CONCLUSION

In this white paper we have discussed the various reasons why IEEE 802.11 standard based equipments are not suitable for long range wireless backhauls. Furthermore, we have proposed an alternative TDD/TDMA based channel access mechanism and technical details of how the proposed channel access mechanism overcome deployment problems in wireless backhaul networks.

ABOUT OMOCO

Omoco develops Do-it-yourself Micro Telecom Network solution, suitable for individuals, enterprises and communities who want to build their own wireless communication circle.

CONTACT US

Email: sales@omoco.in

http://www.omoco.in

omoco
be in charge