ISSN 2348-1196 (print)
International Journal of Computer Science and Information Technology Research ISSN 2348-120X (online)
Vol. 2, Issue 4, pp: (242-249), Month: October - December 2014, Available at: www.researchpublish.com

A Priority Based Cooperative CSMA/CA Protocol For Long Distance Wifi Links

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Abstract: **With the growing need for Internet connectivity in rural areas, an alternative to the wired technology need to be used to provide Internet connectivity because of cost constraint. Wi-Fi can be a cost effective and efficient solution to provide Internet connectivity in rural areas. Wi-Fi based long distance networks with long distance outdoor links have become an attractive option to provide low cost internet connectivity to rural areas. The existing MAC protocol, CSMA/CA used by Wi-Fi has its coverage on comparatively smaller range and this aspect puts a hurdle in providing Internet, when it comes to rural areas. So, for practical applicability of Wi-Fi in long distance networks, modifications need to be made in the MAC protocol. As this protocol is originally not fit for long distance Wi-Fi networks, we have taken an initiative to tune certain parameters in this protocol and proposed two algorithms (Pre_BackOff algorithm, BackOff algorithm) to make it acceptable operable for long distance Networks.**

Keywords: **CSMA/CA, Long Distance Wi-Fi, MAC in long distance Wi-Fi, Proposed algorithms (Pre_BackOff algorithm, BackOff algorithm), Wi-Fi.**

1. INTRODUCTION

With over 68 percent or 833 millions of Indians still living in villages, development of rural areas has become one of the key concern of the government. For this to happen, it is a necessity that the continually upgrading latest news and technologies, particularly the schemes introduced by the government reaches even the farthest and the remotest areas. With more than 638,000 villages, providing technology that is efficient but at a low cost is crucial. Solution is Wi-Fi for long distance. Wi-Fi networks have a range that is limited by the transmission power, antenna type, the location they are used in, and the environment. A typical wireless router in an indoor point-to-multipoint arrangement using 802.11b or 802.11g and a stock antenna might have a range of 32 meters. So, 802.11 long-distance links are used to provide wireless connectivity to rural areas. WiLD (Wi-Fi for Long Distance) networks comprise of point-to-point wireless links that use high-gain directional antennas with Line Of Sight over long distances. Although, the network we are working has 1 hop in it. And we are not considering a complex topology.

As the existing CSMA/CA protocol is not suitable for WiLD [3], we have made certain changes in the protocol by tuning some parameters in it. In addition to this, we have proposed two algorithms- Pre_BackOff and BackOff, which is absent in all previous studies. We have summarized the IEEE 802.11 standard (emphasis on the MAC sub layer), and have briefly described the simulation model. Performance evaluation after adjusting the parameter values in existing CSMA/CA MAC layer and after implementation of the proposed algorithm using NS-2 has been presented.

2. BACKGROUND

More than half of India's population lives in rural areas. Most of them are remote and too isolated to benefit from the country's economic progress. Yet there is a growing desire among people in rural India to be part of its modernisation process. Increasingly the government is looking at better ways to reach remote, rural India. And it is hoping that technology will provide a solution.

2.1 WI-FI

Wi-Fi is the marketing name for IEEE standard 802.11. It is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high-speed internet connections. A Wi-Fi network can be used to connect computers to each other, to the Internet, and to wired networks (which use IEEE 802.3 or Ethernet). It is an open standard technology that enables wireless connectivity between equipments and LAN.

2.2 LONG DISTANCE WI-FI

WiLD networks use multi-hop point–to-point links. To achieve long distances in single point-to-point links, nodes use directional antennas with high gains, and may use high-power wireless cards. In multi-hop settings, nodes have multiple radios with one radio per fixed point-to-point link to each neighbour.

2.3 MAC

MAC is responsible for taking incoming frames from the host operating system's network stack. It decides when the antenna has to send the frames to the air. The MAC accepts frames from the operating system for delivery through a system bus interface. The IEEE standard 48-bit MAC addressing is used to identify a station.MAC protocol is used to provide the DLL (data link layer) of the Ethernet LAN system. Ethernet protocols refer to the family of LAN covered by the IEEE 802.3. In the Ethernet standard, there are two modes of operation: half-duplex and full-duplex modes. In the half duplex mode, data are transmitted using the popular CSMA/CD protocol on a shared medium. The main disadvantages of the half-duplex are the efficiency and distance limitation, in which the link distance is limited by the minimum MAC frame size. This restriction reduces the efficiency drastically for high-rate transmission. Therefore, the carrier extension technique is used to ensure the minimum frame size of 512 bytes in Gigabit Ethernet to achieve a reasonable link distance.

2.4 MAC IN LONG DISTANCE WI-FI

IEEE 802.11 wireless LANs use a MAC protocol CSMA/CA. Wi-Fi systems are half duplex shared media configurations where all stations transmit and receive on the same radio channel. The fundamental problem that occurs 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 specification came up with a collision avoidance mechanism, DCF (distributed coordination function). According to DCF, a 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 that collision has occurred and retries after a random waiting time interval.

2.5 CSMA/CA

CSMA/CA is a protocol for carrier transmission in 802.11 networks. In CSMA/CA, as soon as a node receives a packet that is to be sent, it checks to be sure the channel is clear (no other node is transmitting at the time). If the channel is clear, then the packet is sent. If the channel is not clear, the node waits for a randomly chosen period of time, and then checks again to see if the channel is clear. Collisions are avoided through the use of three CSMA/CA strategies. They are:

2.5.1 INTERFRAME SPACE (IFS)

When an idle channel is found, the station does not send immediately. It waits for a period of time called the IFS. Even though the channel may appear idle when it is sensed, a distant station may have started transmitting. The IFS time allows the front of the transmitted signal by the distance station to reach this station. If after the IFS time the channel is still idle, the station can send, but it still needs to wait a time equal to prioritize station or frame types.

2.5.2 CONTENTION WINDOW

Amount of time is divided into slots. The number of slots in the window is set to 1 the first time and then doubles each time the station cannot detect an idle channel after the IFS time. The station needs to sense the channel after each time slot. If the station finds the channel busy, it does not restart the process; it just stops the timer and restarts it when the channel is sensed as idle.

2.5.3 ACKNOWLEDGEMENTS

The data may be corrupted during the transmission. The positive acknowledgement and the time out timer can guarantee that the receiver has received the frame [7]. In CSMA/CD, when a collision is detected on the medium, the station needs to wait a random amount of time before it retransmits. For this reason, CSMA/CD works well for wired networks. However, in wireless networks, there is no way for the sender to detect collisions the same way as in wired networks as here the sender is only able to transmit and receive packets on the medium but is not able to sense data is traversing that medium. Therefore, CSMA/CA is used on wireless networks instead of CSMA/CD.

3. DESIGN

The existing CSMA/CA is not suitable for long distance Wi-Fi because of collisions at long distances, inefficient link-level recovery and inter-link interference. We have made an attempt to bring certain changes in the existing CSMA/CA protocol by modifying the parameters: SIFS time, Slot time, Contention Window (CW) size, RTSThreshold, ACKTimeout. We have developed a BackOff algorithm with the motive of making CSMA/CA protocol feasible for WiLD.

3.1 TUNING OF PARAMETERS

In CSMA/CA, after receiving the frame, the receiver has to wait for SIFS time and then it sends the acknowledgement (ACK) to the station (sender). If the ACK is received, the transmission is considered as successful, and the station is considered ready to restart the whole process with another frame. If ACKTimeout occurs and no ACK is received, retransmission is performed. For distances exceeding 150 m, we guarantee that ACKTimeout has a sufficient value as-

ACKTimeout = SIFS + Standard slot time + (2 * Maximum Propagation Delay) + Tx_time (RTS) + Tx_time (CTS)
Where, SIFS = Short Interframe spacing time
Tx-time = Transmission time
So, to obtain a better throughput and considerable amount of packet loss we have adjusted the ACKTimeout.

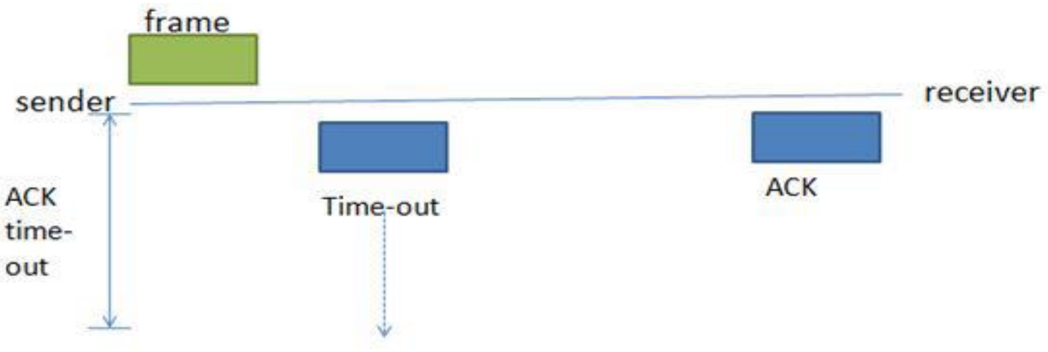

Figure 1: ACK Timeout for long distance Wi- Fi

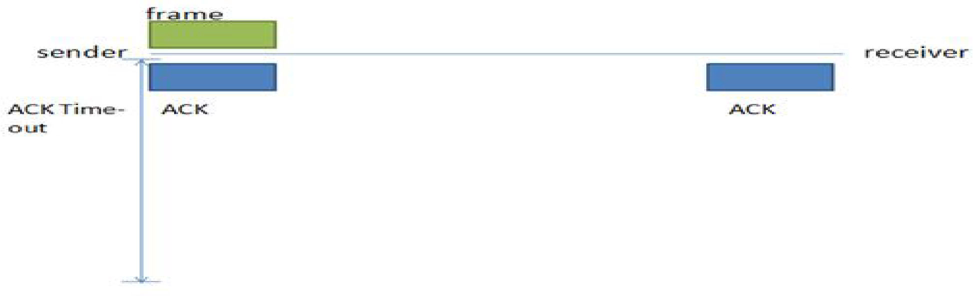

Figure 2: Acknowledgement Received within the ACKTimeout

We have increased the ACKTimeout value by increasing the Max-propagation delay. We calculate the propagation delay as t = D/C.

Where, t=propagation delay, D=distance travelled, C=speed of light.

We found in long distance Wi-Fi the value of ACKTimeout increases by 2 µs after the increment of each 300 m distance. Therefore, we have increased the value of Max-propagation delay to 90 µs from its default value [10].

3.2 PROPOSED BACKOFF ALGORITHM

When we use various traffics at the same time, it creates unnecessary collision resulting in throughput degradation, and packet loss/delay increases. So, we have disabled the RTSThreshold. The algorithm we have designed works for two nodes, whose BackOff time sets to 1 slot time or 2 slot time randomly. The algorithm is constructed in such a way that priority is provided to the nodes based on the priority of traffic in which the packet is sent.

3.2.1 Assumption

In reality the topology is very complex and has a multi-hop network. But for simplicity we have assumed that there are only two nodes and it is a 1-hop network.

Pre-Back Off:

In this algorithm we define the steps taken to maintain the variables that are used to execute the BackOff algorithm. The variables maintained by this algorithm are- my_traffic, your_traffic, my_queue_len, your_queue_len.

Each node maintains four variables -

my_traffic = counts the priority of the last packet that is sent by the node.

your_taffic = counts the priority of the last packet that is being received by the node.

my_traffic = 0 for highest priority packet (control packets, voip)

= 1 for 2nd highest priority packet (CBR)

= 2 for 3rd highest packet and so on.

Before sending the packet, length of the queue is assigned to the my_traffic_len variable and placed in the packet header. So, the receiver will know the sender‘s queue length from “my_queue_len” and will update your_queue_len (receiver’s queue length). Same is done in the sender side too.

Back Off:

In this algorithm, nodes are assigned priority during transmission so that they do not compete among themselves for accessing the same CW (contention window) size when collision occurs. This priority is based on the variables maintained by the pre-BackOff algorithm and the queue length of each node.

3.2.1.1 Pre-BackOff (ni)

cwmin>2 (contention window) , cwmax-> 3, ni= node

1. Start
2. ni .my_traffic = 3

ni .your_traffic = 3

ni .my_queue_length = 0

ni .your_queue_length = 0

3. while rcv (pkt)

if pkt.type = VOIP then

your_traffic = 0

else if pkt.type = CBR then

your_traffic = 1

else

your_traffic = 2

4. while send (pkt)

if pkt.type = VOIP then

my_traffic = 0

else if pkt.type = CBR then

my_traffic = 1

else

my_traffic = 2

5. If ACKTimeout, then

Backoff (ni)

3.2.1.2 BackOff (ni)

6. Compare ni.my_traffic and ni.your_traffic

7. If (ni.my_traffic < ni. your_traffic) then

ni.priority = 1

else if ni.my_traffic > ni.your_traffic then

ni.priority = 2

Else if ni.my_traffic = ni.your_traffic then

Compare ni.my_queue_len and ni.your_queue_len

if ni.my_queue_len > ni.your_queue_len then

ni.priority = 1

else if ni.my_queue_len < ni.your_queue_len then

ni.priority = 2

8. Else ni.priority = random

9. End

4. PERFORMANCE EVALUATION

Using existing CSMA/CA with default parameters, we have achieved a maximum distance of 500 metres.

Table 1: In existing CSMA/CA for 500 metres packet loss, delay, throughput.

Output	FTP	CBR	VOIP
Total packet sent	215	1817	4122
Packet loss (%)	19.611	0.97799	18.8273
Delay (sec)	0.17076	0.02594	0.446145
Throughput (kbps)	386.976	585.248	401.01

From the above result we observe that the packet loss, delay and throughput obtained is not efficient for long distance Wi-Fi. So we have made the following changes in ns-2.34 (ns-default.tcl) [14].

- Cwmin = 2 from 31
- Cwmax = 3 from 1023
- Slot Time = 0.000040 (40 µs) from 0.000020 (20 µs)
- SIFS_Time = 0.000001 (1 µs) from 0.000010 (10 µs)

- Preamble_Length = 72 bit from 144 bit
- RTSThreshold = 3000 from 0
- ShortRetryLimit = 0 from 7
- LongRetryLimit = 0 from 4
- Bandwidth = 11 Mbps from 2

Table 2: After tuning the parameters in CSMA/CA for 2 kilometres packet loss, delay, throughput.

Output	FTP	CBR	VOIP
Total packet sent	818	1549	987
Packet loss (%)	16.117	0.97799	4.68273
Delay (sec)	0.01766	0.00594	0.06145
Throughput (kbps)	588.774	1027.721	553.701

From the above simulation result we observe that the throughput obtained is not efficient for long distance Wi-Fi. Also if we increase the distance beyond 2 km throughput degrades tremendously as well as the end to end delay and the packet loss increases, due to ACKTimeout. Therefore for long distance Wi-Fi we have to adjust the ACKTimeout value. Therefore after increasing the ACKTimeout we have achieved a maximum distance of 7 kilometres.

Table 3: After increasing the ACKTimeout for 7 kilometres packet loss, delay, throughput.

Output	FTP	CBR	VOIP
Total packet sent	215	1817	4122
Packet loss (%)	13.9534	0	0
Delay (sec)	0.10986	0.00106	0.000450
Throughput (kbps)	677.163	1347.883	593.424

The simulation result as shown in the above table is not acceptable for long distances. So after using our algorithm, we achieved an acceptable throughput and considerable amount of end to end delay and packet loss for a distance of 7 km.

Table 4: Using proposed BackOff algorithm.

Output	FTP	CBR	VOIP
Total packet sent	4950	3623	496
Packet loss (%)	0.055	0.080	0.336
Delay (sec)	0.0369587	0.0263629	0.0761
Throughput (kbps)	4363.634	4022.064	1056.24

After implementing the algorithm, we obtained the results as shown in the graphs below.

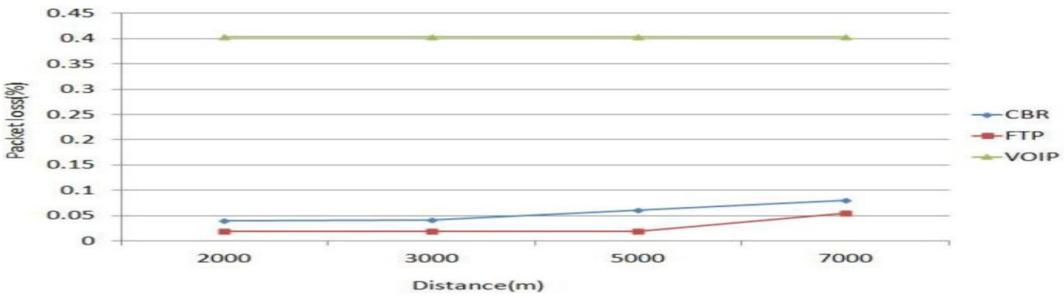

Figure 3: Packet loss vs. Distance

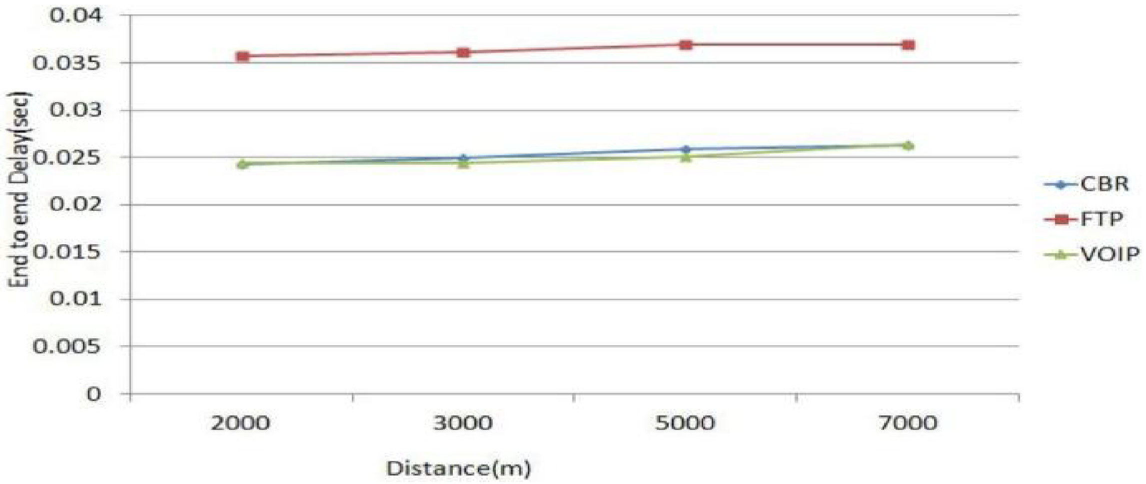

Figure 4: End to end delay vs. Distance

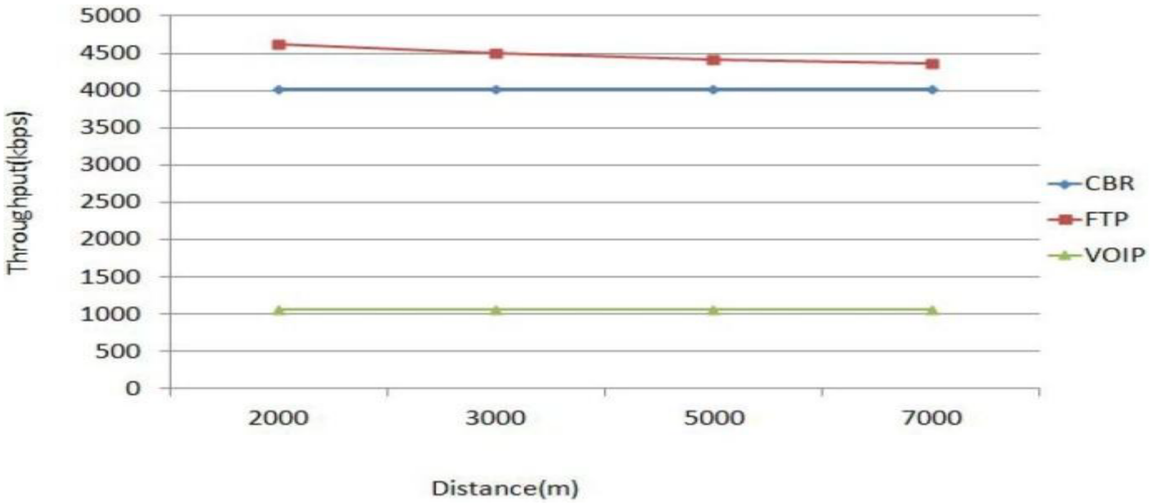

Figure 5: Throughput vs. Distance

Table 5: Comparison table for tuning parameters and proposed Back Off algorithm.

Output	Tuning Parameters			Proposed BackOff algorithm		
Total Packet Sent	9084			3023		
Traffics	FTP	CBR	VOIP	FTP	CBR	VOIP
Throughput (kbps)	677.16	1347.883	593.424	4363.63	4022.06	1056.24
End to end delay (sec)	0.1098	0.00106	0.00045	0.0369587	0.026269	0.0761
Packet loss (%)	13.95	0	0	0.0552	0.0808	0.336

5. CONCLUSION

In this paper, we have done a thorough study of the existing CSMA/CA protocol in NS2 and have found that it is not suitable for long distance Wi-Fi. So, we tuned some parameters of CSMA/CA protocol and the result obtained is still not efficient enough. The reason is that congestion is more in the network when various traffics are generated simultaneously. Therefore, we designed an algorithm to assign priority to the nodes based on the priority of the traffic in the packet. Due to time constraint, we were unable to extend our paper for multi-hop network, which is the major consideration for long distance Wi-Fi in rural areas. In our future work, we will look forward to implement the same for multi-hop network.

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