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Throughput Based Packet Examination Using Markov Chain Model

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Abstract: Wireless computer network that associates two or more devices using a wireless distribution method often using spread-spectrum or OFDM within a limited zone such as a campus or small building. IEEE 802.11 agrees for fragmentation tuning and rate selection to attain highest throughput. Fragmentation is the procedure by which 802.11 frames are divided into smaller fragments that are transmitted independently to the destination. The aim of this study is to study the performance of IEEE 802.11 of throughput and packet delay by using two types of algorithms, i.e., Constant contention window and binary exponential back-off.

Key words: IEEE 802.11, fragmentation, contention window, packet delay, performance, delay

INTRODUCTION

A Local Area Network (LAN) is a computer network that interconnects computers in a narrow area such as a home, school, computer laboratory or office building using network media. The defining characteristics of LANs in contrast to Wide Area Networks (WANs), include their higher data-transfer rates, smaller geographic area and lack of a need for leased telecommunication lines. In the infrastructure topology, there is a fixed (wired) infrastructure that supports communication between mobile terminals and between mobile and fixed terminals (Fig. 1)(IEEE Standard 802.11, 1999; Lettieri and Srivastava, 1998; Pavon and Choi, 2003).

In modern year the IEEE 802.11 (IEEE Standard 802.11, 1999) family of WLAN standards has developed as the dominant technology for broadband wireless access networks. Although, it supports relatively low transmission rates compared to the wired technologies the number of WLAN users continues to grow dramatically mostly due to its flexibility and low cost. A station can initiate a transmission when the back-off timer reaches zero. The back-off (Ni *et al*., 2004; Rappaport, 2002) time is uniformly chosen in the range (0, w-1). Also (w-1) is known as Contention Window (CW) which is an integer with the range CW_{min} and CW_{max} determined by the PHY characteristics. After each unsuccessful transmission, w is doubled, up to a maximum value 2 mW, where W equals to (CW_{min+1}) and 2 mW equals to (Cw_{max+1}).

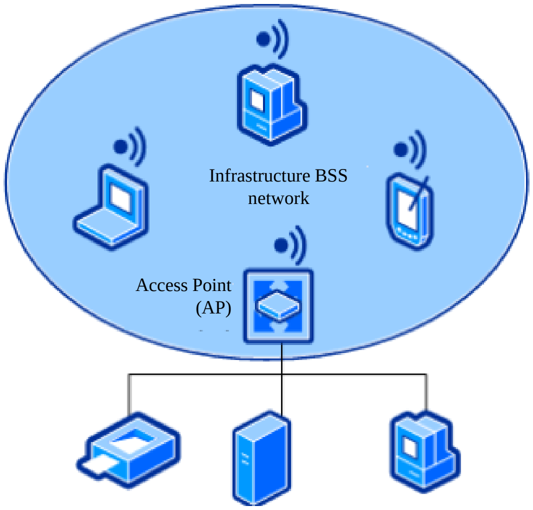

Fig. 1: Infrastructure BSS networks

MATERIALS AND METHODS

Saturation throughput analysis of IEEE 802.11 WLAN using Fragmentation: In communication systems such as Ethernet or packet radio, throughput or network throughput is the average rate of successful data delivery over a communication channel. The throughput (Marcum, 1950; Chang *et al*., 2007) is usually measured in bits per second (bit/sec or bps) and sometimes in data packets per second or data packets per slot. The system

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throughput or aggregate throughput is the sum of the data rates that are delivered to all the terminals in a network.

The time to transmit this packet t_T is shown as (Papoulis *et al.*, 2002; Qiao and Choi, 2001; Heusse *et al.*, 2005; Tellambura and Bhargava, 1994):

$$t_T = \text{DIFS}+\text{OVERHEAD}+\frac{\text{Data}(\text{Bits})}{\text{Rate}(\text{Bit/sec})}+\text{SIFS}+\text{ACK}$$

Following is a list of parameters defined by the protocol IEEE 802.11b: SIFS = 10 µsec, DIFS = 50 µsec, ACK = 112 µsec Overhead = Preamble + Header = 144 µsec + 48 µsec = 192 µsec Rate = 1, 2, 5.5, 11 Mbps data = 1000 bytes:

$$\begin{aligned}
&(1\text{-p}).\sum_{i=1}^{\infty}\text{i.p.t}_T.\text{p}.(1\text{-p}).\sum_{i=1}^{\infty}\text{i.p}^{i-1}\\
&= \text{t}_T.\text{p}.(1\text{-p}).\frac{1}{(1\text{-p})^2} = \frac{\text{t}_T.\text{p}}{(1\text{-p})}\\
&T_w = t_T+(1\text{-p}).\sum_{i=1}^{\infty}\text{i.p}^i.t_T = t_T+\frac{t_T.\text{p}}{(1\text{-p})} = \frac{t_T}{1\text{-p}}
\end{aligned}$$

Using the above equation, the throughput can be derivedas:

$$\text{Throughput}\left(\text{Bits}/_{\text{sec}}\right) = \frac{\text{Data}}{T_w} = \frac{\text{Data}}{t_T}.(1\text{-PER})$$

Binary Exponential Backoff (BEB) algorithm: In BEB (Chang *et al.*, 2007) when a node over the network has a packet to send, it first senses the channel using a carrier sensing technique. If the channel is found to be idle and not being used by any other node, the node is granted access to start transmitting. Otherwise, the node waits for an inter-frame space and the back-off mechanism is invoked. A random back-off time will be chosen in the range [0, CW-1]. A uniform random distribution is used here where CW is the current contention window size. The following equation is used to calculate the Back-Off time (BO):

$$t_T = \text{DIFS}+\text{OVERHEAD}+\frac{\text{Data}(\text{Bits})}{\text{Rate}(\text{Bit/sec})}+\text{SIFS}+\text{ACK}$$

If the medium is found to be idle then the back-off period is decremented by one time slot:

$$\text{Back-off time }(\text{BO})\text{ new} = (\text{BO})\text{ old} - \text{a slot time}$$

The BEB algorithm uses the following equation to increase the contention window size:

$$\text{Back-off time }(\text{BO}) = (\text{Rand () MOD CW})*\text{a slot time}$$

Contention window scheme for WLANs: The constant contention window algorithm is the modification of the IEEE 802.11 BEB algorithm which is used to control the contention window in the case of collisions in order to provide a better throughput. In case of collisions, the contention window size is selected between [0 to CW] and CW is fixed for every retry. The value of CW is selected between CW_{min} and CW_{max}.

Fragmentation in IEEE 802.1: Fragmentation is the procedure of separating a long frame into short frames. MSDU is passed down from the LLC layer if the size of the MSDU is bigger than the fragmentation threshold and it is separated into smaller fragments. Each fragment, namely an MPDU, becomes a MAC layer frame with a MAC header. Then, a Physical Layer Convergence Protocol (PLCP) header and a preamble are added to the MPDU. The resulting frame is called a PLCP Protocol Data Unit (PPDU) which is the frame transmitted by the physical layer over the air.

When the transmission of a fragment fails, the contention process activates after a DIFS idle time period. The remaining fragments are transmitted when the node seizes the channel again through the contention process. The transmission procedure for the fragments of an MSDU is called a fragment burst. Because the header of each MAC frame contains the information that defines the duration of the next transmission, the nodes that overhead the header update the NAV value for the next fragment transmission.

Throughput analysis: The performance of the wireless Communication network can be evaluated in terms of QOS parameters like throughput (Wu *et al.*, 2002; Bianchi, 2000), packet delay and packet delivery ratio, packet drop, etc. Let n be the fixed number of contending stations and τ be the probability that a station transmits the packets:

$$\tau = \frac{2.(1\text{-}2p).(1\text{-}p)}{w.\left(1\text{-}(2p)^{m+1}\right).(1\text{-}p)+(1\text{-}2p).(1-p)^{m+1}}$$

Where:

P = The probability of collision

W = The contention window size and m is the retry limit

$$P_n = (1\text{-}\tau)^n$$

Probability that the channel is demanding is given as:

$$P_b = 1\text{-}(1\text{-}\tau)^n$$

The communicating a packet P_{tr} in an idle time can be expressed as:

$$P_c = P_{tr} = 1-(1-\tau)^{n-1}$$

The throughput considering the transmission faults can be derived as:

$$S = \frac{P_s(1-P_{frag\text{-}error})L}{P_s(1-P_{frag\text{-}error})T_{success} + (1-P_s)T_{collision} + T_{idle} + P_s P_{frag\text{-}error} T_e}$$

where, L is the average packet payload size

Packet delay analysis of IEEE 802.11 WLAN using fragmentation: The delay performance of IEEE 802.11 (Qiao and Choi, 2001; Cantieni *et al*., 2005) protocol can be done by taking the retry limits of a data packet transmission into account. The packet drop probability is defined as the probability that a packet is released when the retry limit is gotten and it is equal to:

$$p_{drop} = p^{m+1}$$

The normal length of a slot time is:

$$E[slot] = (1-p_{tr}).\sigma + p_{tr}.p_s.T_s + p_{tr}.(1-p_s).T_c$$

where E [X] is the normal number of slot times required for positively transmitting a packet and is given by:

$$E[X] = \frac{(1-2p).(cw+1)+p.cw.(1-(2p)^m)}{2.(1-2p).(1-p)}$$

RESULTS AND DISCUSSION

Simulation analysis: Figure 2 depicts the number of nodes rises, the throughput reductions but by properly adjusting the contention window, the maximum throughput can be achieved Table 1.

Here, the quantity of stations is different and uses the packet size of 2000 bytes and fragment size of 256 bytes is taken in Fig. 3 and 512 bytes in Fig. 4. The probability of collision increases with increase in number of contending nodes and hence, the throughput decreases. But the throughput can be increased by selecting the proper contention window even the number of nodes increases. Here, the optimal contention window size is 300. If the contention window is set at 500, the throughput is better but it doesn't work if the numbers of nodes are <20.

Table 1: Simulation parameters

Description	Values
Slot time	20 μsec
SIFS	10 μsec
DIFS	50 μsec
PLCP preamble	144 μsec
PLCP header	48 μsec
Minimum contention window	31
Maximum contention window	1023
Channel bit rate	Up to 54 Mbps
PHY header	24 Bytes
MAC header	28 Bytes
RTS	44 Bytes
ACK	38 Bytes
Propagation delay, (δ)	2 μsec

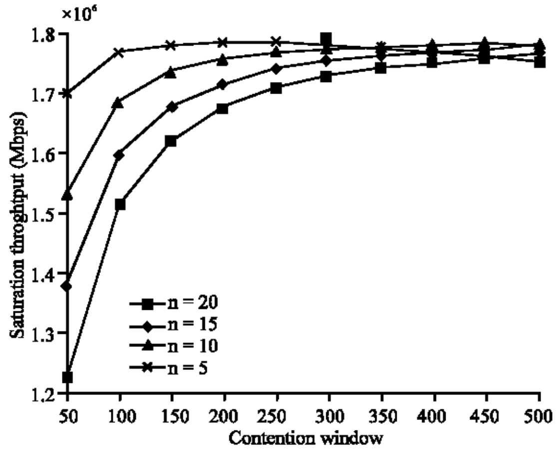

Fig. 2: Contention window vs. saturation throughput

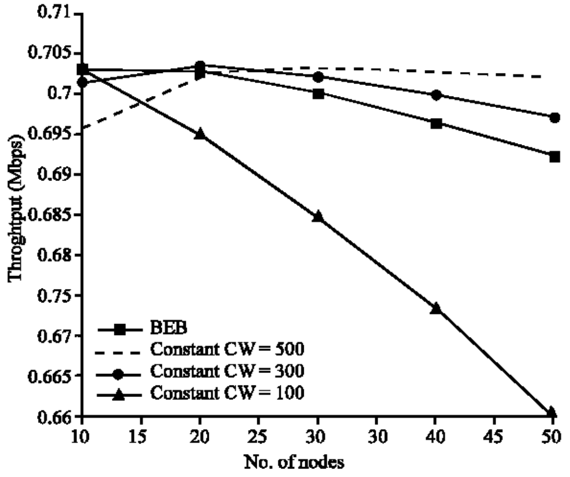

Fig. 3: Number of nodes versus throughput (fragmentsize = 256 bytes, BER = 10-6) packet size = 2000 bytes, fragment size = 256 bytes

The BER is taken as 10^{-4} and the variation of throughput with contending nodes are plotted in Fig. 5 and 6. In this case also, the optimal contention window

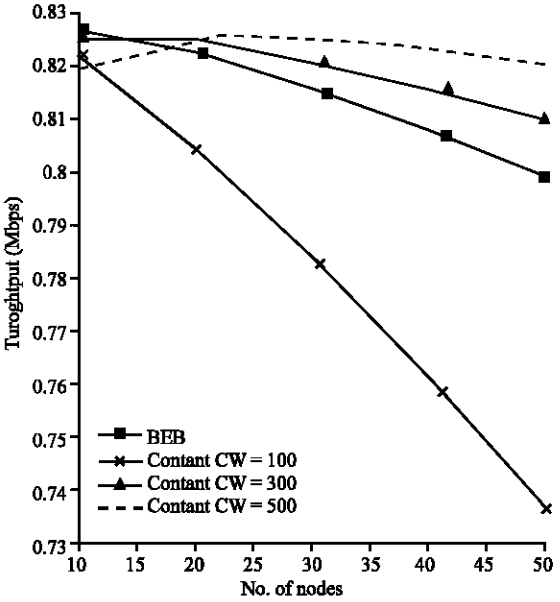

Fig. 4: Number of nodes versus throughput (fragment size = 512 bytes, BER = 10-6) packed size = 2000 bytes

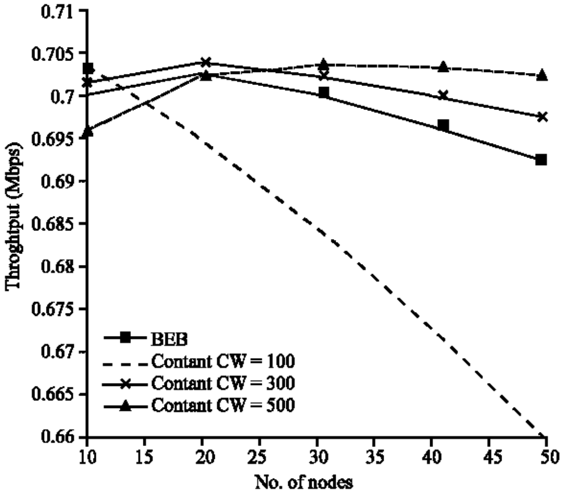

Fig. 5: Number of nodes versus throughput (fragment size = 256 bytes, BER = 10-4) packed size = 2000 bytes, fragment size = 256 bytes

size is 300 and the optimal fragment size is 512 bytes. The packet delay analysis for various nodes using BEB and constant contention window algorithms is plotted in Fig. 7 and 8. The packet delay reduces by properly selecting contention window size in constant backoff algorithm. If the contention window is selected as 300, one can get the minimum packet delay which is very important.

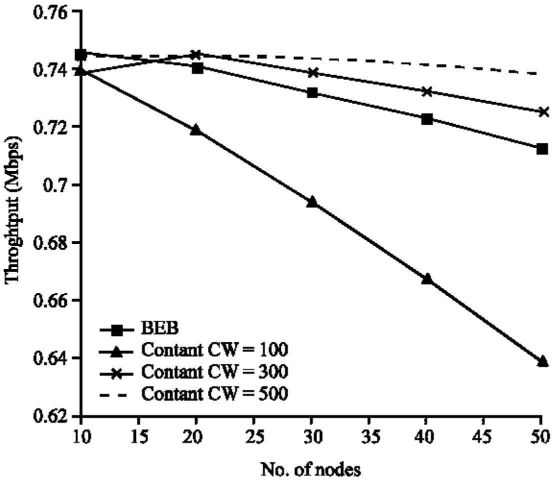

Fig. 6: Number of nodes versus throhghput (fragment size = 512 bytes, BER = 10-4) packed size = 2000 bytes, fragment size = 512 bytes

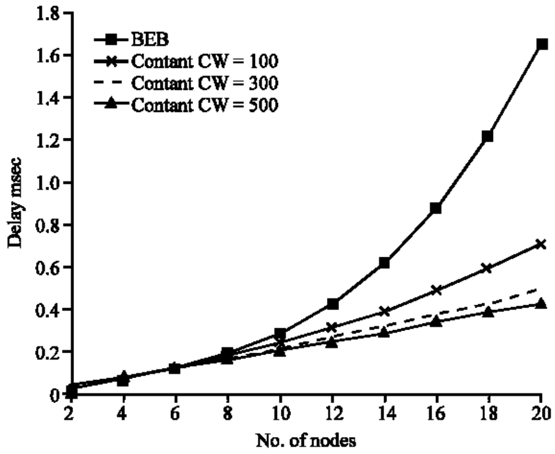

Fig. 7: Number of nodes versus delay

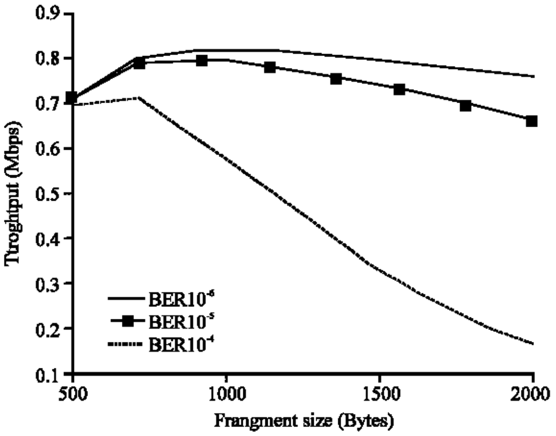

Fig. 8: Fragment size versus throughput

CONCLUSION

Simulation results shows that the packet delay increases and throughput decreases in BEB compared to constant backoff algorithm. The optimal fragment size and optimal contention window are determined to achieve the maximum throughput for the specified BER.

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