Backoff Algorithm Optimization for IEEE802.11 Wireless Local Area Networks

by

Mr.Jesada Sartthong Student

and

Assoc. Prof. Dr.Suvipon Sittichivapak Advisor

Department of Telecommunications Engineering

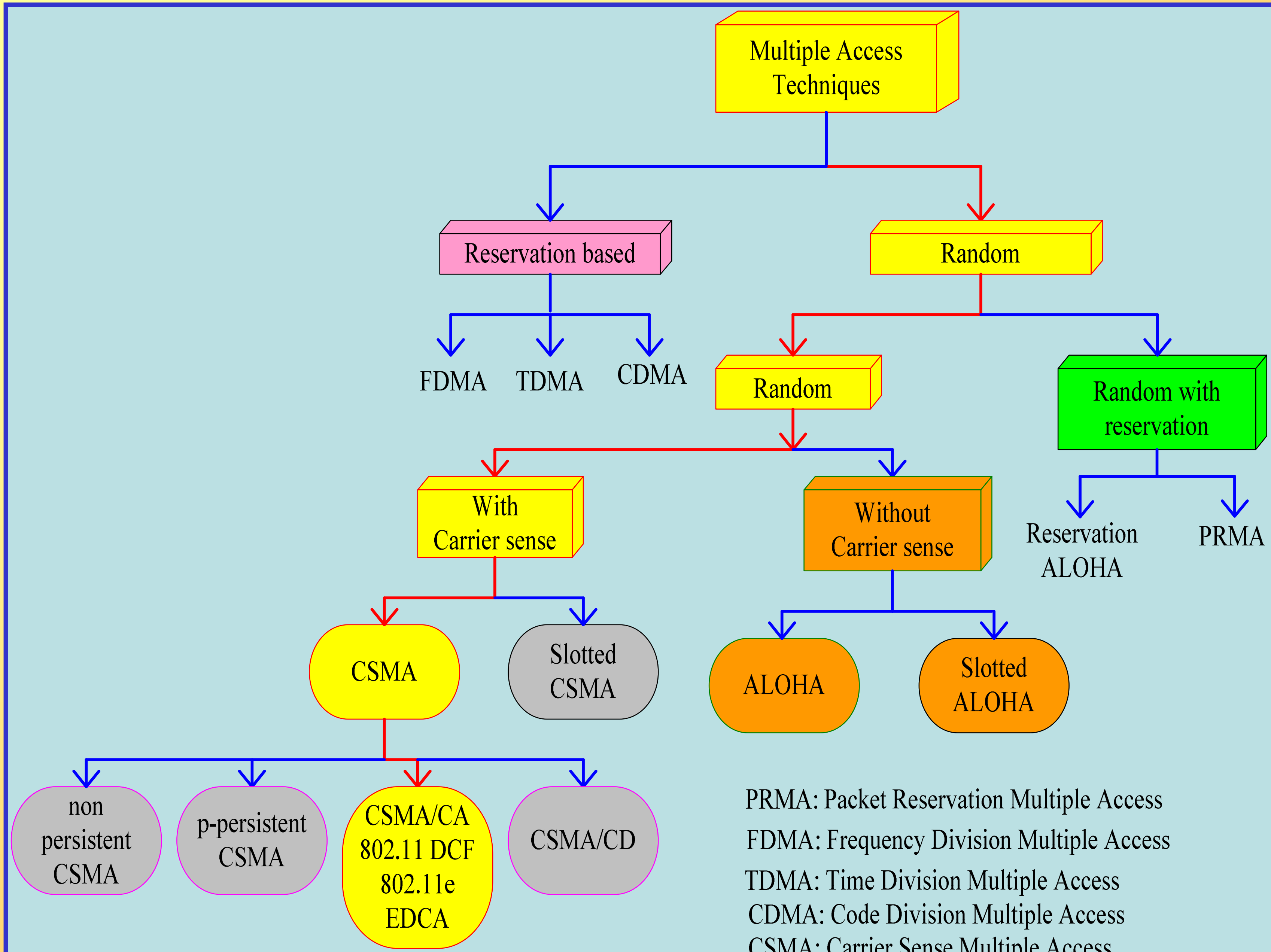
Faculty of Engineering

King Mongkut's Institute of Technology Ladkrabang

Bangkok, Thailand

Overview

- Medium Access Control (MAC)
- CSMA/CA RTS CTS Protocol
- Discrete Markov chain model
- Backoff algorithm processes
- Numerical results
- Conclusion



PRMA: Packet Reservation Multiple Access

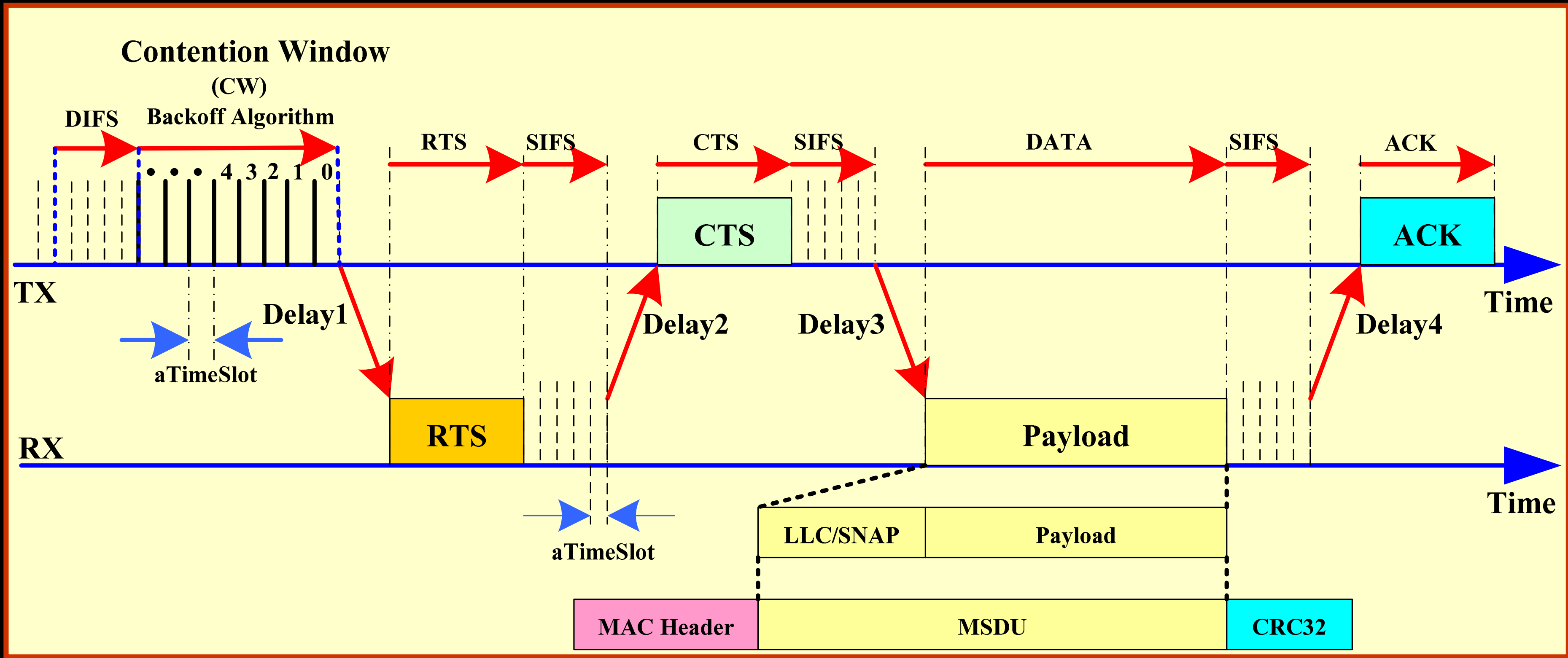
FDMA: Frequency Division Multiple Access

TDMA: Time Division Multiple Access

CDMA: Code Division Multiple Access

CSMA: Carrier Sense Multiple Access

CSMA/CA RTS CTS Protocol



DIFS = Distributed Inter Frame Space (µs)

SIFS = Short Inter Frame Space (µs)

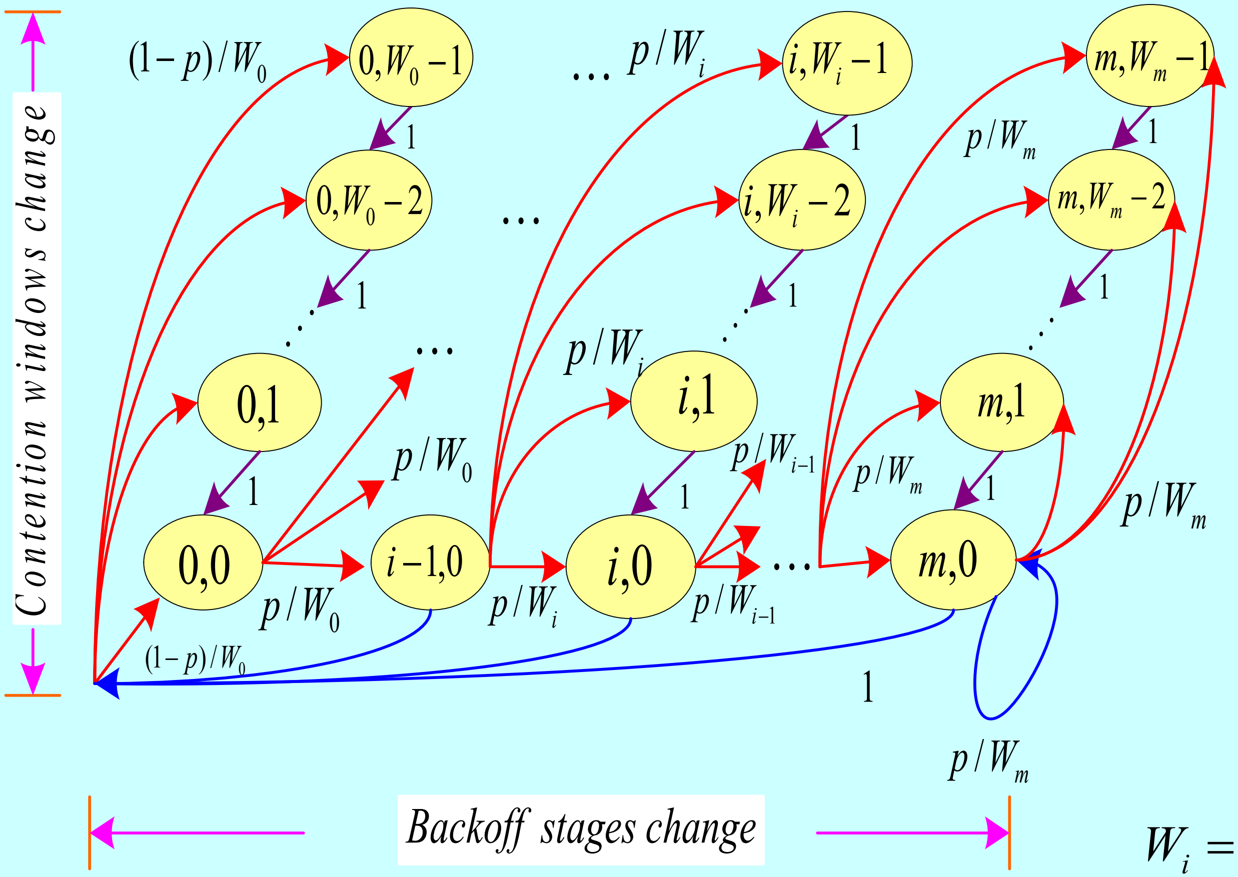
RTS = Request-to-Send frame (µs)

CTS = Clear-to-Send frame (µs)

ACK = Acknowledgement frame (µs)

MSDU = MAC Service Data Unit frame (bytes)

Discrete Markov Chain Model



(G. Bianchi's Model)

IEEE	$T_{aTimeSlot}$
802.11a	9 µS
802.11b	20 µS
802.11g	9 µS

$i = Backoff\ stage$
$(0 \le i \le m)$

$W_i = Contention\ \ window\ \ sizes$
$(aTimeSlots)$

$m = Maximum\ backoff\ stages$
$or\ the\ number\ of\ retransmission$

$p = Collision\ probability$

The Probability that a station transmits a packet in a randomly chosen slot time, note that a packet transmission occurs when the backoff timer (k) of the transmitting Station is equal to zero.

$$\tau = \frac{2(1-2p)(1-p)^{m+1}}{(1-2p)+CW[(1-2p)+p(1-(2p)^{m})]}$$

The probability that at least one station transmits in the considered slot.

Sine n stations contend on the channel, each transmitting with probability τ

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

$n = number\ of\ contending\ stations$

The probability that an occurring packet transmission is successful is given by the probability that exactly one station transmits and the remaining n-1 stations defers Transmission.

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

Consider a slot time ….

Saturation Throughput

$$Throughput = S = \frac{E[payload\ information\ transmitted\ in\ a\ slot\ time]}{E[length\ of\ a\ slot\ time]}$$

Payload size

MAC Service Data Unit sizes (bytes)

$$S = \frac{P_S P_{tr} E[P]}{(1-P_{tr})\sigma + P_{tr} P_S T_{S[CSMA/CA\ RTS\ CTS]} + P_{tr}(1-P_S) T_{C[CSMA/CA\ RTS\ CTS]}}$$

Probability of idle slot

Probability of a successful transmission

Probability of a collision

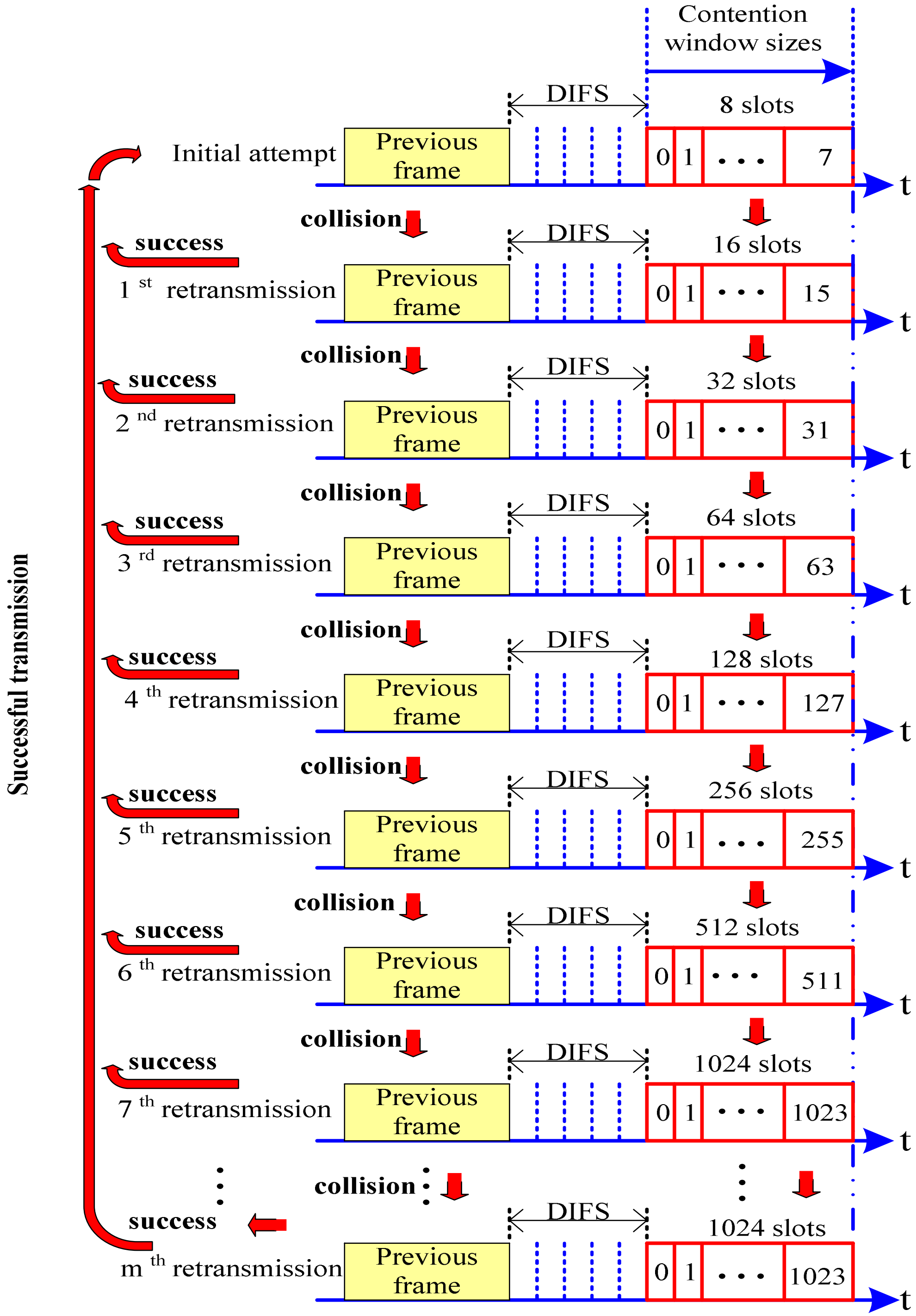
where $E[P] = Packet\ payload\ MSDU\ sizes\ in\ a\ slot\ time\ (bytes)$

$n = The\ number\ of\ contending\ stations$

$T_S = The\ successful\ transmission\ period\ (\mu s)$

$T_C = The\ collision\ transmission\ period\ (\mu s)$

Binary Exponential Backoff Algorithm (BEB)



$$W_{BEB} = 2^i (CW_{\min} + 1) \quad \rightarrow 0 \le i \le m$$

$$CW_{\min} \le W \le CW_{\max}$$

$$CW_{\min} = Minimum\ \ Contention\ \ Window$$

$$CW_{\max} = Maximum\ \ Contention\ \ Window$$

In reference [6], the others proposed Double Increment Double Decrement Backoff Algorithms (DIDD).

$$CW_{DIDD} = [2(1-2a)(1-a^{m+1}) - \tau(1-2a)] / \tau(1-(2a)^{m+1})(1-a)$$

$$a = p/(1-p)$$

In reference [7], the others proposed Estimation-Based Backoff Algorithms (EBB).

$$W_{EBB} \approx n$$ → $$n = \text{the number of contending stations}$$

Contending Stations Backoff Algorithm (CSBA)

We used the maximum function theory (Optimization) for derived optimal contention window in backoff mode.

$$\frac{d}{dCW}\left[\frac{A(MSDU\times 8)}{BT_{slot}+AT_S+CT_C}\right]=0$$

$$\left[\begin{array}{l}\frac{(MSDU\times 8)}{[BT_{slot}+AT_S+CT_C]}\frac{dA}{dCW}-\\ \frac{A(MSDU\times 8)}{[BT_{slot}+AT_S+CT_C]^2}\frac{d}{dCW}[BT_{slot}+AT_S+CT_C]\end{array}\right]=0$$

Where

$$A=\left[\frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n}\right]\left[1-(1-\tau)^n\right]$$

$$B=1-(1-(1-\tau)^n)=(1-\tau)^n$$

$$C=\left[1-\frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n}\right]\left[1-(1-\tau)^n\right]$$

$$\tau=\frac{2(1-2p)(1-p)^{m+1}}{(1-2p)+CW[(1-2p)+p(1-(2p)^m)]}$$

The optimal contention window relates to contending stations in backoff mode. A new backoff algorithm is given by

$$CW_{CSBA} = \frac{[2(1-2p)(1-p)^{m+1} - (1-2p)] \times n}{T_C}$$

It is named Contending Stations Backoff Algorithm

(CSBA)

$$T_{MSDU} = \frac{MSDU \times 8}{Data\ rate}$$

$$T_{C[CSMA/CA\ RTS\ CTS]} = T_{DIFS} + T_{RTS} + T_{delay}$$

$$T_{S[CSMA/CA\ RTS\ CTS]} = T_{RTS} + 3T_{SIFS} + 4T_{delay} + T_{CTS} + T_{MSDU(size)} + T_{ACK} + T_{DIFS}$$

MAC Service Data Unit sizes (bytes)

$$Throughput = S = \frac{P_S P_{tr} MSDU}{(1-P_{tr})T_{slot} + P_{tr} P_S T_S + P_{tr}(1-P_S)T_C}$$

$$1-(1-\tau)^n$$

$$\frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n}$$

$$\tau = \frac{2(1-2p)(1-p)^{m+1}}{(1-2p) + CW[(1-2p) + p(1-(2p)^m)]}$$

Binary Exponential Backoff (BEB) algorithm $CW_{BEB} = 2^i(CW_{\min}+1)\ i = 0,1,2\ldots m$

Estimation-Based Back-off (EBB) algorithm $CW_{EBB} \approx n$

Double Increment Double Decrement (DIDD) backoff algorithm

$$CW_{DIDD} = [2(1-2a)(1-a^{m+1}) - \tau(1-2a)] / \tau(1-(2a)^{m+1})(1-a)$$

$$a = p/(1-p)$$

Contending Stations Backoff Algorithm (CSBA)

$$CW_{CSBA} = \frac{[2(1-2p)(1-p)^{m+1} - (1-2p)] \times n}{T_C}$$

Programming

MathCAD

Engineering

Calculation

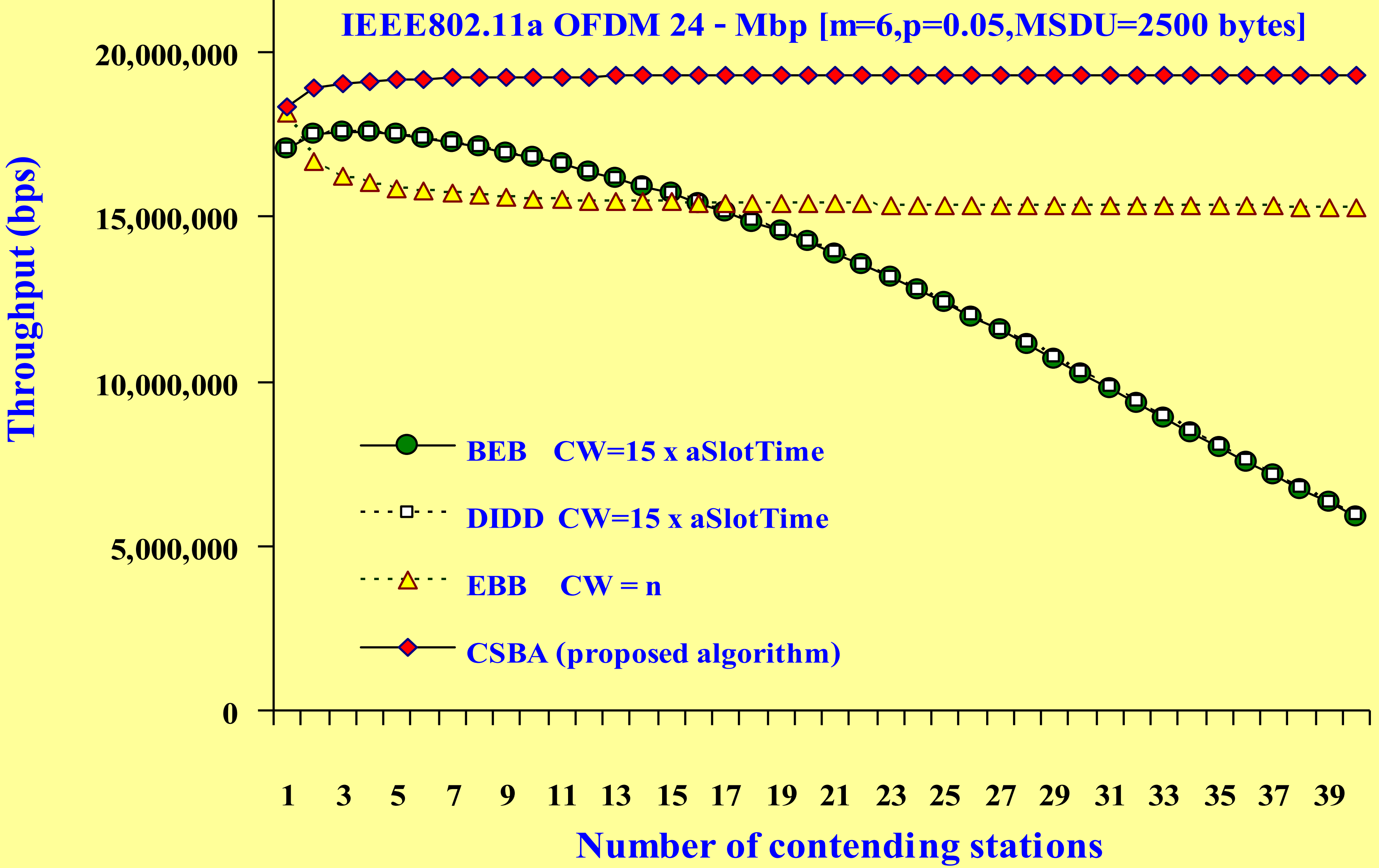
www.pct.com

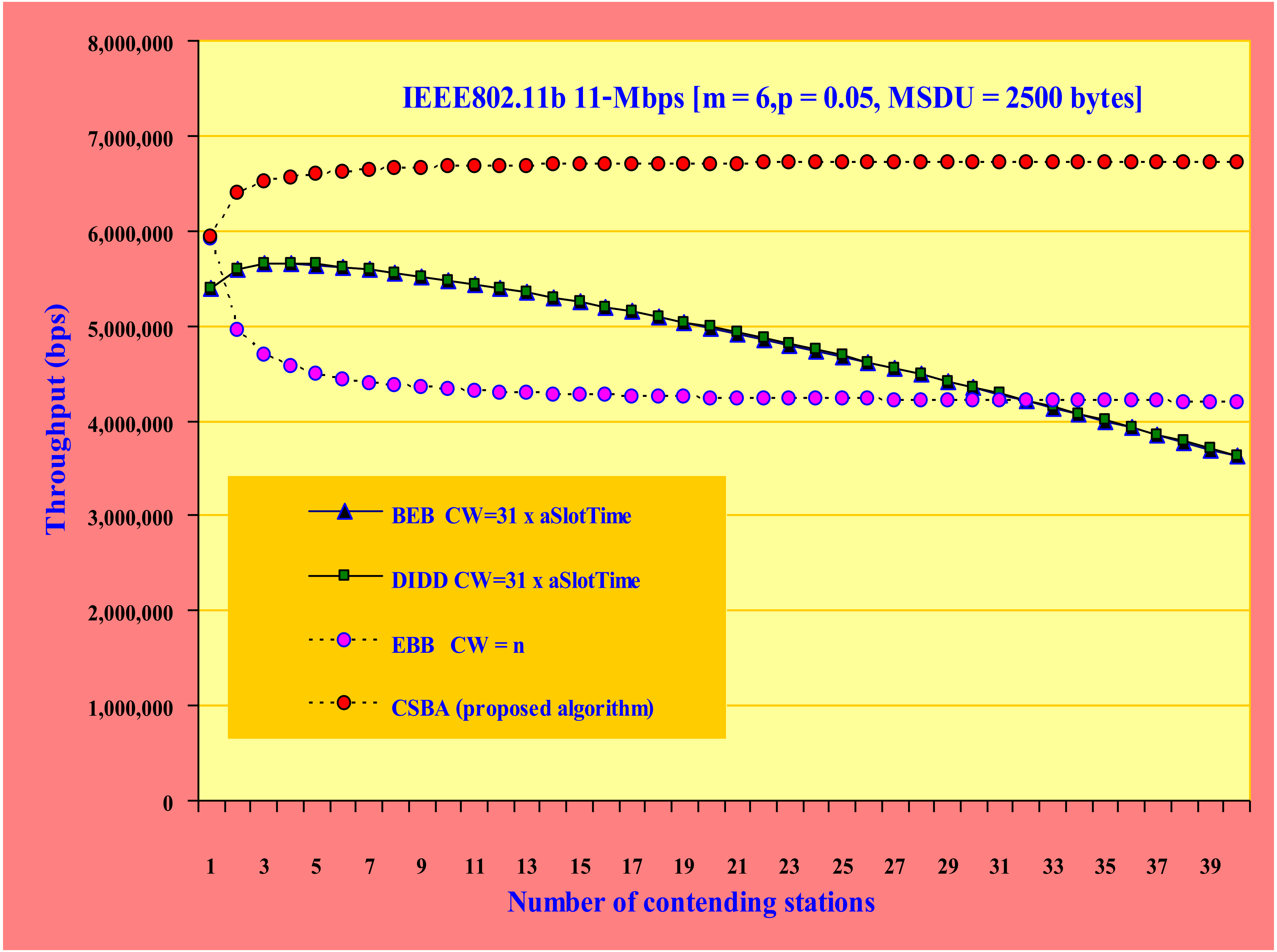
Parameters of IEEE802.11a/b/g standards

$T_{Delay} = 1\ \mu s$

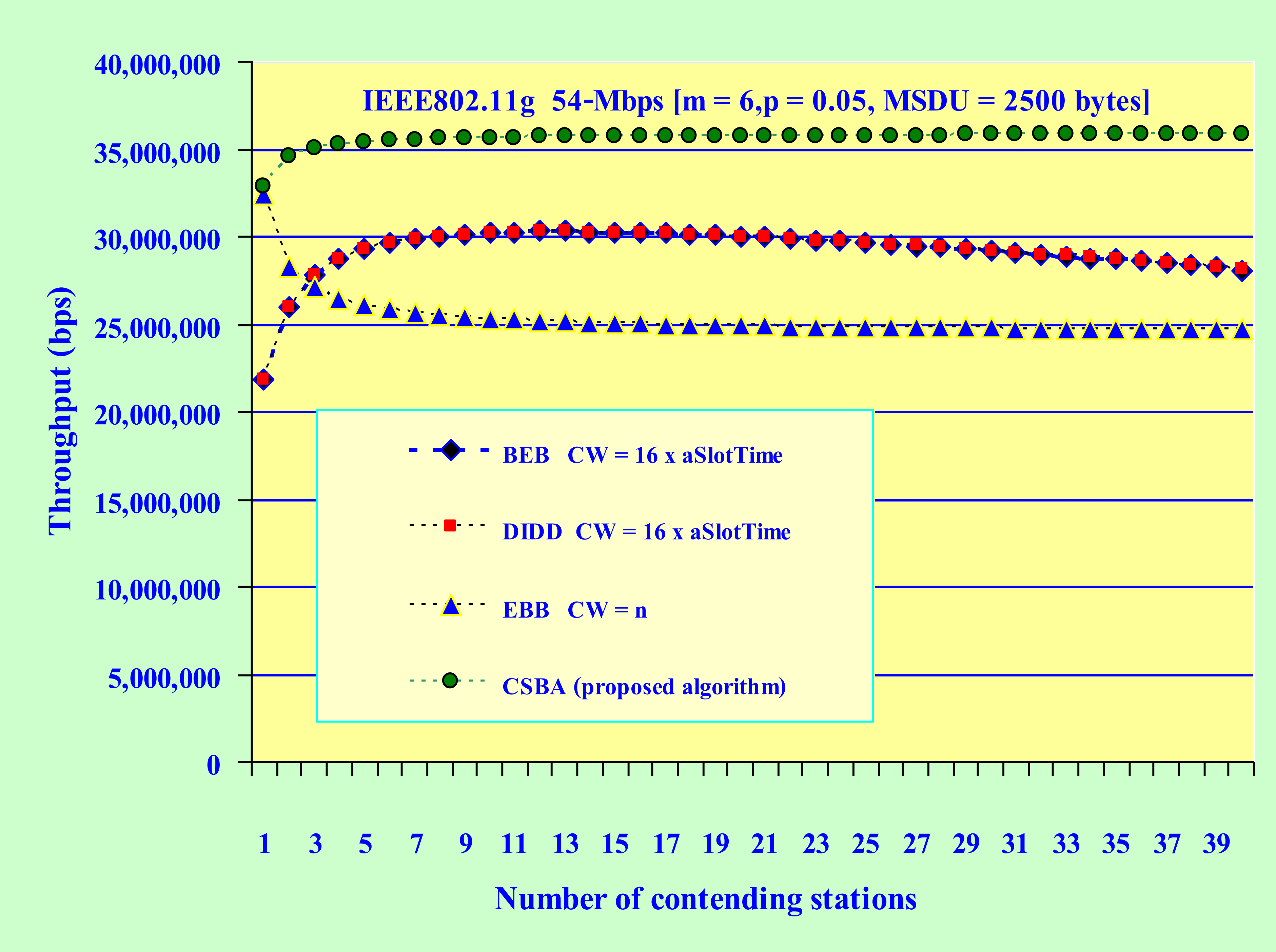
	802.11a	802.11b	802.11g
T_{SIFS} →	16 µs	10 µs	10 µs
T_{DIFS} →	34 µs	50 µs	28 µs
$T_{aSlotTime}$ →	9 µs	20 µs	9 µs
T_{RTS} $OFDM\ 24\ Mbps$ →	28 µs	-	34 µs
T_{CTS} $OFDM\ 24\ Mbps$ →	28 µs	-	32 µs
T_{ACK} $OFDM\ 24\ Mbps$ →	28 µs	-	32 µs
T_{RTS} $OFDM\ 54\ Mbps$ →	24 µs	-	30 µs
T_{CTS} $OFDM\ 54\ Mbps$ →	24 µs	-	30 µs
T_{ACK} $OFDM\ 54\ Mbps$ →	24 µs	-	30 µs
T_{RTS} $HR-DSSS\ 11\ Mbps$ →	-	352 µs	-
T_{CTS} $HR-DSSS\ 11\ Mbps$ →	-	304 µs	-
T_{ACK} $HR-DSSS\ 11\ Mbps$ →	-	304 µs	-
CWmin	15 SlotTimes	31 SlotTimes	16 SlotTimes
CWmax	1023 SlotTimes	1023 SlotTimes	1024 SlotTimes

Numerical Results





IEEE802.11b 11-Mbps [m = 6,p = 0.05, MSDU = 2500 bytes]
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Throughput (bps)
BEB CW=31 x aSlotTime
DIDD CW=31 x aSlotTime
EBB CW = n
CSBA (proposed algorithm)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of contending stations



IEEE802.11g 54-Mbps [m = 6,p = 0.05, MSDU = 2500 bytes]
Throughput (bps)
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Number of contending stations
BEB CW = 16 x aSlotTime
DIDD CW = 16 x aSlotTime
EBB CW = n
CSBA (proposed algorithm)

Conclusion

We study the throughput efficiency of a new backoff algorithm (CSBA) in IEEE802.11a/b/g standards.

Our numerical results show that the proposed algorithm is better than the old backoff algorithms as:

- **Binary Exponential Backoff Algorithm (BEB)**
- **Estimation-Based Backoff Algorithm (EBB)**
- **Double Decrement Double Decrement Backoff Algorithm (DIDD)**

- **Future work , We will investigate the performance of CSBA by using open source Network Simulator 2 (allinone-2.35) on Linux Ubuntu 10.10**

C++ and Otcl Languages

Reference: http://www.isi.edu./nsnam/ns , http://www.isi.edu./nsnam/ns/ns-build.html and http://www.ubuntu.com


Thanks
you
for
your
attention