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Implementation and Performance Analysis of DCWA MAC Protocol for Multihop Wireless Networks

A.B NATARAJU
Research Scholar, Jain University,
Bangalore, India
Acharya Institute of Technology,
Bangalore, India
nataraju.ab@gmail.com

H.D MAHESHAPPA
Acharya Institute of Technology,
Bangalore, India
maheshappahd@acharya.ac.in /
hdmappa@gmail.com

SHILPASHREE B.R
Acharya Institute of Technology,
Bangalore, India
shilpasri2527@gmail.com

***Abstract*— Performance of multi-hop ad hoc networks is severely affected by the hidden and exposed node problems. The e RTS/CTS based handshaking protocol used in the IEEE 802.11 standard was designed to solve the hidden node problem, however it was not successful in completely solving the problem. This paper presents a performance evaluation of adaptive backoff algorithm based on Deterministic Contention Window Allocation (DCWA) on top of IEEE 802.11 Distributed Coordination Function (DCF) standard. The DCWA protocol relies on real-time measurements of the number slots being used in specified cycle time. This algorithm judiciously sets the upper and lower bounds for the contention window in order to adapt to the congestion level in the shared medium at that point in time. This work provides an extension to DCWA in evaluating its performance over noisy channels with varied network density. In this work, the % age of effective utilized time in current and past cycles are used to predict the next cycle's upper and lower bounds of contention window to suit the number of active users at any point in time. Thus overall contentious attempts can be reduced and also system idle time is also kept at best possible minimum values. The performance of DCWA protocol is evaluated via simulations using NS2 simulator. The test results reveal that DCWA based CW allocations perform relatively better with connection less (CL) Constant Bit Rate application protocol (CBR over UDP) traffic than Connection Oriented (CO) protocols application protocols like, File Transfer Protocol traffic (FTP over TCP). In some cases CO traffic performs better than 802.11 DCF, but it is not consistent with all network sizes.**

Keywords*— *IEEE 802.11 DCF, Backoff Algorithm, Contention Window, DCWA

INTRODUCTION

The IEEE 802.11 DCF is makes use of on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) to share the medium across contending users, which is based on Binary Exponential Backoff (BEB) algorithm for contention resolution/avoidance. The backoff time is an additional random defer time before transmission, measured in multiples of Slot_Time, *Backoff_Time = Random * Slot_Time*. The Random variable is a pseudo random integer uniformly distributed over the interval (0, CW). In the DCF 802.11 DCF, the minimum and maximum CW values (CW_{min}, CW_{max}) are fixed, where $CW_{min} <= CW <= CW_{max}$. The backoff interval initializes the backoff timer and indicates the minimum wait time before next transmission attempt. It is decreased when the medium is idle and frozen when the medium is busy. The node can transmit when the backoff timer expires. Upon a successful transmission, the CW is set to the minimum. When a collision occurs, a BEB mechanism is used to randomly defer each node's transmission. According to this mechanism, the CW is doubled after each unsuccessful transmission ($CW_{NEW} = 2 * (CW_{OLD}+1)$) after which nodes execute a new backoff process. This solution is unfair as well as inefficient. When the number of active neighbors increases, the number of collisions increases as well. Although the CW size is doubled after each collision, too many stations can back-off with small contention windows, because they can still pick up a slot randomly in the interval (0, CW).

In this work, we focus on selection of a lower and upper bounds of the CW, which enhances the overall system throughput. The aim of this CW selection algorithm is to decrease the probability of collisions as well as to extend the lifetime of the network. In this paper, we also investigate performance of DCWA as compared to 802.11 DCF with three different routing protocols (DSR, DSDV, AODV) and two different types of application / transport protocols (CBR over UDP, FTP over TCP).

RELATED WORK

Considerable research activities concentrated on the IEEE 802.11 DCF has generated extensive literature. Although lots of research efforts have been spent on improving the throughput [1][2][3][4][5] or maintaining the fairness [6][7] in IEEE 802.11 WLANs, most of them focus on a single aspect while disregarding others. Many approaches have been proposed to reduce the number of collisions by substituting the binary exponential backoff algorithm of the IEEE 802.11 by novel backoff approaches or selecting an intermediate value instead of resetting the CW [8] [9][10][11] value to its initial (minimum) value.

On failure all theses algorithms adapts various method to set the CW size depending upon the environment being used [12][13][14], where as they all reset their contention window to CW_{min} on successful transmission, rather than initializing it to Zero as in case of IEEE802.11 DCF mechanism. Even though these methods leads to reduce collisions, they are not found to be much effective in case of MWNs where the node

density involved in the network is more, and with large coverage area.
The DCWA [15] proposes a mechanism for setting CW such that contention delay times are ALWAYS greater than previous cycles. Also the CW values are reduced upon each successful transmission by any node, but it would not reset it to CW_{min}. Hence the contention probability is kept to minimum and also the system idle times are kept as minimum as possible. This paper was evaluated with CBR type of traffic but there was no mention about the performance of DCWA [12] for TCP traffic.

The DDCWC [16][17] proposed an extension to DCWA based MAC protocol to consider number of active nodes in 1-hop distance to select the optimal values for upper and lower bounds for CW. This paper also inferred that this protocol performs better than DCWA in achieving better throughput for multihop networks. This protocol has got the potential to be a preferred choice for multi-hop networks in supporting fair channel allocation and minimizing the uniform end-to-end delay in multihop networks.

ESTIMATION OF THE SYSTEM UTILIZATION TIME

After each **collision**, following updating are performed to set lower and upper bound for CW selection

$$Backoff\_timer = Random(CWLB(i), CWUB(i)) * SlotTime$$
$$Size(i) = 32 * i;$$
$$CWUB(i) = CWUB(i-1) * 2$$
$$CWLB(i) = CWUB(i) – Size(i)$$

After each **successful transmission**, following updating are performed to set lower and upper bound for CW selection

$$CWUB(i) = CWUB(i-1) * B(T) + CW_{min} * (1- B(T))$$
$$CWLB(i) = CWUB(i) – Size(i)$$

To avoid the short term fluctuations due to wireless channel characteristics, the network measured values, B(T) are weighed with respect to past measured values using the mathematical expression.

$$B(T)\_new = \alpha * B(T)\_cur + (1- \alpha) B(T)\_prev$$

Where $\alpha = 0.8$, which is dependent upon network density and node's speed of movement.

SIMULATION RESULTS & INFERENCES DRAWN

The following results have been found from the extensive simulations using NS-2 simulator (ns-2.34)[18] and inferences are as follows. The parameters being considered are as follows:

Table 1. Simulations parameters

Parameter	**Values**
Number of active nodes	5, 10, 15, 20, 25,…80
Simulations area (m)	(x, y) <= (500, 500)
Topology	Random
txPower	5.0
rxPower	20% of txPower
idlePower	0.01% of txPower
sleepPower	0.002% of txPower
transitionPower	0.4 % of txPower
Initial Energy (J)	100
Radio Propagation Model	Two Ray Ground
Traffic model	CBR over UDP FTP over TCP
Payload size (bytes)	1500
Simulation time (s)	100
No of simulation scenarios	10 each
Phy Basic rate	1Mbps
Routing protocols considered	AODV, DSDV, DSR
Movement	random and constant
Maximal speed (m/s)	5
BT update period (sec)	0.2 (10,000 slots)
CWMin_	31
CWMax_	1023
Slot Time	0.000020 ;# 20us
SIFS_	0.000010 ;# 10us
PLCPDataRate_	1.0e6 ;# 1Mbps

Plots with TCP type of traffic:

Table 2. Simulation results TCP transport

TCP						
Nodes	Non – DCWA			DCWA		
	T_ND_DSR	T_ND_DSDV	T_ND_AODV	T_D_DSR	T_D_DSDV	T_D_AODV
5	550.31	613.65	556.60	531.76	573.68	538.54
10	484.29	517.01	460.25	448.25	506.09	433.60
15	479.55	568.88	493.59	478.61	529.97	498.51
20	495.56	555.29	496.91	483.23	559.81	462.86
25	483.36	561.19	487.69	469.91	548.78	479.21
30	535.03	603.43	537.83	523.88	596.74	531.45
35	534.32	604.38	551.34	530.28	571.53	537.78
40	548.86	645.30	548.30	521.20	619.67	523.25
45	545.89	636.13	585.58	556.66	630.48	569.40
50	535.80	632.09	554.60	534.70	615.67	535.84
55	555.80	647.83	596.16	507.04	637.42	516.53
60	523.73	623.72	548.32	512.00	617.82	537.46
65	525.66	638.10	552.83	531.97	616.37	537.79
70	513.29	637.28	545.27	541.91	623.74	546.25
75	508.24	629.12	543.71	542.83	633.66	536.62
80	490.27	614.76	539.82	518.11	611.24	518.48

Table 3. Differential gain of different routing protocols

Nodes	Gain (DCWA - NonDCWA)		
	T_DSR_Gain	T_DSDV_Gain	T_AODV_Gain
5	-18.55	-39.97	-18.06
10	-36.04	-10.92	-26.65
15	-0.94	-38.91	4.92
20	-12.33	4.52	-34.05
25	-13.45	-12.41	-8.48
30	-11.15	-6.69	-6.38
35	-4.04	-32.85	-13.56
40	-27.66	-25.63	-25.04
45	10.77	-5.65	-16.19
50	-1.10	-16.42	-18.76
55	-48.75	-10.41	-79.63
60	-11.73	-5.90	-10.86
65	6.31	-21.73	-15.04
70	28.62	-13.54	0.98
75	34.59	4.54	-7.09
80	27.84	-3.53	-21.34

Note: -ve gain indicates DCWA underperforms compared to DCF

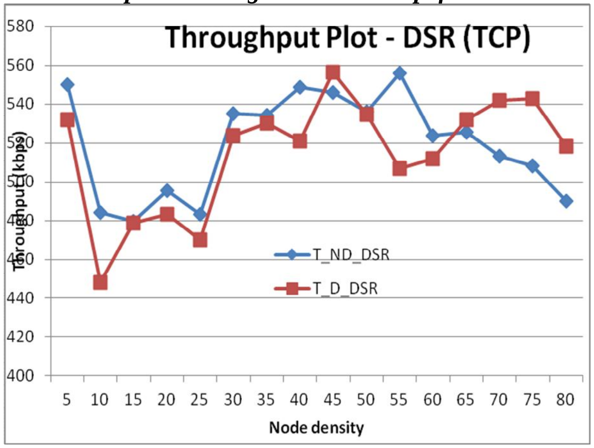

Fig.1 Throughput vs. Node (DSR)

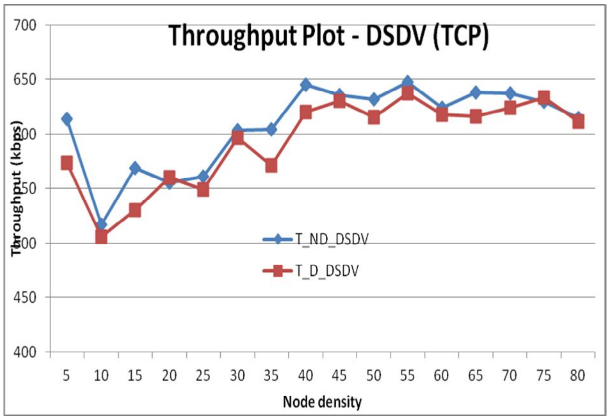

Fig.2 Throughput vs. Node (DSDV)

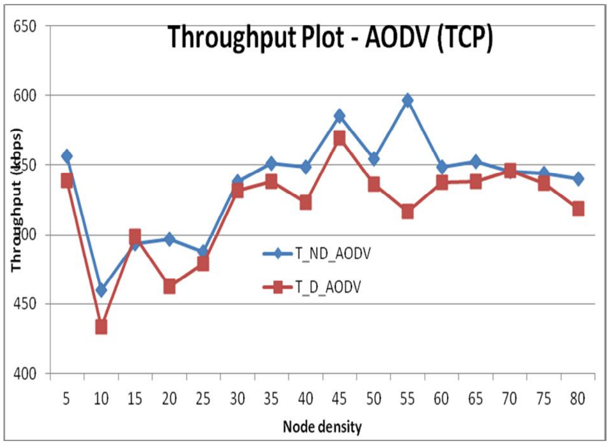

Fig.3 Throughput vs. Node (AODV)

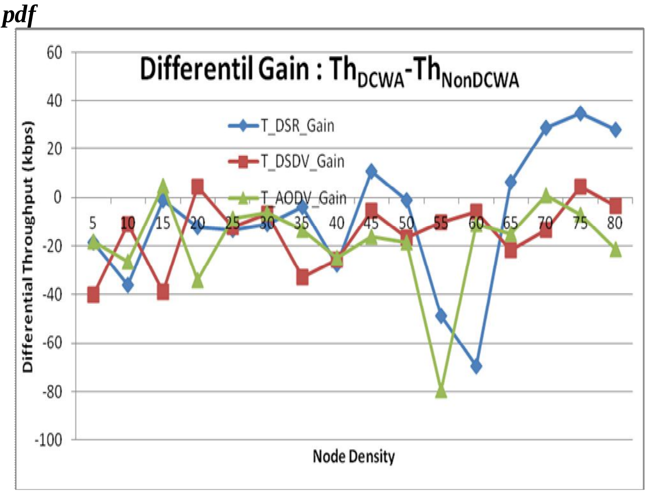

Fig.4 Diffrential gain (Throughput, TCP)

From above plots it can be inferred that

a. DCWA rarely performs better than 802.11 DCF (Ref Fig.1-4).

b. DCWA with DSR routing protocol performs shows some improvement in throughput from node densities 65 onwards.

c. DCWA With TCP transport protocol does not guarantee throughput enhancement irrespective of variation in node density or varied routing protocols.

d. It can be inferred that DCWA based MAC protocols recover faster compared to basic 802.11 DCF (with RTS/CTS)

e. Thus it can be inferred that DCWA SHALL preferably be avoided using with TCP transport, since there is no guaranteed throughput gain with TCP transport protocol.

Table 4. Simulation results TCP transport-delay

TCP Data Analysis							
TCP							
Nodes	Non - DCWA				DCWA		
	Del_ND_DSR	Del_ND_DSDV	Del_ND_AODV		Del_D_DSR	Del_D_DSDV	Del_D_AODV
5	546.90	335.58	425.88		457.50	355.67	360.04
10	520.87	385.42	466.80		608.28	373.85	499.80
15	691.69	415.38	525.92		778.51	497.36	600.64
20	831.86	503.18	554.93		861.31	570.37	830.53
25	1051.45	561.59	634.11		1093.54	674.14	857.91
30	916.41	534.98	655.14		1136.05	604.84	861.63
35	924.17	577.33	650.32		1037.50	699.98	877.91
40	1236.20	595.52	817.46		1463.99	914.66	1293.55
45	1466.11	705.60	814.94		1727.41	1029.70	1259.79
50	1494.05	840.58	940.11		1876.02	1089.42	1425.43
55	1578.56	864.52	890.81		1688.60	1014.02	1293.39
60	1851.35	971.10	988.78		1964.75	1159.29	1632.15
65	1653.04	831.23	915.19		1907.57	1156.71	1640.49
70	1673.32	1043.32	1117.87		2062.05	1328.72	1731.08
75	2113.42	1062.87	1149.49		2051.23	1464.71	1728.10
80	2156.59	1146.74	1137.92		2284.13	1534.35	1896.61

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Table 5. Delay Difference (TCP)

Nodes	End-to-End Delay (ms)		
	DSR_Delay_Diff	DSDV_Delay_Diff	AODV_Delay_Diff
5	-89.41	20.09	-65.84
10	87.41	-11.57	33.00
15	86.81	81.99	74.72
20	29.46	67.19	275.60
25	42.09	112.55	223.80
30	219.64	69.87	206.49
35	113.33	122.65	227.60
40	227.79	319.14	476.09
45	261.31	324.10	444.85
50	381.97	248.84	485.32
55	110.04	149.50	402.58
60	113.40	188.19	643.36
65	254.54	325.48	725.30
70	388.72	285.40	613.21
75	-62.20	401.84	578.62
80	127.54	387.61	758.69

Note: +ve delay difference indicates, DCWA underperforms compared to DCF in terms of End-to-End delay.

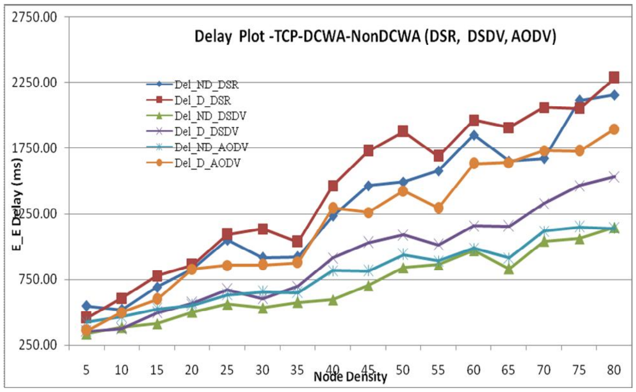

Fig.5 End-to-End delay - TCP(ms)

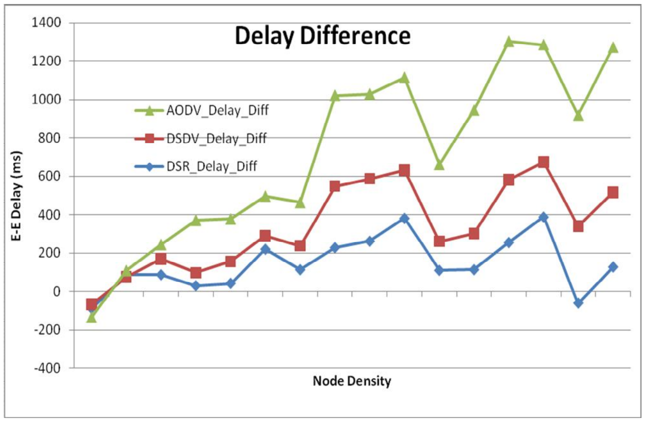

Fig.6 Delay Difference-TCP (ms)

From above plots it can be inferred that

a. Their is an uniform increase in end to end delay as the node density increases.

b. DCWA underperformns interms of End-to-End delay compared to IEEE 802.11 DCF.

c. DSR delivers less end-to-end delay when compared with that of other two protocols.

Plots with CBR type of traffic:

Table 6. Simulation results UDP transport

Nodes	CBR					
	Non – DCWA			DCWA		
	C_ND_DSR	C_ND_DSDV	C_ND_AODV	C_D_DSR	C_D_DSDV	C_D_AODV
5	44.12	60.09	66.34	43.82	61.20	67.52
10	65.79	86.20	100.84	65.82	80.98	101.08
15	126.37	159.61	192.70	125.64	165.46	193.16
20	127.42	174.00	195.36	127.39	171.45	195.32
25	154.82	202.44	237.11	154.87	207.88	239.47
30	188.75	268.88	285.02	192.63	265.40	278.82
35	206.74	295.95	313.03	209.66	288.18	315.07
40	255.29	386.32	382.74	262.34	380.11	395.03
45	246.44	382.22	376.10	258.36	376.24	382.95
50	233.08	359.58	344.51	246.04	352.97	357.18
55	242.48	379.13	373.18	263.11	377.46	379.80
60	253.95	407.80	371.37	280.61	411.06	398.36
65	244.98	408.68	370.21	274.84	414.21	374.82
70	258.33	439.37	396.62	297.47	450.40	416.86
75	248.33	407.48	379.92	273.23	420.39	402.95
80	226.60	396.59	335.28	270.19	399.86	359.52

Table 7. Differential gain of different routing protocols (CBR)

Nodes	Gain (DCWA - NonDCWA)		
	C_DSR_Gain	C_DSDV_Gain	C_AODV_Gain
5	-0.31	1.11	1.18
10	0.03	-5.22	0.24
15	-0.73	5.85	0.47
20	-0.02	-2.55	-0.03
25	0.05	5.45	2.36
30	3.88	-3.48	-6.20
35	2.91	-7.77	2.04
40	7.05	-6.21	12.28
45	11.92	-5.98	6.85
50	12.97	-6.61	12.67
55	20.63	-1.67	6.62
60	26.66	3.27	26.99
65	29.86	5.53	4.60
70	39.14	11.03	20.24
75	24.90	12.91	23.03
80	43.59	3.27	24.24

Note: -ve gain indicates DCWA underperforms compared to DCF

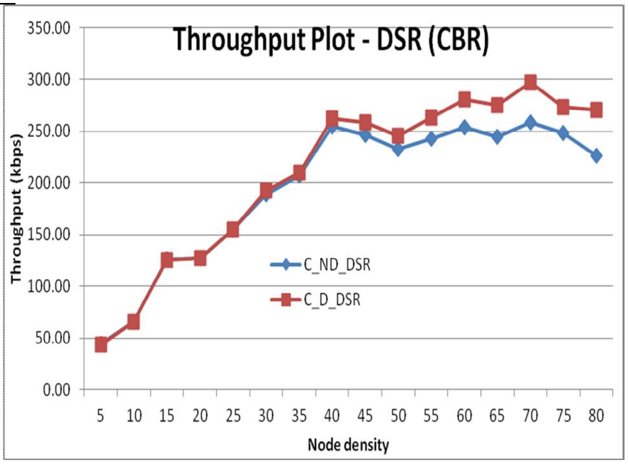

Fig.7 Throughput vs. Node (DSR)

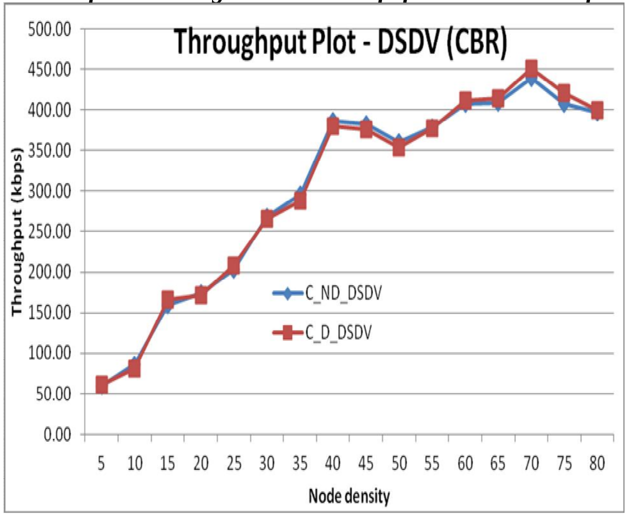

Fig.8 Throughput vs. Node (DSDV)

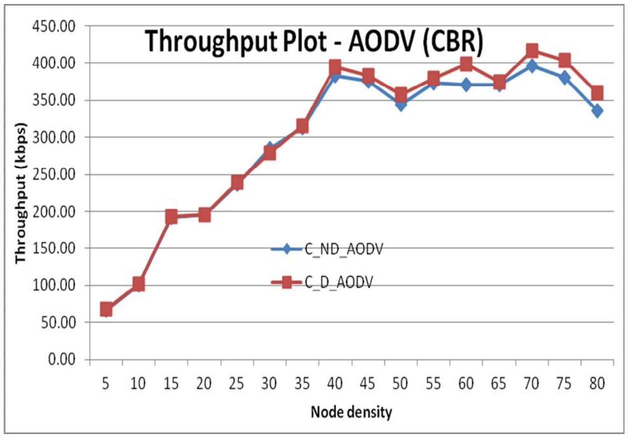

Fig.9 Throughput vs. Node density (DSR)

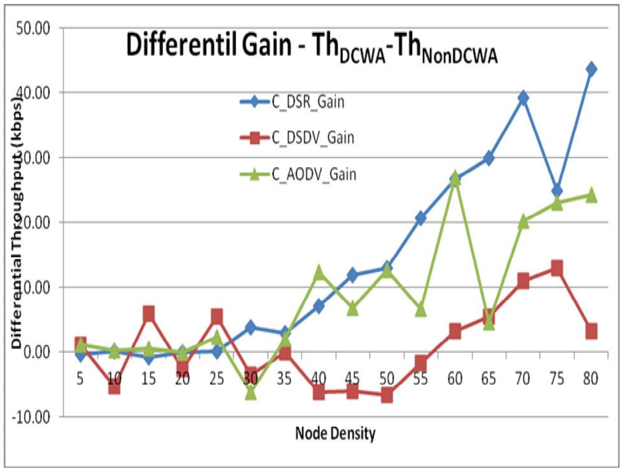

Fig.10 Diffrential gain (Throughput, CBR)

From above plots it can be inferred that

a) DCWA performs better than basic 802.11 DCF for node densities 35 on wards, whereas it is observed no improvement at very low densities (Ref Fig.1-3)

b) DCWA with DSR routing protocol outperforms AODV and DSDV protocols for medium to highly dense networks. Again at lighly dense networks DCWA does not show any improvement irrespective of type of routing protocol in use (Fig.4)

c) Even at low dense networks, DCWA with DSR and AODV protocols do perform better than IEEE 802.11 DCF.

d) It can be inferred from the graphs that maximum throughput is achievable when the node density is in the range 40 through 70.

e) Significant throughput improvement can be observed from node densities of 60 or more.

f) Thus it can be inferred that DCWA can be used with UDP transport (CBR application).

g) It can also be inferred that DCWA based MAC protocols recover faster compared to basic 802.11 DCF (with RTS/CTS)

CONCLUSION

In this paper we have presented an algorithm for dynamically selecting a lower and upper bounds for the CW interval. It has been tested with different routing protocols (DSR, DSDV, AODV) and different level of network densities (5, 10, 15, 20, ….80). It is observed that DCWA outperform IEEE 802.11 DCF with CL traffic than CO traffic (when throughput is considered). It is also observed that DCWA underperform in terms of end-to-end delay. Thus it is inferred that DCWA can conditionally be used with CL type of traffic preferably when the node densities are in the range of 35 through 75, whereas DCWA is not a preferred choice for CO traffic.

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