Chapter 6
Conclusions

This chapter presents the final remarks and conclusions on the research work. The thesis work is focused on development of a new Collision Alleviating DCF (CAD) protocol and Contention Window based Multiplicative Increase Decrease Backoff (CWMIDB) algorithm for enhancement of QoS parameters such as throughput and End-to-End delay in IEEE 802.11 based wireless networks.

IEEE 802.11b, 802.11a 802.11g are the most popular standard protocols used in WLANs. Since most of the existing backoff algorithms have been analysed for IEEE 802.11b protocol to compare with, the performance of the proposed algorithm is also analysed considering the parameters of IEEE 802.11b protocol. The performance of a wireless network is highly dependent on several parameters such as the wireless channel model, data rate, packet length, number of nodes, etc. When the frames are transmitted through a wireless channel, they may get corrupted due to channel noise. An extensive analysis is carried out on how the frame error probability, $P_e$, is affected by the data rate and packet length under Rayleigh fading channel. The probability of frame error obtained for a given $E_b/N_0$ of 5 dB and for MSDU of size 256 bytes is 0.00000448 and 0.9947 using 1 Mbps and 11 Mbps data rates respectively. In other words, frame error probability increases with increase in data rate. It is also observed that the frame error probability increases from 0.00682 to 0.02529 when the size of MSDU is increased from 256 to 1024 bytes respectively for the data rate of 11 Mbps. The time delay required to transmit the frame reduces when these are transmitted at higher data rates but, the probability of error observed is more. The performance of a wireless network can be improved by selecting a suitable modulation technique and packet size based on channel conditions and these aspects are considered while analyzing the performance of a wireless network (Ch. 2).
The backoff algorithm plays a vital role in packet transmission. The behavior of backoff algorithms (BEB, DIDD, EIED, BNEB and HB) for each unsuccessful packet transmission and upon collision is investigated. The throughput and End-to-End delay performance of the DCF protocol using these backoff algorithms is analyzed assuming saturated traffic and ideal channel conditions. The effect of number of nodes on busy and collision probabilities is also investigated since the throughput and End-to-End delay of the protocol also depend on these parameters. The effects of network size, backoff stage, data rate, packet size, etc. on the performance of DCF protocol for both basic and RTS/CTS mechanisms have been analyzed. It is observed that the throughput increases by 6.4% and 7.5% using EIED and DIDD algorithms respectively compared to BEB algorithm and the throughput decreases by 44.06% and 1.1% using BNEB and Hybrid backoff algorithms respectively compared to BEB algorithm for a network with 25 nodes under basic access mechanism. This variation is even larger for more number of contending nodes. The reason for drastic reduction of throughput when using BNEB algorithm as compared to other backoff algorithms, is that the size of the contention window becomes smaller at higher backoff stages. The throughput decreases and the End-to-End delay increases with the number of active nodes because more collisions occur in this case. The delays obtained in a wireless network with 25 nodes are 0.3003 sec, 0.2831 sec, 0.2812 sec and 0.3066 sec using BEB, EIED, DIDD and hybrid backoff algorithms respectively. Compared to the BEB algorithm, the delay is reduced by 5.7% and 6.3% using EIED and DIDD algorithms respectively. The packet delay experienced using hybrid backoff algorithm is high compared to BEB, DIDD and EIED algorithms. Since the number of collisions reduces using RTS/CTS mechanism, throughput increases and End-to-End delay reduces when compared to basic access mechanism. Even though the performance of DIDD and EIED algorithms is better compared to other backoff algorithms, the disadvantage of using these algorithms is that these are not designed for real traffic
It is also observed that when the backoff period increases exponentially for each unsuccessful transmission such as in BEB algorithm, the packet delay increases. On the other hand, when the backoff period decreases for each unsuccessful transmission such as in BNEB algorithm, the throughput also decreases. But an efficient backoff algorithm should enhance the network throughput and reduce the End-to-End delay even in highly congested environments for real-time applications (ex. during emergencies such as rescue operations during natural calamities, military operations in battle fields, etc.). In order to satisfy these characteristics, the backoff procedure has to be modified (Ch. 3).

The packet transmission procedure in the DCF protocol is modeled with a Markov chain. Researchers have proposed several modifications to the existing DCF protocol. However, the existing models suffer with high packet collisions and degradation in throughput particularly under congested environments. Also, most of these models cannot predict the performance of a wireless network accurately. Therefore, a new Markov chain model has been proposed to predict the performance of a wireless network more accurately and to enhance the performance of IEEE 802.11 DCF protocol. This is named as Collision Alleviating DCF (CAD) protocol. A post backoff stage is introduced to avoid channel capture effect which usually occurs in DCF protocol. Mathematical equations are derived for transmission probability and End-to-End delay for the proposed CAD protocol and its performance is compared with the existing models in non-saturated and Rayleigh fading channel conditions. The proposed model is compared with five of the existing models (Bianchi’s, Ziouva’s, Chatzimisios’, Daneshgaran’s and Haitao’s). The collision probability is greatly reduced by more than 10% using the proposed model when compared to other models for a network with 25 nodes. In saturated traffic conditions, the proposed model is compared with Ziouva’s and Bianchi’s models. When the number of nodes is 10, throughputs of 0.7718 Mbps, 0.7597 Mbps and 0.7266 Mbps are obtained using the proposed model, Bianchi’s model and
Ziouva’s model respectively. Since Ziouva’s, Chatzimisios’ and Bianchi’s models have been
designed for saturated traffic and ideal channel conditions, the performance of the proposed
model is compared with Daneshgaran’s and Haitao’s models under non-saturated traffic and
Rayleigh fading channel conditions. The impact of packet arrival rate on throughput is
investigated. When the number of nodes is 50 and packet arrival rate is 40 Pkts/sec, under
basic access mechanism, the proposed model improves the throughput by 6% and 10% when
compared to Daneshgaran’s and Haitao’s models respectively. The performance of the
proposed model is found to have higher throughput even using RTS/CTS mechanism. The
dependency of throughput on number of nodes is observed. The number of packet collisions
increases with increase in number of nodes, which results in decrease in throughput. When
the number of contending nodes is 50, the proposed CAD protocol gives a throughput of
6.6% and 10.5% higher when compared to Daneshgaran’s and Haitao’s models respectively
under basic access scheme. When the number of active nodes increases, the increase in
throughput is even higher. The dependency of the mean packet delay on the number of nodes
and data rates under saturated conditions is investigated. An exact packet delay analysis
under saturated traffic conditions is carried out by Ziouva et al., and hence, the delay
performance of the proposed model is compared with Ziouva’s model. When the contending
nodes are 25 and data rate is 1 Mbps, the delay required for successful packet transmission
using Ziouva’s model is 1.248 sec. But in the proposed model, the packet delay reduces to
0.7241 sec under basic access mechanism. In other words, the delay is reduced by 41.98%.
For the same parameters, the reduction in delay is 39.7% under RTS/CTS mechanism. The
delay decreases with increase in data rate. But even at higher data rates, the proposed model
gives better performance. The delay performance of the protocol is also evaluated for the
proposed CAD protocol (Ch. 4).
In order to obtain better QoS parameters such as throughput and End-to-End delay, a new Contention Window based Multiplicative Increase Decrease Backoff (CWMIDB) algorithm is proposed in this thesis and it is applied to the developed CAD protocol. In the proposed algorithm, the size of the contention window will be selected based on the number of collisions. The backoff procedure is modified in such a way that the backoff period increases and decreases alternately for each unsuccessful packet transmission until the contention window reaches its maximum value. The transmission, collision and success probabilities have been analysed for the proposed algorithm and it is found that the performance is fairly better when compared to Ziouva’s, Chatzimisios’s, Bianchi’s models and the proposed model with BEB algorithm. Results show that the saturation throughput performance of the DCF protocol using CWMIDB algorithm is improved by 8.97% compared to the proposed model with BEB algorithm and 15.7% compared to DIID algorithm. Compared to the HB and legacy BEB algorithms, this improvement is 27.14% and 20.2% respectively. From the above analysis, it is clear that the CWMIDB algorithm consistently outperforms other backoff algorithms due to the presence of post backoff stage, backoff freezing states and the selection of contention window for each collision. The impact of number of nodes, packet length and packet arrival rate on throughput and delay is analyzed under basic and RTS/CTS mechanisms. For a network with 25 nodes and when $P_e = 5 \times 10^{-2}$, the throughputs obtained are 0.6512 Mbps, 0.6765 Mbps and 0.6925 Mbps using Daneshgaran’s model, CAD protocol with BEB algorithm and CWMIDB algorithms respectively under basic access mechanism. The performance of CWMIDB algorithm is also better even under RTS/CTS mechanism. It is observed that the delay required to transmit the packet is very less using CWMIDB algorithm compared to BEB algorithm. This reduction is 61.8% under basic access mechanism and 60.85% under RTS/CTS mechanism for a packet arrival rate of 50 Pkts/sec when the contending nodes are 25 and $P_e=10^{-1}$. So, the proposed CAD protocol with CWMIDB
algorithm improves the throughput and End-to-End delay performance in all traffic conditions. Finally, it is concluded that among the existing backoff algorithms, the proposed collision alleviating DCF protocol with CWMIDB algorithm is the best choice for wireless and Ad hoc networks, especially for dense networks (Ch. 5).

**Future scope of the research work**

Wideband Code Division Multiple Access (WCDMA) is the third generation (3G) wireless network developed by Nippon Telegraph and Telephone (NTT), Japan and also suitable for deployment in the highly dense cities of Europe and Asia. Code Division Multiple Access 2000 (cdma2000) is also a 3G mobile technology standard that uses CDMA channel access to send data and voice between mobile phones and cell sites. The proposed collision alleviating DCF protocol with CWMIDB algorithm can be applied to WCDMA, cdma2000 and beyond 3G packet switched cellular and mobile communication networks which are seeking for an efficient backoff algorithm to maximize the overall system throughput and reduce the delay at base stations, base station controllers and Master Switching Centers (MSCs). The actual performance of the proposed protocol and the algorithm may be tested in real-time situations like rescue operations during natural calamities (eg. earthquakes, tsunamis, floods etc.), military operations in battle fields, etc.