Indonesian Journal of Interdisciplinary Research in Science and Technology (MARCOPOLO)
Vol. 3, No. 4, 2025 : 509 - 520

Performance Assessment of the CA-DCF Protocol in Wireless Networks

Harpreet Singh Bedi[1*], Shakti Raj Chopra[2]
School of Electronics and Electrical Engineering, LPU, Punjab, India
Corresponding Author: Harpreet Singh Bedi harpreet.17377@lpu.co.in

A R T I C L E I N F O

Keywords: CSMA, DCF, EDCF, SIFS, DIFS

Received : 03 March 2025
Revised : 26 March 2025
Accepted: 28 April 2025

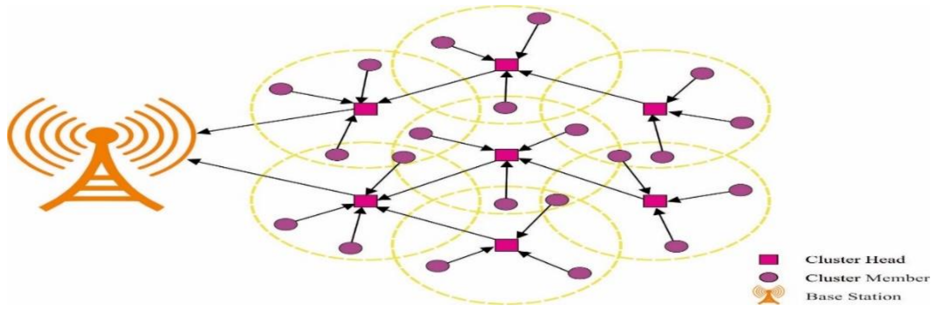
A B S T R A C T

With the development of Wireless Local Area Networks (WLANs), portable devices may now transmit high-quality, high-speed information using industry-standard protocols from anywhere in the globe without the need for network cabling. Wireless LANs are generally based on IEEE 802.11 standards. The most widely used wireless local area network (WLAN) standard is IEEE 802.11. The main challenge wireless network faces are to provide proper Services to their customers but there is less throughput and more delay in the system which deals with performance degradation. Network performance also degrades due to propagation through erroneous channels. Furthermore, a lot of energy is consumed during wireless data transmission. A credible Markov chain model is suggested by this study to accurately forecast wireless network performance. The proposed method considerably reduces latency, which is network delay while improving throughput when compared to the prior models.

DOI: https://doi.org/10.55927/marcopolo.v3i4.65
E-ISSN : 2986-8009
https://journal.formosapublisher.org/index.php/marcopolo

INTRODUCTION

In the past two decades, the growth rate of wireless communication has consistently been among the highest in the telecommunications and networking industry. Wireless networking, a rapidly evolving technology for connecting computers while moving from one location to another and establishing connections between wireless devices, has become an essential component of everyday life. WLAN standards are typically used in infrastructure and Ad hoc modes. In both infrastructure-based and Ad hoc networks, when many users try to access the medium to transmit data, more data collisions occur than usual, which result in frequent retransmissions causing unpredictable delays and degradation of network throughput. Network performance also degrades due to propagation through erroneous channels. Furthermore, a lot of energy is consumed during wireless data transmission.



. Figure 1. Overview of WSN

In WLANs, the DCF uses the BEB algorithm. But, the ing BEB algorithm, the node which has transmitted the packet most recently, may capture the channel and transmit subsequent packets. This will result in burst data transmission from that node only and other nodes that joined the network more recently may not get access to the channel. For this, a new, well-designed, and accurate analysis based on Markov chain modelling is developed. A literature survey reveals that several backoff algorithms have been developed to improve the performance of the DCF protocol. Local area networks based on the IEEE 802.11 standard represent the largest global arrangement of remote system innovation, and such systems have accelerated the development of mixed media applications, according to Jiménez, A. et al. (2018)[10] Y. Lee and colleagues (2012): An identical EDCA model prototype was created in this study, and it nearly fully addresses all the significant QoS features. Different access points and priorities are given to frames by this layer. The performance of the network is specifically examined in this article in terms of maximum protocol capacity or throughput, delay, and packet loss rate.[11]. The authors of this study address this problem and offer an analytical approach to assess DCF performance in suboptimal wireless channels. According to Waqar Aslam et al., a performance analysis must be exact and founded on plausible hypotheses to produce reliable forecasts. The following system components are what we consider to be reasonable conjectures: The likelihood of channel arbitration success following a transmission change throughout the allotted period; the likelihood of collision changes over various retry efforts; and each backoff procedure has a limited number of retries.

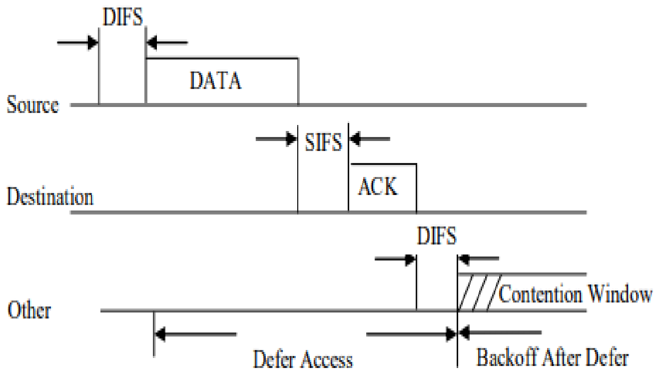


Figure 2. Basic access mechanism in DCF

A review of the literature finds that no model accounts for the backoff immobility, collision packet issues, and error of channel circumstances that occur during the post-backoff period. This research develops a CA DCF (CAD) protocol to accurately anticipate and increase system characteristics.

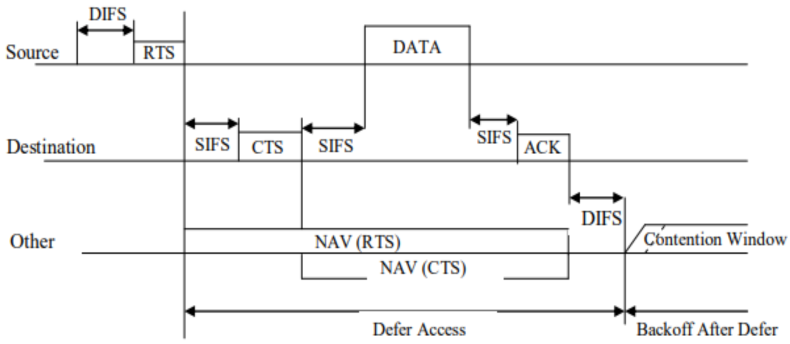


Figure 3. RTS/CTS mechanism in DCF

RTS/CTS access is shown in Figure 3 as a mechanism. A station that wishes to send a packet waits for a DIFS to indicate that the channel is idle, then follows the backoff procedures described above before sending a preliminary message in place of the packet.

LITERATURE REVIEW

1. Description of CA DCF CAD protocol

It has received a lot of interest from researchers to simulate IEEE 802.11. Many academics have spent a long time concentrating on the performance of 802.11 DCF utilising CSMA/CA. Numerous academic studies have utilized Markov chain models to evaluate the performance of IEEE networks. Considerable attention has been given to analyzing the Distributed Coordination Function (DCF) under ideal channel conditions. Bianchi's model has become a foundational reference for subsequent research in this area. Recognizing that network traffic is rarely saturated in real-world scenarios, the model was designed to reflect real-time network behavior, incorporating both collision-induced errors and channel-related errors.

The proposed Markov state transition model introduces a post-backoff phase intended to delay packet transmission in order to mitigate channel capture. This means that in both saturated and non-saturated traffic conditions, packets should only be transmitted after completing the post-backoff interval. Otherwise, the channel may become dominated by recent transmitters and their immediate competitors, limiting fair access for other nodes. If a node successfully transmits a packet and its buffer is empty, it transitions to an idle state, represented as (-1, 0), and remains there until a new packet enters its queue. During the post-backoff phase, the node sets a random backoff interval between (0, W_0-1) before initiating the next transmission, helping to prevent repeated channel monopolization.

Development of CA DCF CAD protocol

Assume that n is the constant number of rival nodes. Let the stochastic processes b(t) and s(t) represent the backoff counter and the backoff stage (0, h), where m is the maximum backoff stage, for a certain node at slot time t, respectively

The likelihood of an accident and the likelihood of a transmission fault are thought to be statistically independent .

$$P_{eq} = P_e + P_{col} - P_e P_{col} \quad (1)$$

The packet transmission procedure mirrors that of the Binary Exponential Backoff (BEB) algorithm discussed in the previous chapter, with the key distinction that a delay is introduced between consecutive packet transmissions. Following each successful transmission, a node is required to wait for a randomly determined backoff interval to minimize the risk of channel capture. During this period, the backoff counter decreases only when the node detects that the channel is idle.

$$P\{(i,k)|(i,k+1)\} = 1 - P_b, \quad k \in (0, W_i - 2), \quad i \in (0,m) \quad (2)$$

The back-off counter freezes when the channel is occupied.

$$P\{(i,k)|(i,k)\} = P_b, \quad k \in (1, W_i - 1), \quad i \in (0,m) \quad (3)$$

Each time a transmission is successful, the node holding the waiting packet enters the post-backoff stage.

$$P\{(-1,k)|(i,0)\} = \frac{(1 - P_{eq})q}{W_0} \quad k \in (0, W_0 - 1) \quad (4)$$

For every not successful transmission at stage i − 1, the node is to reschedule a backoff delay for the following stage.

$$P\{(i,k)|(i-1,0)\} = \frac{P_{eq}}{W_i}, \quad k \in (0, W_i - 1), \quad i \in (1,m) \quad (5)$$

When a transmission fails at every level, the node moves on to the last stage of the backoff operation and stays there until the packet transfer succeeds.

$$P\{(m,k)|(m,0)\} = \frac{P_{eq}}{W_m} \quad k \in (0, W_m - 1) \quad (6)$$

$$P\{(-1,0)|(i,0)\} = (1-P_{eq})(1-q) \quad i \in (0,m) \qquad (7)$$

$$P\{(-1,0)|(-1,0)\} = 1-q$$

$$P\{(0,0)|(-1,0)\} = q(1-P_b) \qquad (8)$$

When the channel is busy, the node having a packet to transmit chooses a backoff phase.

$$P\{(0,k)|(-1,0)\} = \frac{qP_b}{W_0} \quad k \in (0, W_0-1) \qquad (9)$$

$$P\{(-1,k)|(-1,k+1)\} = (1-P_b) \quad k \in (0, W_0-2) \qquad (10)$$

$$P\{(-1,k)|(-1,k)\} = P_b \quad k \in (1, W_0-1)$$

$$\sum_{i=-1}^{m} b_{i,0} + \sum_{i=-1}^{m}\sum_{k=1}^{W_i-1} b_{i,k} = 1 \qquad (11)$$

Let t represent the likelihood that a node will send a packet during a slot time that is selected at random. When the backoff counter approaches 0, the node sends the packet. Consequently, the t equation becomes

$$\tau = \sum_{i=0}^{m} b_{i,0} = \frac{1}{1-P_{eq}} b_{0,0} \qquad (12)$$

Without considering exponential backoff, t drops to t = 2/ W + 1 due to errors and collisions when Pb = 0.

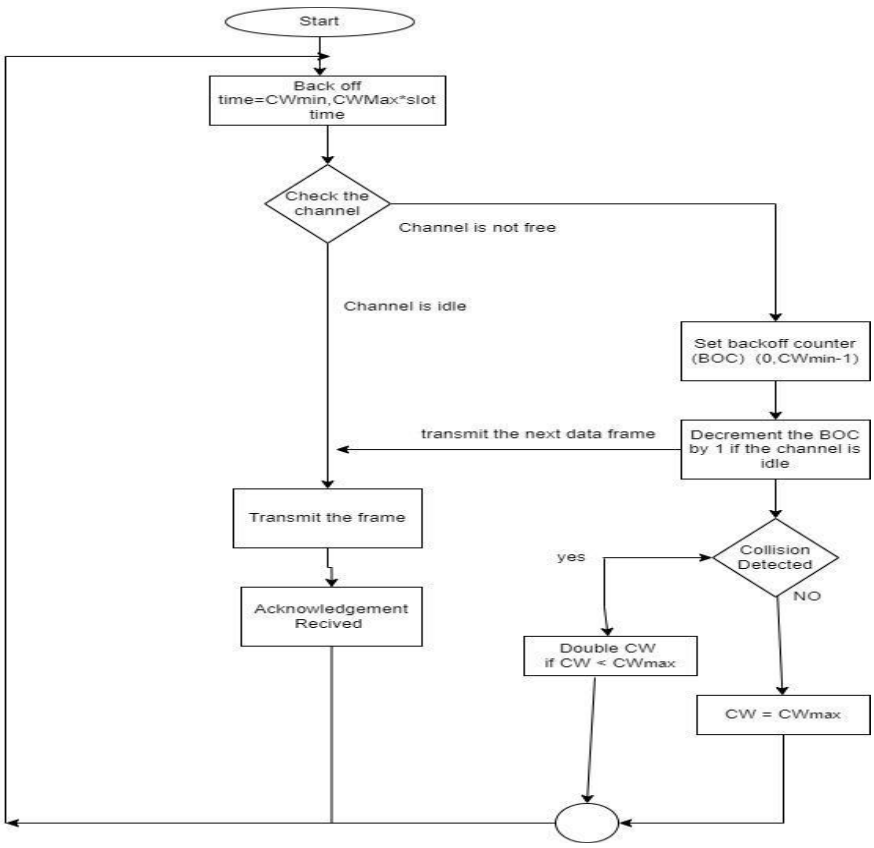


Figure 3. Flow Chart for Research Methodology

RESEARCH RESULT AND DISCUSSIONS

System throughput, Delay, probability of collision, and other metrics may be used to assess the wireless communication network's performance. There are differences between connection data rate and throughput.

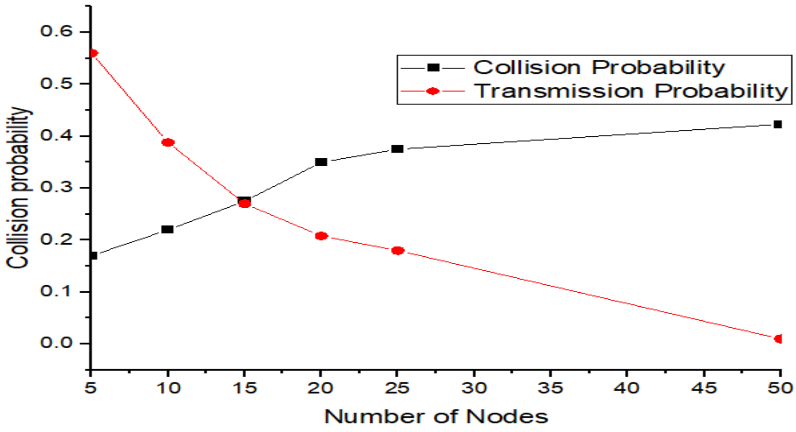


Figure 4. Variation of Collision and Transmission probabilities as a function of nodes

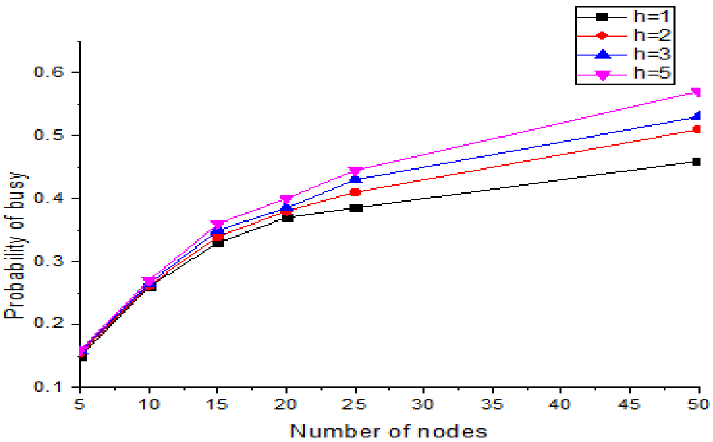


Figure 5. describes nodes versus collision probability

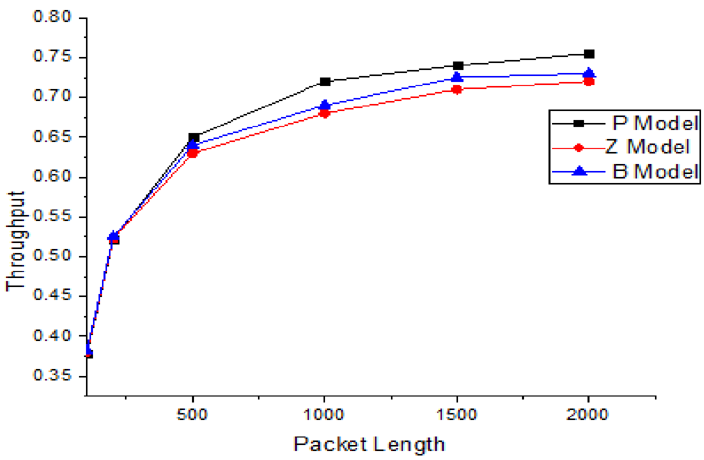


Figure 6. Packet length versus throughput for different models

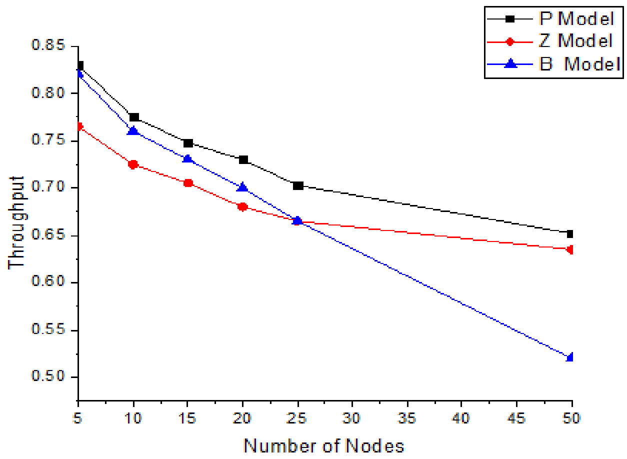


Figure 7. Nodes Versus Throughput (basic access mechanism)

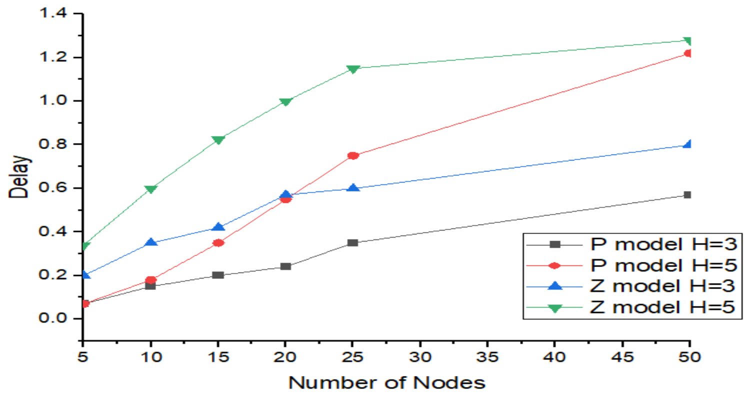


Figure 8. Nodes versus delay (RTS/CTS mechanism)

The suggested model's use of the **CA DCF CAD protocol** results in fewer collisions than other models. When compared to the suggested model utilising the BEB method, adopting the CWMIDB algorithm reduces the collision risk for a network of 25 nodes by 8%. **(CA DCF CAD protocol)**

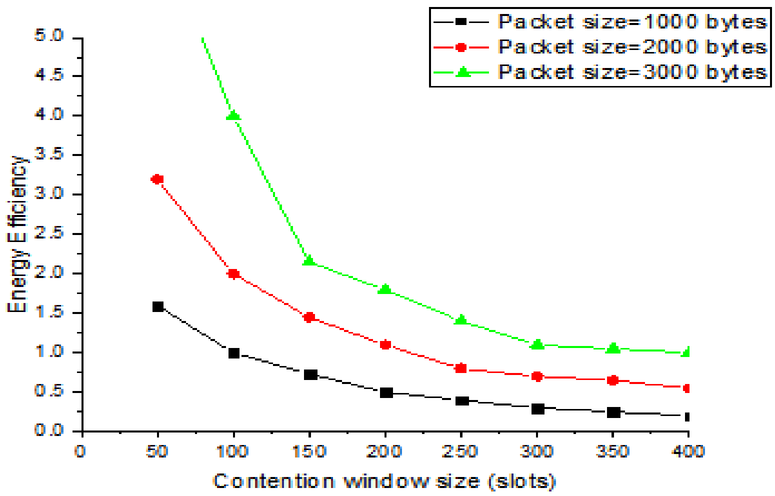


Figure 9. Energy Efficiency of Basic access

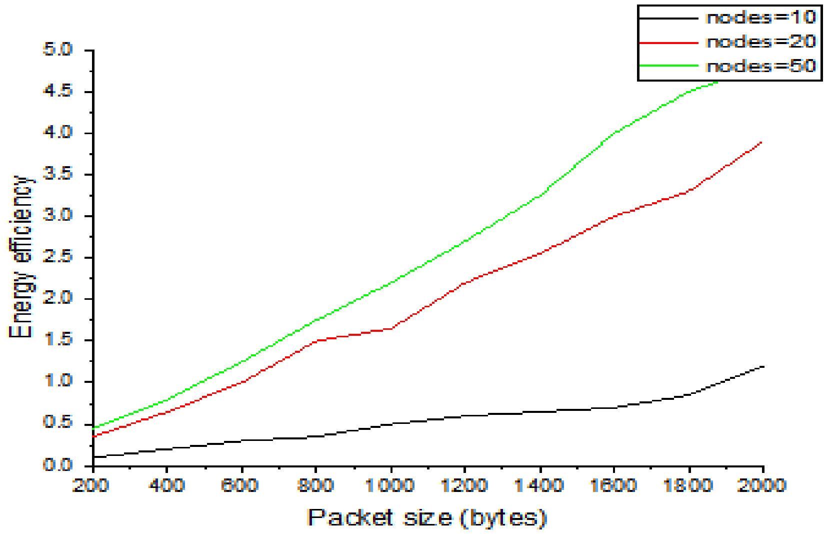


Fig 10. Energy Efficiency of Basic access

It can be shown from Figs. 9 and 10 that the energy efficiency declines as the size of the contention window increases. There will always be 25 nodes. Figure 10 depicts the variation in energy efficiency, which rises with packet size and falls with node count. The contention window in this is set at 32.

CONCLUSION AND RECOMMENDATION

The primary objectives of this technique are to prevent channel capture and improve the overall performance of wireless networks. Compared to existing models, the CA DCF CAD protocol demonstrates superior throughput. In scenarios with non-saturated traffic and a network of 50 nodes, the protocol achieves a 6% increase in throughput over Daneshgaran's model and a 10% improvement over Haitao's model. Findings indicate that the proposed CA DCF CAD algorithm outperforms traditional backoff strategies in both throughput and latency. Additionally, integrating the RTS/CTS mechanism yields better performance, providing higher throughput and reduced average latency compared to the basic access method. The algorithm also proves to be effective in high-traffic environments where simple access schemes typically struggle.

ADVANCED RESEARCH

While the CA DCF CAD protocol has shown notable improvements in throughput and latency over existing models such as Daneshgaran's and Haitao's, further research is needed to enhance its adaptability in more complex and dynamic wireless environments. Future work could focus on incorporating adaptive mechanisms that respond to real-time network conditions, including varying traffic loads and node mobility. Additionally, evaluating the protocol's performance in different network types—such as mesh networks or IoT systems—would help determine its broader applicability and limitations.

Another important direction is to investigate the energy efficiency of the protocol, especially in scenarios involving battery-powered devices. Exploring lightweight enhancements or energy-aware adjustments could make the CA DCF CAD protocol more suitable for resource-constrained environments. Moreover, while the use of RTS/CTS has proven beneficial, further analysis is necessary to optimize its use in dense networks where control overhead might affect performance.

REFERENCES

A survey on enhancing quality of service in wireless sensor networks Bedi, H.S., Verma, S., Singh, B. ***International Journal of Control Theory and Applications***, 2016, 9(41), pp. 37–42

Al-Jubari A. M., Othman M., Ali B. M. and Hamid N. A. W. A., ―TCP performance in multi-hop wireless ad hoc networks: challenges and solution‖, EURASIP Journal on Wireless Communications and Networking, No.1, pp.1-25, 2011.

Analysis of a adaptive Backoff algorithm to improve the utilization of the network Bedi, H.S.***2022 1st International Conference on Sustainable Technology for Power and Energy Systems, STPES 2022***, 2022

Anastasi G., Conti M. and Gregori E., ―IEEE 802.11 Ad Hoc Networks: Protocols, Performance and Open Issues‖, Mobile ad hoc Networking, A John Wiley & sons, inc., publication, pp.69-116, 2004

Andrea Goldsmith, ―Wireless Communications‖, Cambridge University Press, 2005.

Anouar H. and Bonnet C., ―Optimal Constant-Window Backoff Scheme for IEEE 802.11 DCF in Single-Hop Wireless Networks Under Finite Load Conditions‖, Wireless Personal Communications, Vol. 43, No. 2, pp. 1583–1602, 2007.

Babich F. and Comisso M., ―Throughput and Delay Analysis of 802.11-Based Wireless Networks Using Smart and Directional Antennas‖, IEEE Transactions on Communications, Vol. 57, No. 5, pp. 1413-1423, May 2009.

Bedi, Harpreet Singh, et al. "Traffic Surveillance Using Computer Vision and Deep Learning Methods." *IOP Conference Series: Earth and Environmental Science*. Vol. 1285. No. 1. IOP Publishing, 2024.

Bedi, Harpreet Singh. "Utilization of a wireless network performing CSMA/CA with random backoff algorithm." Journal of Physics: Conference Series. Vol. 2327. No. 1. IOP Publishing, 2022.

Bedi, Harpreet, Kamal Kumar, and Gupta Raghav. "A review paper on improving the network efficiency of IEEE 802.11 e networks." Intelligent Circuits and Systems (2021): 206-211.

Bedi, Harpreet, Kamal Kumar, and Gupta Raghav. ″ A review paper on improving the network efficiency of IEEE 802.11 e networks.″ Intelligent Circuits and Systems (2021): 206- 211.

Bianchi G., ―IEEE 802.11 Saturation Throughput Analysis‖, IEEE Comm. Letters, Vol. 2, No. 12, pp. 318-320, December 1998.

Bianchi G., ―Performance analysis of the IEEE 802.11 distributed coordination function,‖ IEEE J. on Selected Areas in Comm., Vol. 18, No. 3, pp. 535-547, March 2000.

Bisnik N. and Abouzeid A. A., ―Queuing network models for delay analysis of multihop wireless ad hoc networks‖, Ad Hoc Networks, Vol. 7, No.1, pp. 79-97, 2009. 201.

Bob O'Hara and AI Petrick, ―IEEE 802.11 Handbook – A Designer's Companion‖, Standards Information Network IEEE Press, ISBN: 0-7381-1855-9, 1999.

Calì F., Conti M. and Gregori E., ―Dynamic Tuning of the IEEE 802.11 Protocol to Achieve a Theoretical Throughput Limit‖, IEEE/ACM Transactions on Networking, Vol. 8, No. 6, pp. 785-799, December 2000.\

Cantieni G. R., Ni Q., Barakat C., and Turletti T., ―Performance analysis under finite load and improvement for multirate 802.11‖ Elsevier Computer Communications Journal, Vol. 28, issue 10, pp. 1095–1109, June 2005.

Chatzimisios P., Boucouvalas A. and Vitsas V., ―Packet delay analysis of IEEE 802.11 MAC protocol‖, Electronics Letters, Vol. 39, No. 18, pp. 1358–1359, September 2003

D. Chen, and P.K. Varshney, "QoS Support in Wireless Sensor Networks: A Survey", International conference on wireless networks, vol. vol. 233, 2004, pp. 1-7

Fingerprint Image Identification System: An Asset for Security of Bank Lockers Apoorva, M., Pavan, S., Bedi, H.*Digital Forensics and Internet of Things: Impact and Challenges*, 2021, pp. 227–235.

H.S. Bedi, K.K. Sharma, and R. Gupta, "A Review Paper on Performance Analysis of IEEE 802.11 e", 1st International Conference on Computing, Communications, and Cyber-Security (IC4S 2019), 2020, pp. 47-56.

Harpreet Bedi, Kamal Kumar Sharma; Analyses of CSMA/CA Protocol Without Using Virtual Channel Sensing in DCF Mode, Global Emerging Innovation Summit (GEIS-2021) (2021) 1: 484.

Harpreet Singh Bedi, Kamal Kumar Sharma, Shakti Raj Chopra and Balraj Singh Analysis of QoS parameters using different back off window algorithm in the IEEE 802.11e networks, Advances and Applications in Mathematical Sciences Volume 21, Issue 10, August 2022, Pages 6147-6157 © 2022 Mili Publications, India

I. Syed, and B-h. Roh, "Delay analysis of IEEE 802.11 e EDCA with enhanced QoS for delaysensitive applications", 35th International Performance Computing and Communications Conference (IPCCC), 2016, pp. 1-4.

J.S. Vardakas, and M.D. Logothetis, "End-to-end delay analysis of the IEEE 802.11 e with MMPP input-traffic", International Symposium on Autonomous Decentralized Systems, 2009, pp. 1-6

K. Langendoen, and G. Halkes, "Energy-efficient medium access control", Embedded systems handbook, vol. 6000, 2005.

N.S. Chauhan, and L. Kaur, "Implementation of QoS of different multimedia applications in WLAN", International Journal of Computer Applications (0975 – 8887), vol. 62, no. 8, 2013.

O. Tsigkas, and F-N. Pavlidou, "Providing QoS support at the distributed wireless MAC layer: a comprehensive study", IEEE Wireless Communications vol. 15, no. 1, pp. 22-31, 2008.

Performance comparison of companding techniques and new d-cast method for reduction of PAPR in OFDM Bedi, H., Puri, I., Sharma, R.K., Verma, S. *International Journal of Control Theory and Applications*, 2016, 9(24), pp. 217–222.

S. Singh and A. Kumar, "Performance analysis of adaptive clipping technique for reduction of PAPR in alamouti coded MIMO-OFDM systems in 6th International Conference on Advances In Computing & Communications, ICACC 2016, 6-8 September 2016, Cochin, India., vol. 93, pp. 609- 616, 2016.

Singh, Harpreet, Shekhar Verma, and Gaganpreet Kaur Marwah. "The new approach for medical enhancement in texture classification and feature extraction of lung MRI images by using gabor filter with wavelet transform." *Indian Journal of Science and Technology* 8.35 (2015): 1-7.

Soft computing based robust and dynamic road traffic control system-a initiative to development of intelligent transportation system (ITS) Mittal, P., Bedi, H.S., Arora, K.*Journal of Engineering and Applied Sciences*, 2016, 11(2), pp. 210–215.

T. Wark, P. Corke, P. Sikka, L. Klingbeil, Y. Guo, and C. Crossman, "Transforming agriculture through pervasive wireless sensor networks", IEEE Pervasive Computing vol. 6, no. 2, 2007.

Utilization of a Wireless Network Performing CSMA/CA with Random Backoff Algorithm Bedi, H.S.,2022, 2327(1), 012060.

Vanteru, M. K., Bedi, H. S., Azam, M., Chakravarthi, M. K., Raffik, R., & Pant, B. (2022, December). Empirical Investigation on Smart Wireless Autonomous Robot for Landmine Detection with Wireless Camera. In *2022 5th International Conference on Contemporary Computing and Informatics (IC3I)* (pp. 200-205). IEEE.

W. Pattara-Atikom, P. Krishnamurthy, and S. Banerjee, "Distributed mechanisms for quality of service in wireless LANs", IEEE Wireless Communications vol. 10, no. 3, pp. 26-34, 2003.

X. Liu, and W. Zeng, "Throughput and delay analysis of the IEEE 802.15. 3 CSMA/CA mechanism considering the suspending events in unsaturated traffic conditions", 6th International Conference on Mobile Adhoc and Sensor Systems, 2009, pp. 947-952

Z.G. Khaki, and H.S. Bedi, "Transient correction using EDFA: in-line optical fibre with feedback", International Conference on Computing Sciences, 2012, pp. 233-238.