A Review of De-facto MAC Standard: IEEE 802.11 DCF

Shifali Hans
M.Tech (CST)
Central University of Punjab, Bathinda
India
shifali.hans@yahoo.com

Anand Nayyar
Assistant Professor
Department of Computer Applications & IT
KCL Institute of Management & Technology, Jalandhar
India
anand_nayyar@yahoo.co.in

***Abstract*—Advancement in the wireless networking technologies has drastically changed our world and has led us to new direction of "Infrastructure-less networking- Mobile Adhoc Networks". MANETs is a troupe of mobile nodes tied by wireless links in peer to peer fashion. Mobile nodes in MANETs often struggle for the wireless medium access. IEEE have defines certain rules for the medium access control (MAC). IEEE 802.11 DCF is a de-facto MAC standard. These rules have been laid down at MAC sublayer of link layer of TCP/IP reference model. One interesting research area in MANETs is MAC. This article provides a brief review of IEEE 802.11 DCF MAC standard.**

Keywords- MANETs, IEEE, MAC, DCF, carrier sensing, NAV

I. INTRODUCTION

Information sharing and communication are the crucial aspect of today's world. It is impossible to imagine a world without email, online news papers, blogs, chat and the other services offered by the internet. Networks connect various systems and allow them to talk i.e. to communicate, share information, resources. Systems in the network are also called as nodes and can be computer, laptops, mobile phones, PDAs, etc. These systems can be connected in a network through cable media or by wireless media.

Due to the development of cheap portable devices and the progress made in the wireless technology, the wireless networking took a leap. Wireless simply means that links among nodes are established through radio waves, i.e. through the air. Wireless networks have their own advantages, no need to lay down expensive cables, free to roam -- need not to tie up your desk or cabin; you can start an online conversation anywhere anytime. Sometimes there is a need of spontaneous deployment of network, and that too for temporary basis like in the fields of military and rescue operations, crisis management services, virtual class room sessions, emergency operations, enterprise networks, home networks, and location aware services, disaster recovery operations, etc [1][5] [6] [13]. In such fields, deployment of Mobile Adhoc Network (MANETs) is the apt choice.

Mobile Adhoc Network (MANETs) are the wireless networks established for a special, extemporaneous service, and do not require pre-existing infrastructure [1][3]. MANETs uses the traditional TCP/IP networking model to provide end-to-end communication between nodes [5]. They are decentralized, self configurable and self healable networks [3] [5] [6]. Nodes in MANETS are autonomous, i.e. free to move and organize themselves [5]. Nodes share the wireless channel and topology of network changes dynamically [5]. Communication occurs usually in multi-hop paths, and breaking of communication link is often, as nodes move independently [5] [6] [14].

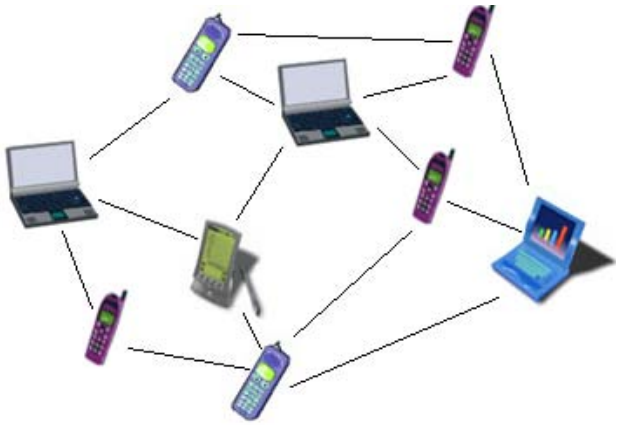

Figure 1: MANET

Some specific attributes of MANETs are listed below [13] [14]:

- Decentralised control i.e. nodes are arranged in peer-to-peer fashion, there is no centralized administration or base station.
- Dynamic topology: Nodes in MANETs are free to roaming. They can join or leave the network and they may move randomly, which result in rapid and unpredictable topology.
- Autonomous terminals: Nodes in MANETS can act as host as well as the router.
- Shared Physical medium: Nodes communicate with each other via wireless links. Wireless medium is free and is accessible to all nodes. MAC defines the rules for multiple access.
- Multi hop routing: Nodes that lie within each other's send range can communicate directly but when the receiver and the sender are not in direct

978-1-4799-4910-6/14 $31.00 © 2014 IEEE
DOI 10.1109/ACCT.2014.19

transmission range, packets are forwarded by intermediate nodes.

II. MAC

Wireless medium is free open shared medium. All the nodes on MANETs use this open medium. And due to its shared nature, nodes in MANETs often compete for medium access. So in order to resolve the problem of medium contention there are some rules and MAC lay down those rules. These rules are implemented at the MAC sublayer. In OSI model of networking and in TCP/IP reference model, Link layer is divided into two – LLC and MAC [2]. MAC is the sublayer of link layer and is sandwiched between LLC and Physical layer [2]. MAC furnishes medium access control mechanisms and addressing, make it possible for several nodes or network terminals incorporated in a shared medium to communicate network [2]. In the MANETs, the common MAC protocol or channel mechanism used is IEEE 802.11.

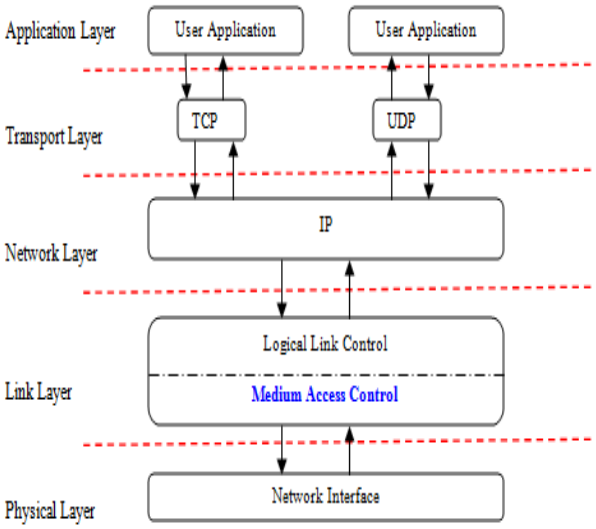

Figure 2: MAC in Protocol Stack [17]

The access methods for sharing are based on some elementary philosophies like: first come, first served and taking turns [18]. Number of MAC protocols has developed for wireless; some have been adopted form wired domain, while some are unique. But, yet most of MAC Protocols use the subset of techniques used in Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA), ALOHA, CSMA protocols [17].

Based on channel access strategy the Adhoc networking MAC protocols have been divided into three broad categories [17]:

- Contention Protocols
- Allocation Protocols
- Hybrid Protocols

Contention Protocols: Contention among mobile nodes is when two or more nodes simultaneous try to transmit data across a network. Contention Protocols utilizes contention to govern medium access rights and rectify collision problem through randomized retransmissions [17].Except ALOHA, most of the contention protocols deploy asynchronous communication model [17]. Control signaling help in avoiding collisions [17]. Some of the main renowned contention protocols are BTMA, RI-BTMA, WCD, MACAW, MACA/PR, MACA-BI, and CSMA/CA [17]. IEEE 802.11 also belongs to contention protocol and is explained in next section.

Allocation Protocols: Such type of protocols uses synchronous communication model, and a scheduling algorithm, that creates a mapping of time slots to nodes. This mapping ultimately produces transmission schedule that decides in which particular slots a node is allowed to access the medium. Most allocation protocols generates collision-free transmission schedules, therefore the schedule length, which is measured in slots, forms the basis of protocol performance. These time slots can either be allocated statically or dynamically, which thereby accordingly lead to a fixed and variable schedule length [17]. Many allocation protocols have been proposed. TSMA, FPRP are allocation protocols [17].

Hybrid protocols: These can be considered as the combination of two or more protocols [17]. Hybrids TDMA/CSMA, ADAPT, ABROAD, AGENT are some of the hybrid protocols [17].

MAC performance metrics helps in comparing one protocol from the other MAC protocol. The key metrics are [20]:

- Delay
- Throughput
- Fairness
- Stability
- Robustness against channel fading
- Power Consumption
- Support for multimedia

III. IEEE 802.11

IEEE 802.11 is a MAC layer standard developed by IEEE. The Institute of Electrical and Electronics Engineers (IEEE) is a professional organization that is dedicated to advancing technological innovation and excellence. It is the leading standards making association [9]. IEEE 802 LAN/MAN group of standards which contain the IEEE 802.3 Ethernet standard and the IEEE 802.11 Wireless Networking standard, are the most widely known and remarkable standards of IEEE [9].

IEEE 802 deals with local area networks and metropolitan area networks. IEEE 802 is concerned with the

networks carrying variable packet size [10]. Isochronous networks which data is transmitted as a steady stream of octets, or groups of octets, at regular time intervals, are out of the horizon of this standard [10]. The number 802 was simply the next free number IEEE could assign, though sometimes "802" is associated with the date the first meeting was held — February 1980 [10]. The protocols and services defined in IEEE 802 map to the lower two layers (Data Link and Physical) of the OSI networking reference model.

TABLE 1: VARIOUS ACTIVE STANDARDS OF IEEE 802 [9] [10]

Standards	Description
802.1	Internetworking
802.2	Logical link control
802.3	Ethernet
802.4	Token bus
802.5	Token ring
802.6	Metropolitan area network (MAN)
802.7	Broadband technology
802.8	Fiber-optic technology
802.9	Voice and data integration
802.10	Network security
802.11	**Wireless LAN**
802.15	Wireless Personal Area Network (WPAN)
802.16	Broadband Wireless Access
802.18	Radio Regulatory TAG
802.19	Wireless Coexistence Working Group
802.21	Media Independent Handover Services Working Group
802.22	Wireless Regional Area Networks
SG ECSG	Smart Grid Executive Committee Study Group

IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network computer communication [7]. IEEE 802.11 defines two medium access techniques - Point Coordination Function (PCF) based on polling, and Distributed Coordination Function (DCF) based on contention [5]. Sometimes when PCF and DCF coexist in a network, the time is divided into sequence of repetition intervals with equal length. In each repetition interval, the system runs first in a PCF mode (contention-free period) than in the DCF mode (contention mode) [15].

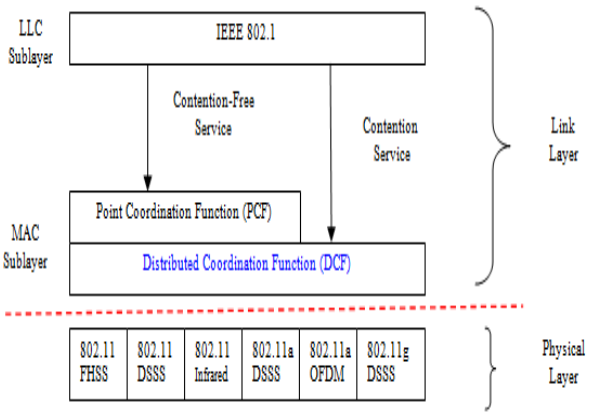

Figure 3: IEEE 802.11PCF and DCF at MAC Sublayer [16]

PCF is MAC technique that is implemented in the infrastructure networks (not in Adhoc networks) and is an optional access method [16]. It is used in the time sensitive application and is implemented on the top of DCF [4]. PCF has centralized, contention free polling access method [15]. It resides in a point coordinator also called as Access Point (AP) to coordinate the communication between the networks. The AP (access point) performs polling for the nodes that are capable of being polled. The terminals are polled one after another, sending data that they have, to AP [16]. The AP waits for PIFS (PCF interframe Space) duration to hold the channel. PCF has priority over DCF as the terminals that only use DCF may not get the medium access [15]. To remove this priority problem, a repetition interval have been introduced which cover both PCF and DCF. PCF is implemented in very few hardware devices as it is not the part of the Wi-Fi Alliance's interoperability standard [9].

DCF is the elementary MAC technique used in wireless networks and it is the de-facto MAC standard. DCF employs a carrier sense multiple access with collision avoidance (CSMA/CA) with binary exponential backoff algorithm [8] [12]. CSMA/CD (carrier sense multiple access with collision detection) cannot be implemented in wireless networks because of signal fading and the hidden station problem, so CSMA/CA is used. Carrier sensing is performed at both air interface as well at MAC layer. Physical carrier sensing at physical layer checks the presence of IEEE 802.11 users on the network by analyzing all the detected packets and by detecting activity in the medium via relative signal strength from other sources. Virtual carrier sensing at MAC layer is performed by the network allocation vector (NAV). The following section explains IEEE 802.11 DCF in detail.

IV. IEEE 802.11 DCF

The basic MAC is a DCF which allows automatic channel sharing between compatible physical layer through the use of CSMA/CA and a random backoff time following a busy medium condition [19]. All directed traffic uses immediate positive acknowledgment (ACK frame) but if there is no AWK then retransmission is scheduled by the sender [19].

The physical carrier sensing as performed by CSMA/CA helps in diminishing collision between mobile modes when accessing the channel. The nodes can only transmit when the medium is idle.

A terminal senses the medium, for medium status, whether idle or busy, for DIFS interval. If the medium is busy for the DIFS interval, the terminal delays its transmission. And if the medium is idle, terminal start transmitting. DCF uses four way handshake mechanisms, RTS-CTS-DATA-ACK [11]. If the medium remains idle for a time interval equal to distributed interframe space (DIFS), the station is allowed to transmit RTS (ready-to-send). On receiving the RTS, the destination node will wait for certain time period- short interframe space (SIFS) and then send (clear-to-send)CTS. This will indicate that destination is ready to receive the data. Sender after waiting for SIFS time period will then send the data packet. Finally, the destination after waiting for time period SIFS will send the acknowledgement (ACK) to the sender, to show that it has successfully received the data packet. If the medium is busy, the transmission is postponed until the ongoing transmission concludes and BEB procedure is called [7] [8].

DCF also support the virtual carrier sensing through network allocation vector (NAV) [3]. NAV predicts duration for which the medium will be busy [3]. RTS usually include the duration of the time for which node will be busy. So the other node in the vicinity set the NAV accordingly. NAV represents that how much time must pass before checking the channel for idleness and this will eventually avoid the collision from other nodes [3].

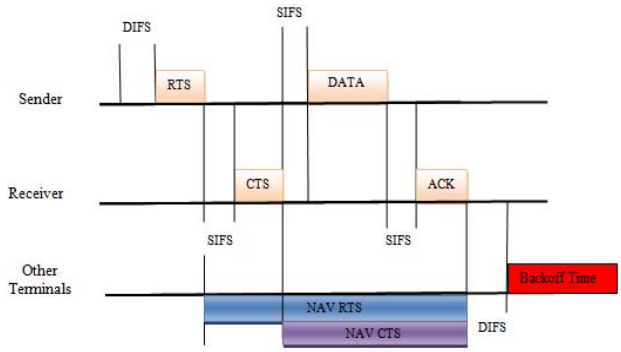

Figure 4: RTS-CTS-DAT-ACK and NAV setting [4]

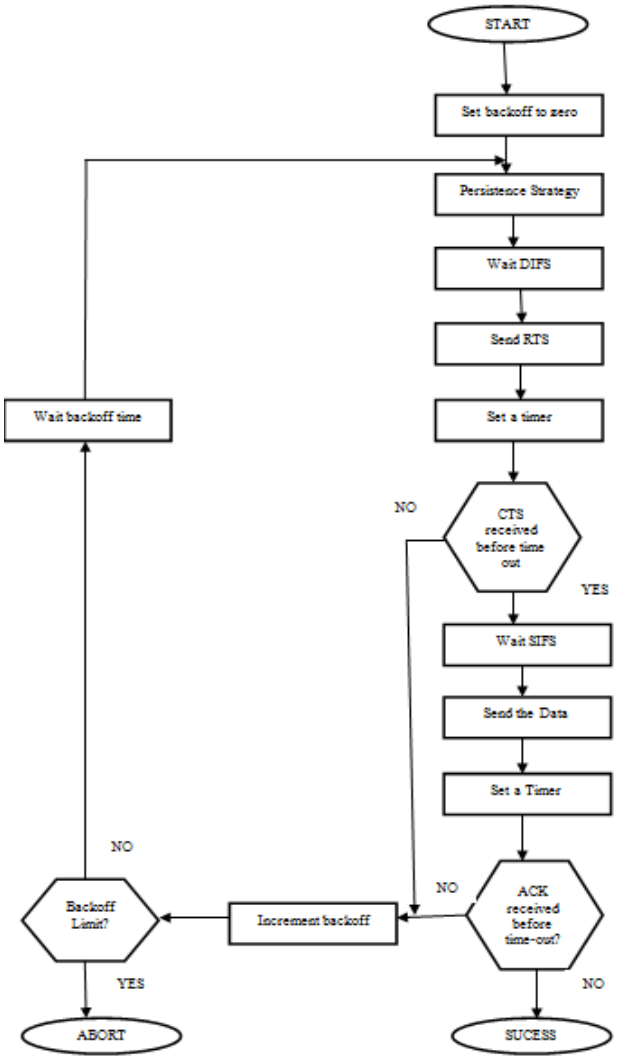

Figure 5: IEEE 802.11 DCF Flowchart [16]

In a MANET, numbers of nodes compete for the medium, if multiple nodes sense the medium and defer their communication, they will essentially at same time find the medium being released and try to capture the medium. So in order to avoid such collision, nodes need to be displaced in time. And to displace them temporally, backoff algorithm called binary exponentially backoff (BEB) algorithm is used. In BEB whenever a node is involved in collision, a random waiting time is allotted to the node and the node has wait for that time before trying again. If it is not successful in its attempt its contention window size will be doubled.

BEB algorithm uses uniform random distribution function to generate a random backoff value for the node. Backoff time is a random integer of uniform distribution over the interval [0, CW], multiplied by the slot time size. The back off value increases exponentially if the channel is busy or there is a collision. But if the channel is idle and there is

successful transmission, then backoff value is set to minimum CW size [12]. Backoff time is calculated as
BackoffTime = random ()*aSlotTime

IEEE 802.11 DCF up to some extent resolves the problem of collision but IEEE 802.11 DCF does not consider the QoS or the fairness issues. IEEE 802.11 DCF uses the random function in BEB algorithm to generate back off value. This backoff value is doubled for every collision and is reduced to minimum value of contention window for every successful transmission. This results in large variations in backoff counter, ultimately leading to unfairness problem, low throughput, and higher jitter and wasting bandwidth [12].

V. CONCLUSION

No doubt, MANETs have heralded a new era of extemporaneous and infrastructure-less networking, but still they are in their adolescence, requiring more detailed exploration and study. Wireless medium is open sharable medium, which has lead to new problem of contention between mobiles nodes and collision of data packets. It is the need of hour to carry out more in-depth research on MAC techniques of wireless networks, so as to reduce the contention and collision. The default MAC standard IEEE 802.11 DCF, which employ carrier sensing with binary backoff algorithm, contains some flaws. As in BEB algorithm exponential extension of the contention window size, leads to the problem of unfairness, higher delay and jitter.

Future work: Our future work we will be focus on the improvement of BEB algorithm of IEEE 802.11 DCF. Instead of using exponential increment every time, we try to incorporate some other approach. Moreover, the effect of contention window size will be probed. Succinctly, overall focus will be to improve the efficiency of MAC for MANETs, so that it can provide service flawlessly.

REFERENCES

[1] I. Chlamtac, M. Conti and Jennifer J-N Liu. "Mobile ad hoc networking: imperatives and challenges." Sciencedirect Journal on Ad Hoc Networks 1, vol 1, pp. 13-64, 2003

[2] L. Litwin, "Medium Control Sublayer", Communication Technology, IEEE Potentials, vol. 17, no. 1, pp. 30-34, 2001

[3] H Zhai, J Wang, X Chen and Y Fang, "Medium access control in mobile ad hoc networks: challenges and solutions", Wireless Communications And Mobile Computing, pp. 151-170, 2006

[4] G. Anastasi, E. Borgia, Marco Conti, and Enrico Gregori. "IEEE 802.11 ad hoc networks: Performance Measurements." 23rd International Conference on Distributed Computing Systems, 2003. Proceedings, pp. 758-763. IEEE, 2003

[5] P. Mohapatra, S. Krishanmurthy, "Adhoc networks technology and protocols", Springer, 2005

[6] S. Basagni, M. Conti, S. Giardano, I. Sto, "Mobile Adhoc Neworking", IEEE Press, John Wiley & Sons, INC., Publication, 2004

[7] Chaudet, D. Dhoutaut, I. Lassous, "Performance issues with IEEE 802.11 in ad hoc networking", IEEE communication Magazine, vol 43, issue 7, pp. 110-116, 2005

[8] G. Bianchi, "Performance Analysis of the IEEE 802.11 Distributed Coordination Function", IEEE Journal On Selected Areas In Communications, Vol. 18, No. 3, pp. 535-547 March 2000

[9] IEEE 802 LAN/MAN Standards Committee, http://www.ieee802.org, last accessed on 02 November

[10] IEEE standard association, http://standards.ieee.org, last accessed on 07 November 2013

[11] S. A. Chowdhury, Mohd. Tauhldullslam, F. T. Jaigirdar, Mohd. R. U. Faruqui, S. A. Noor , "Performance study and simulation analysis of CSMA and IEEE 802.11 in Wireless Sensor Networks and limitations of IEEE 802.11", 12 International Conference on Computer and Information Technology, ICCIT , pp. 431-435, 2009

[12] A. Khalaj, N. Yazdani, M. Rahgozar, "Effect of contention Window size on the performance and fairness of the IEEE 802.11 standard", Springer Wireless Communication, vol 43, pp. 1267 -1278, 2007

[13] Aarti, S. S. Tyagi, Study of MANET: Characteristics, Challenges, Application and Security Attacks, IJARCSSE, vol 3, issue 5, May 2013-11-30

[14] Deepika Dhiman, Anand Nayyar ,Complete Scenario of Routing Protocols, Security Leaks and Attacks in MANETs, IJARCSSE, vol 3, issue 10, October 2013

[15] Li Feng, Jianqing Li, Xiaodong Lin, A new Delay analysis of IEEE 802.11 PCF, IEEE Transactions on Vehicular Adhoc Network, vol 62, no 8, October 2013

[16] Behrouz A. Forouzan, Data Communications and Networking, TataMc-Graw-Hill publication, 2007

[17] Myers, Andrew D., and Stefano Basagni. "Wireless media access control."*Handbook of wireless networks and mobile computing* , 2002

[18] Medium access Control, http://www.slideshare.net/nizam143/media-access-methods, last accessed on December 03, 2013

[19] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, ANSI/IEEE Std 802.11, 1999 Edition (R2003), LAN MAN Standards Committee

[20] Drs. Baruch Awerbuch & Amitabh Mishra, Medium Access Control (MAC) Protocols for Ad hoc Wireless Networks – I, http://www.cs.jhu.edu/~cs647/mac_lecture_1.pdf, last accessed on 04 November 2013