Use of Game Theory In IEEE 802.11 WLAN

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Abstract-*The Backoff Algorithm is considered as the heart of Medium Access Control(MAC) protocol which determines the system throughput in IEEE802.11 networks. In Wireless medium, nodes are not immediately allowed to transmit data as they have data to send. Backoff algorithm takes an important and crucial decision to determine the precious waiting time for the node before accessing the medium. Hence designing an effective and efficient Backoff algorithm is required for Wireless Networks. In this project, we have simulated and analyzed the Binary Exponential Backoff Algorithm using NS2 simulator.*

Keywords-BEB, DCF, Game Theory, Protocol, WLAN.

I. INTRODUCTION

Wireless communication is the fastest growing technologies. In the last two decades, the demand for wireless services and the number of mobile subscribers has been increased. Due to increase in wireless services mobile operators and researches are developing new transmitting technologies, protocols, algorithms and network infrastructure solution to improve the network performance.

Wireless networks are of different types such as Wireless LAN, Wireless WAN and Wireless MAN. IEEE 802 is a family of IEEE standards dealing with LAN and MAN networks. The first WLAN standard was created in 1997 by the Institute of Electrical and Electronics Engineers (IEEE).The IEEE 802.11-based WLANs is the most popular wireless network standard, and the IEEE 802.11 standard [1] has two basic operation modes: distributed coordination function (DCF) and point coordination function (PCF). PCF is centralized MAC protocol in which an access point (AP) is required for communication between devices.

However, DCF is a contention-based access scheme and is based on the carrier sensing multiple access/collision avoidance (CSMA/CA) protocol using the binary exponential backoff (BEB) algorithm. The BEB algorithm is the main backoff scheme implemented in the IEEE 802.11 DCF. However, in terms of the collision rate and throughput of the BEB algorithm, its performance decreases dramatically when the number of stations increases beyond a certain limit. An improper CW adjustment increases the collision probability such that the nodes experience many collisions before it reaches the optimal CW.

Section II determines literature survey of BEB algorithm. Performance Evaluation Parameters are defined in Section III. Section IV specifies simulation methodology. Finally the section IV and V gives simulation results and concludes the paper.

II. LITERATURE SURVEY

A. Binary Exponential Backoff (BEB)

Backoff mechanism is used to avoid collisions in mobile ad hoc networks when more than one node attempts to access the channel. Collision is avoided when only one of the nodes is granted access to the channel, while other contending nodes are sent into a backoff state for some period , before trying to access the channel after a transmission failure [3]. This concept is used in Backoff Algorithms.

The Binary Exponential Backoff (BEB) is used in the IEEE 802.11 standard MAC protocol. DCF is used in CSMA/CA as the access method [4]. In the mechanism of DCF, the carrier sense activity continues in listening to the channel before transmitting: If the channel is found to be idle for a time period greater than the Distributed Inter-Frame Space (DIFS) period, the station transmits directly; otherwise the station alters its transmission time until the ongoing transmission terminates. When the channel becomes idle again for a DIFS [5], the station enters the collision avoidance mode by selecting a random interval of time slots called backoff interval that is used to initialize a backoff timer. If wireless channel is found to be busy, the node is frozen and backoff counter is paused. When the wireless channel is converted to an idle condition and passed the DIFS time, the node continues the remaining backoff countdown. Until counting backward to zero, the node may access the channel and begin to transmit packets.

If the channel is found idle and not being accessed by any other node, the node is permitted access to start transmitting. Otherwise, the node waits for an inter-frame space and the backoff mechanism invited. A random backoff interval will be selected in the range [0, CW-1]. A uniform

random distribution is used here, where CW is the current contention window size.
If the medium is found to be busy during backoff, then the backoff timer is suspended. This means that backoff period is counted in term of idle time slots. Whenever the medium is found to be idle for longer than an inter-frame space, backoff is resumed. When backoff is finished with a BO value of zero, a transfer should take place. If the node successfully sends a packet and receive an acknowledgment for it, then the CW for this node is reset to the minimum, which is equal to 31 in the case of BEB. If the transmission fails, the node goes into another backoff period. When going for another backoff period again, the contention window size is exponentially increased with a maximum of 1023.

One major disadvantage of the BEB scheme is that it faces a fairness problem; some nodes can achieve significantly larger throughput than others. The fairness problem occurs due to the fact that the scheme resets the contention window of a successful sender to CWmin, while other nodes continue to maintain larger contention windows, thus lowering their chances of accessing the channel and resulting in channel domination by the successful nodes.

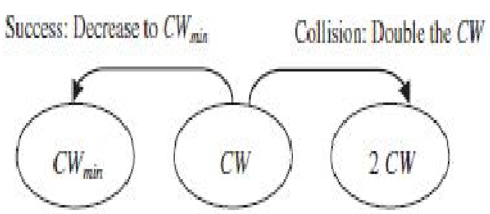

Figure.1.Binary Exponential Backoff Scheme

- In case of Collision

CW (new) = 2*CW (1)

- In case of Successful Transmission

CW = CWmin (2)

B. Game Theory

The functioning of a given wireless device may affect the communication capabilities of a neighboring device, especially because the radio communication channel is usually shared in wireless networks. By making use of game theory we can handle this type of situation. The different terminologies that are associated with the game theory are explained below.

1. Players: An agent who makes decisions in a game is called as player. That is there are two players in a game. The players maybe any two companies (for e.g., two persons bidding in a game, etc.)

2. Strategy: The course of action taken by a player is termed as strategy. A strategy is one of the given possible actions of a player in a strategic form whereas a strategy is a complete plan of choices, one for each decision point of the player in an extensive form. The strategy can be further classified into pure strategy and mixed strategy.

3. **Payoff matrix**: A payoff is a number, also called utility that reflects the desirability of an outcome to a player.

4. **Nash equilibrium**: A Nash equilibrium also called as strategies equilibrium, is a list of strategies, one for each player, which has the property that no player can unilaterally change his strategy and get a better outcome.

5. **Pareto Optimal Equilibrium:** In the Pareto optimal, every player finds its own better outcome without knowing the payoff of other players.

6. **Perfect information**: When only one player makes a move at any point in time and knows all the actions that have been made until then the game is said to have perfect information.

7. **Dominating strategy**: If a strategy dominates strategy of a another player and it always gives a better payoff to that player, regardless of what the other players are doing then it is known as dominating strategy.

8. **Rationality**: If a player plays in a manner which maximizes his own payoff then he is known as rational.

9. **Strategic form**: It is a dense representation of a game in which players simultaneously choose their strategies. The resulting outcomes are presented in a table with a cell for each strategy combination.

10. **Zero-sum game**: Zero-sum in game theory is defined as if for any payoff, the sum of the payoffs of all players is zero.

11. **Two-person zero-sum game**: It can be defined as the gain of one player is equal to the loss of another player.

Cooperative Game Theory: Cooperative communication has been developed to improve the channel capacity in wireless network. Cooperation from other nodes is required to achieve this.

		Klein	
		Confess	Not confess
Calvin	Confess	(5,5)	(0,15)
	Not confess	(15,0)	(1,1)

Figure 2. The Prisoners' Dilemma.

The Figure 2. shows that the example of Prisoner's Dilemma. Two prisoners, Calvin and Klein, are arrested for a suspected crime and interrogated in different rooms. The investigating officer talks to each prisoner separately and offers each of them the following deal: "Confess to the crime, turn a witness for the State, and betray the other guy. Of course, if you confess it will be worth a lot less if the other suspect confesses as well. If it happens, you both go to jail for five years. If one does not confess and other does then you will go to jail 15 years. In the event that I cannot get a confession from either of you, I have enough evidence to put you both away for a year." Either to confess or not to confess are each players pure strategies. Figure 2. shows the strategy form of the game. One strategy is chosen by Calvin and another by Klein from the above matrix table. The strategy combination (Confess, Confess) has payoff 5 for each player; and the combination (Not confess, Not confess) gives each player payoff 1. The combination (Confess, Not confess) results in payoff 0 for Calvin and 15 for Klein, and when (Not confess, Confess) is played, Calvin gets 15 and Klein gets 0. Each player is individually rational in a game theory; in other words, one always chooses a strategy that gives the outcome he most prefers. Rationality of all players is considered as a common knowledge; thus, each player knows other players are also rational. Therefore, confession is the best strategy for each rational player whichever strategy is chosen by his partner. The strategy profile (Confess, Confess) is composed of the best strategy that each player chooses and thus is a Nash equilibrium of the game. An astonishing fact in the Prisoners' Dilemma is that from the pair's point of view, the result of the Nash equilibrium (Confess, Confess) is obviously inferior to the result of the strategy profile (Not confess, Not confess), which is (1, 1). Therefore, Pareto optimal is not the Nash equilibrium of this game.

The DCF Game:

When a node has data to transmit, it autonomously decides when to transmit in IEEE 802.11 DCF based Ad-Hoc networks. Consider an example, if there are two neighboring nodes transmitting their data frames simultaneously, both transmissions will fail. Therefore, one node must compete with its neighboring nodes so that it can transmit as many packets as possible.

		Node 2	
		Not transmit	Transmit
Node 1	Not transmit	(u_i, u_i)	(u_i, u_s)
	Transmit	(u_s, u_i)	(u_f, u_f)

Figure 3. The DCF game with two nodes.

In the DCF game, every node has two strategies: Transmit or Not transmit (i.e. wait). Figure 3 shows the strategy table of the DCF game with two nodes (node1 and node2) are competing for the channel. Let u_s denotes outcomes when the transmission is successful, u_i denotes the outcome when a node is idle, and u_f is the outcome when a transmission fails. The relation of outcome values can be given as: $u_f < u_i < u_s$. This is a two-player non-cooperative game, where players in this game would prefer higher outcomes. This game has two Nash equilibrium in pure strategy: (Transmit, Not transmit) and (Not transmit, Transmit). The DCF realizes the two equilibrium strategies in the following way. When a node have packets to transmit, it checks whether medium is occupied or idle.. If the channel is idle which has period of time equal to a distributed interframe space (DIFS), the node transmits or else, the node does not transmit and continuously monitors the channel until the medium is determined to be idle. Moreover, the DCF game has another Nash equilibrium in mixed strategy, in which each node chooses the strategy Transmit with probability $(u_s - u_i)/(u_s - u_f)$ and chooses the strategy Not transmit with probability $(u_i - u_f)/(u_s - u_f)$. The DCF realizes this mixed strategy as follows. When the channel is busy, the node continues in listening to the channel until it becomes free for a DIFS; then the node waits a random backoff interval. The random backoff interval can be stated by the mixed strategy. If we analyze the values of u_s, u_i and u_f , we find that: • u_i determines delay sensitivity of the traffic being transmitted. The lower the value of u_i, the more delay-sensitive the traffic. • u_s should be the increasing function of the length of the data frame. The longer the data packet transmitted successfully, higher is the channel utility ratio. • u_f should be the decreasing function of the length of the data frame. Different DCF game models can be constructed for traffic with different priorities and different lengths by adjusting the values of u_i, u_s, and u_f accordingly, acquiring different Nash equilibria in mixed strategy and thus different random waiting intervals so that the performance of DCF can be improved.

III. PERFORMANCE EVALUATION PARAMETERS

To analyze behavior of the network following parameters have been evaluated.

Throughput: Throughput calculates the number of packets successfully delivered in a network [8]. Unit for throughput is packets/second. Equation (3) shows how to calculate the throughput.

TH=∑Packet Delivered /∑Packet Arrival-Packet time (3)

End to End Delay: Latency or delay is defined as the time taken by the packets to reach from source to destination. The main sources of delay are categorized as: source delay, destination processing delay, network delay and propagation processing delay. Here we have calculated end to end delay which is a measure of elapsed time taken by the packets to reach from source to destination and the time taken during modulation of the signal. The difference between packet arrival and packet start time could be measured as end to end delay. Equation (4) is the formula to calculate the average end to end delay

$$\text{Delay} = \sum \text{Packet Arrival} - \text{Packet Start} \quad (4)$$

Packet Delivery Ratio (PDR): Packet delivery ratio defines the total number of packets successfully delivered to the destination. Formula to calculate PDR (Packet Delivery Ratio)is shown in equation (5).

$$\text{PDR} = (\text{Packet Delivered}/\text{Packet Sent})*100 \quad (5)$$

IV. SIMULATION METHODOLOGY

Network Simulator NS2 is used for the purpose of implementation and simulation an open source discrete event. NS2 is an open-source event-driven simulator designed specifically for research in wireless networks. To investigate network performance, researchers can simply use an easy-to use scripting language to configure a network and observe results generated by NS2 [9], [10]. The most widely used open source network simulator is NS2.

Table I and II gives the brief details of the simulation specifications used in this paper.

Table 1.Simulation Parameters Used in the Network.

Parameter	Value
Simulator	NS2
Type of Channel	Wireless Channel
Propagation Model	Two Ray Ground
MAC Protocol	802.11
Interface Queue type	Drop Tail Queue
Antenna Type	Omni Directional
Traffic Source	TCP
Routing Protocol	AODV
Max. Simulation Time	150ns
Number of nodes	10,40,80,100,150

V. SIMULATION RESULT

Performance Parameters Variations with different number of nodes					
Number of Nodes	10	40	80	100	150
Throughput	139.45	143.84	132.62	132.62	132.62
End to End Delay	72.85	72.28	73.96	73.96	73.96
Energy	170	172	166	166	166
Packet Delivery ratio	85.9	85.55	84.82	84.82	84.82

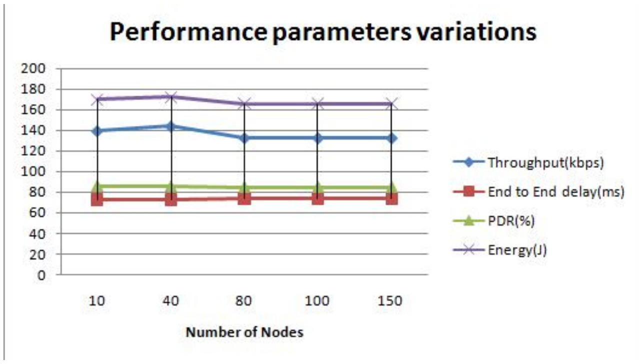

Figure 4.Graphical Analysis of performance parameters for BEB Algorithm

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