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On the Selection of Efficient Back-off with QoS Aware Routing in VANET

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Abstract

Vehicular Ad-Hoc Network (VANET) is a new communication paradigm creating a network on wheels. QOS becomes critical in VANET because of its unique characteristics, such as high mobility, frequent disconnections, rapidly changing topology, bandwidth constraints. It necessitates the need to assess the suitability of different routing protocols in various vehicular environments. In this paper, we enhanced the default back-off method of MAC 802.11p by embedding other methods, called Binary Exponential Back-off (BEB) and Modified Back-off method (MBA).The three methods are compared and the best among these in terms of QoS parameters is selected for further analysis. Further, the resulting best back-off procedure is considered to evaluate the performance of various routing protocols AODV, OLSR and ZRP. The simulations are carried out using NS-2.Nakagami propagation model with different modulation schemes, packet size variations and vehicle densities also used. The performance is investigated in terms of throughput, packet delivery ratio, routing load and end to end delay. The objective is to determine the suitable routing protocol in realistic urban scenarios with an efficient back-off mechanism.

Keywords: *VANET, MAC, Mobility, Modulation*

1. Introduction

VANET supports the short range wireless links without using centralized scheduling and can be categorized into V2V and V2I. VANET supports the various applications related to traffic conditions, safety etc. Messages generated by these applications can be delivered by assigning the priorities to each one. These high priority messages are delivered in real time environment. High priority message flooding over VANET leads to collisions, packet loss, and degradation in network performance and also affects the Quality of Experience (QoE). All these issues can be resolved by developing a reliable MAC layer protocol which can easily adopt the dynamic environment. Researchers have enhanced the existing MAC 802.11 standard, called MAC 802.11p/ MAC 802.11e to ensure the QoS constraints. [1]

IEEE 802.11p standard was developed by enhancing the existing IEEE 802.11 to provide the QoS support for the VANET based applications related to Intelligent Transportation Systems (ITS), driver's safety and assistance, speed management and location services etc. It operates the channel of 10MHz bandwidth over 5.9 GHz band [4]. The IEEE 802.11p uses physical layer as communication interface between the MAC layer and the wireless links, which are based on OFDM modulation. The IEEE 802.11p physical layer utilizes the 64 subcarriers which can be modulated using BPSK and QPSK, 16-QAM or 64-QAM modulation schemes under the constraints of channel quality. It uses error handling methods with various coding rates to produce different transmission modes with multiple data rates [14].

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VANET has enough resources battery backup, location monitoring system and high end on-board processing units. VANET can easily adopt the dynamic network topology and can operate in high mobility environment but all these features act as major challenges for the traditional MAC layer protocols and there is need to upgrade MAC protocols in such a way that they can easily adopt the VANET requirements. VANET based MAC protocols can be categorized into the various categories Contention-Based Protocols and Contention-Free protocols. In contention based, all nodes try to get channel access, in case of successful attempt by a node, channel will be allocated to that node for a fixed time interval only and this is not suitable for real time communication. Contention Free Protocols work on the basis of time and frequency division method. In a particular slot, node can communicate but it suffers from fair channel distribution among the node density. Hybrid MAC Protocols are operated on the basis of token ring that can be used to control the transmission over channel and priority of the various messages can be pre-defined for the token selection [3].

MAC layer plays an important role in wireless communication. In earlier stage of wireless communication, researchers had developed an initial standard for wireless communication ALOHA, CSMA/CA/CD. Further all these were extended to adopt the frequent change in the behavior of the wireless networks.

Researchers developed solutions for MAC layer QoS and introduced MAC 802.11 for ad-hoc networks that was further extended to support the vehicle based wireless communication, called MAC 802.11p because MAC 802.11 was not designed to work in high mobile environments. As per the survey done in this research work, we can analyze that still there is need to explore the MAC 802.11p to provide the QoS support over VANETs to fulfill the future requirements. So we decided to explore the MAC 802.11p over VANET using different ad-hoc routing protocols and to analyze the behavior of routing protocols as well as the behavior of MAC layer.

The remainder of the paper is organized as follows. Section 2 presents the related research work done. Section 3 presents the proposed scheme. Section 4 presents the simulation environment. Section 5 discusses the results of the study. Section 6 finally concludes the paper.

2. Related Work

In previous research work we did the performance analysis of various routing protocols that fall under different categories of reactive, proactive and hybrid. We used different constraints of node density variation, packet size variation and modulation scheme variation with the mobility of 10m/s and with the Nakagami propagation model, in each case. We used NS-2 network simulator for simulation purpose. All the scenarios employed the default back-off method that exists in IEEE 802.11p MAC. This paper involves embedding two back-off methods in IEEE 802.11 MAC that were not originally present. The best among the three back-off methods that is, the default and the two embedded is further selected for analyzing its performance for the protocols AODV, OLSR and ZRP in environments of variable node density, packet size and modulation schemes. The results obtained are better than those in our previous work that used default back-off algorithm. [10]

A lot of previous work has been done by researchers in evaluating existing MAC protocols and developing efficient ones. Some of the work done in this regard is explained briefly.

Lin Zhang [1] developed a solution which utilizes both CSMA and TDMA together for concurrent channel scheduling and switching. This combination can easily slice the channel control intervals and the service control intervals, thus results in efficient broadcasting. Simulation results show its performance in terms of minimum delay, collision rate and maximum throughput, as compared to IEEE MAC, SOFT MAC and VeMAC. Proposed work can be further extended to provide the support for RSU.

E. A. Feukeun [2] explored the Doppler Effect under high mobility environment and developed a solution, called Automatic Doppler shift adaptation (ADSA) method. This method uses the Doppler shift to cope with the Bit Error Rate (BER). Scope of work is not limited up to BER, they have also done the performance analysis using various parameters throughout, elapsed time, packet loss, model efficiency and data transfer rate etc.

Saira Andleeb Gillani [3] explored the issues related to the application of VANETs which can affect the MAC performance. On the basis of requirements, they categorized these applications in to safety applications, user applications and traffic management etc. Each of this application type has different impact over the performance of MAC layer. They explored the different MAC protocols contention based, contention free and their combination can be termed as Hybrid MAC protocol.

Naila Bouchema [4] proposed a scheme for traffic modeling over ITS based VANET. They enhanced the 802.11p by introducing the channel access classes warning to a foggy zone alerts, inter-distance measurement and road warning events etc. They also developed an analytical model to prove its efficiency and also did the simulation for its performance analysis in terms of packet loss, delay and vehicle density variations etc. under the QoS metric. Proposed work can be extended to adopt the high mobility models and to support the Car-to-Car following model.

Rui Zou, Zishan Liu.proposed [5] CFR MAC protocol based on TDMA for vehicular networks. It can manage the delay in transmission as well as it can also set the priorities of safety messages, can deal with hidden terminal problem also. It can assign the different slots for each node in order to control the collision in entire network. Simulation results show its performance in terms of reduction of collisions and delay. Proposed scheme can be further extended to fulfill the QoS requirements of the network for unicast and broadcast operations.

Yamen Y. Nasrallah.proposed [6] a scheme which maintains a buffer between application layer and MAC layer using mathematical model, known as Markov chain analytical method. This method is used to IEEE 802.11p protocol operations. Throughput can be calculated on the basis of successful transmission time, idle time and number of transmission failure due to collisions. They estimated the throughput and delay using different simulation scenarios by varying node density from 5 to 200 and buffer sizes. MATLAB was used for simulation purpose and results show its performance in terms of maximum throughput with minimum delay in transmission and it is suitable for real time communication where delay is the major constraint.

Kazi Atiqur Rahman.proposed [7] a cross-layer solution by modifying the sliding frame reservation ALOHA, known as Cross-Layer Extended Sliding Frame Reservation Aloha MAC Protocol (CESFRA). It can be used to resolve the issues related to contention, hidden station and the variations in radio link’s quality. It assumes that mobile station can be three hops away from the sender and in this situation there is no need for routing information. This information can be further utilized in early collision warning, avoidance system and V2I based communication. Each node uses cross layer information (CI) and reserves a lot for this, in case of collision, each node updates the CI data and also updates the slot reservation status. This CI updation information is replicated to nearest (3 hop) neighbor nodes and finally message reaches to third hop and so on. Simulation results show its capabilities to perform well with less dependency over routing data, collision avoidance and detection ratio.

Md. Habibur Rahman [8] explored the behavior of the various reactive and proactive routing protocols, MAC 802.11p using different propagation and mobility models. They used periodic broadcast (PBC) agents to propagate the safety messages over network. Simulation results show that it could not perform well and results in reduction of QoS parameters of delay, jitter and load. The proposed solution also results in extra overhead over network and it is not suitable for real time VANET applications and these issues can be explored further.

Ping Wang [9] proposed a solution for distributed channel using MAC 802.11p under message strict priority constraints. They used M/M/1 queue model to estimate the delay in broadcast at each access category. They also developed an analytical model for proposed scheme and did simulation to validate the results. As per analysis, it increases the PDR for higher priority messages but also increases the delay for low priority messages. Proposed analytical model can be used to evaluate IEEE 802.11p EDCA broadcast.

3. Proposed Scheme

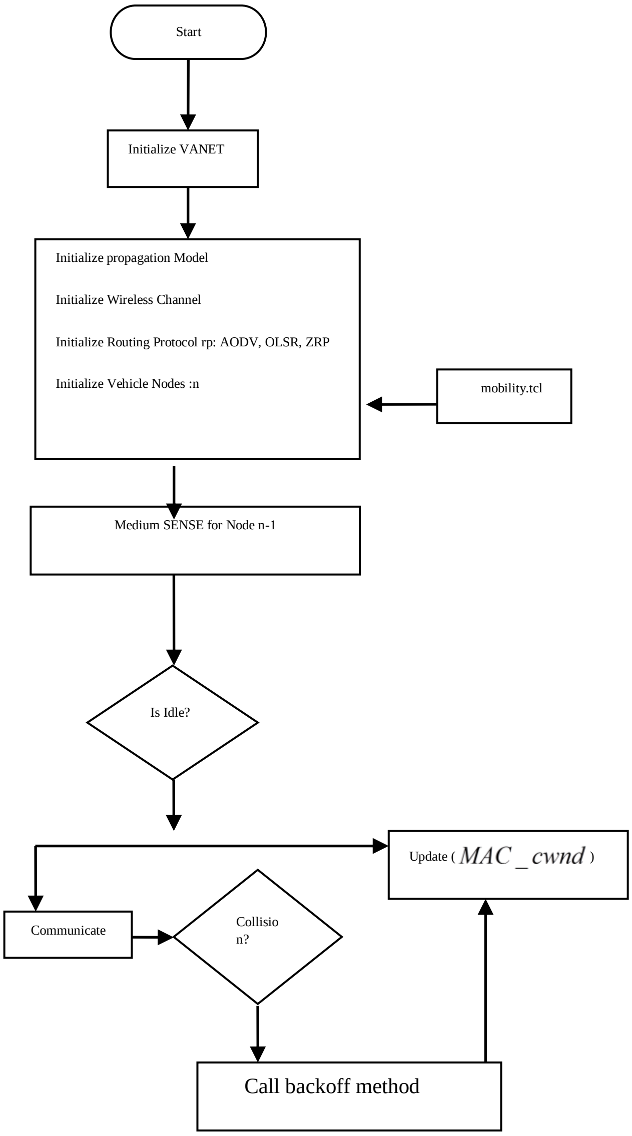


Figure 1. Flow Chart of Back Off

3.1. Default Back-off

The contention window is incremented step by step only and when it reaches to its maximum limit, its value is reset to minimum.cwnew=cw++In case of success when the channel is idle: cwnew= CWmin= 32

3.2. Binary Exponential Back-off (BEB)

The contention window (CW) doubles itself and then decreased to CWmin every time a node experiences a packet collision or success.

In case of collision unsuccessful transmission:

$$CWnew = (2*CW) * Slot\ Time$$

In case of success when the channel is idle:

$$CW= CWmin = 32$$

3.3. Modified Backoff Algorithm

The CW exponentially increased and then decreased to CWmin every time a node experiences a packet collision or success.

In case of collision unsuccessful transmission:

$$CWnew =1.5 * CW * Slot\ Time$$

In case of success when the channel is idle:

$$CW= CWmin = 32$$

4. Simulation Environment

For the purpose of analyzing and evaluating the MAC algorithm performance for various protocols, simulations are carried out using a popular discrete event simulator, NS-2 (Version 2.35). Two studies are done. The first case involves comparing the performance of default MAC back-off algorithm, Binary Exponential Back-off (BEB) and Modified Back-off Algorithm (MBA). The second case further involves three different scenarios that is: varying the number of nodes, various packet sizes, using two different modulation schemes at the physical layer. All these scenarios consider MBA as the back-off method because it proved to be the best from the results of case 1. The upcoming tables will summarize the simulation scenarios.

Table 1. Simulation Parameters for Analysis of Back-Off Methods

Network Simulator	NS-2 (Version 2.35)
Wireless Terrain	1200x1200
Simulation Time	10 min
Routing Protocol	AODV,OLSR,ZRP
Vehicle Density	30
MAC	MAC 802_11 Ext
PHY	WirelessPhyExt
Backoff Algorithms at MAC	Default, BEB, MBA
Radio Propagation Model	Nakagami
Data Traffic Source	UDP,CBR
Packet Size	1024 Bytes

Modulation Scheme	BPSK
Speed of Vehicle	10 /s

Table 2. Simulation Parameters for Comparing Protocols Using MBA

Network Simulator	NS-2 (Version 2.35)
Wireless Terrain	1200x1200
Simulation Time	10 min
Routing Protocol	AODV,OLSR,ZRP
Vehicle Density	30,60,90
MAC	MAC 802_11 Ext
PHY	WirelessPhyExt
Backoff Algorithm at MAC	MBA
Radio Propagation Model	Nakagami
Data Traffic Source	UDP,CBR
Packet Size	256, 512,1024 Bytes
Modulation Scheme	BPSK,QPSK
Speed of Vehicle	10 m/s

Scenario 1: Varying the number of vehicles as 30, 60, 90
Scenario 2: Varying Packet Size as 256, 512, 1024 Bytes
Scenario 3: Varying Modulation Scheme used as BPSK, QPSK

5. Simulation Results and Analysis

We enhanced the existing back-off method used by MAC 802.11p with the modified back-off algorithm and did the performance analysis by varying the node density, packet sizes, modulation schemes etc.

5.1 Case 1. Performance Analysis of Back-Off Methods

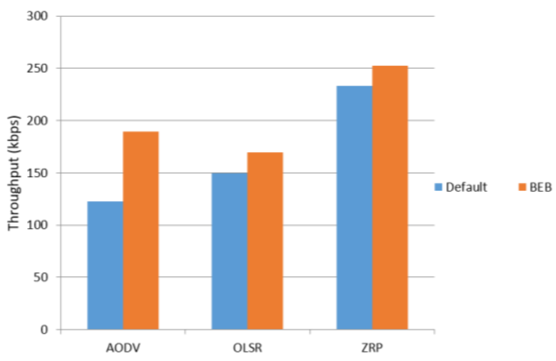


Figure 2. Throughput vs. Back-off Methods

Figure above shows the variations in throughput using different back-off methods with various routing protocols AODV, OLSR and ZRP.As per the results it can be seen that with default back-off method, throughput is very less. With BEB method, it is average and with the MBA back-off method, it is highest. Throughput of ZRP is the highest followed by AODV and OLSR has the lowest throughput.

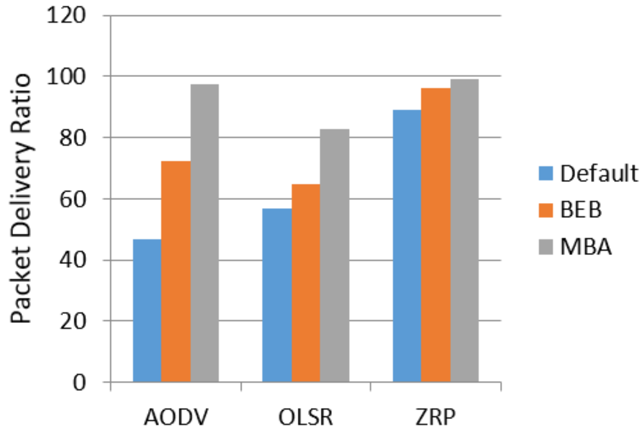


Figure 3. Packet Delivery Ratio vs. Back-off Methods

Figure above shows the variations in PDR using different back-off Methods with various routing protocols AODV, OLSR and ZRP.As per the results we can observe that with default back-off method, PDR is the lowest. With BEB method, it increases and with the MBA back-off method, it becomes the highest. PDR of ZRP is the highest followed by AODV and OLSR has the lowest PDR.

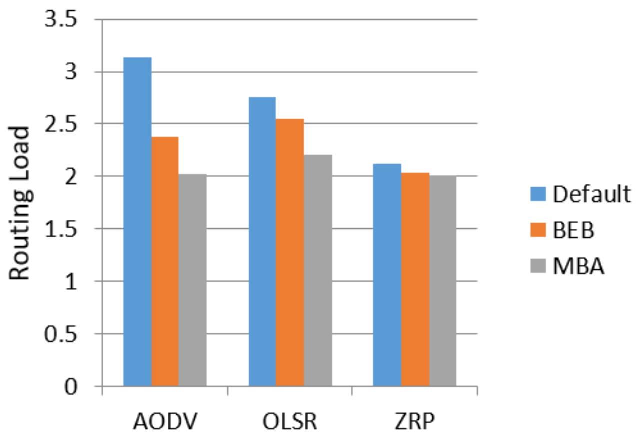


Figure 4. Routing Load vs. Back-off Methods

Figure illustrates the routing load using different back-off methods with AODV, OLSR and ZRP. As per the results we can observe that using default back-off method, routing load is very high, with BEB method, it is average and with the MBA back-off method, it is lowest. Routing load of ZRP is the lowest. OLSR has an average load and AODV has the highest routing load.

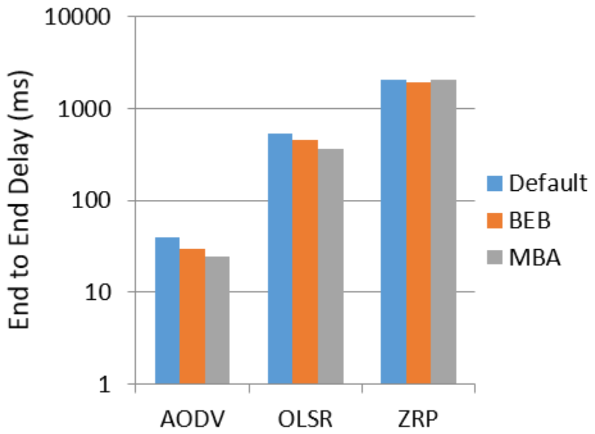


Figure 5. End-to-End Delay vs. Back-off Methods

Figure above shows the end-to-end delay using different back-off methods with various routing protocols. The results reveal that AODV has the lowest delay followed by OLSR and ZRP has the highest delay using all back-off methods.

5.2 Case 2. Performance Analysis of Routing Protocols

1) Scenario 1

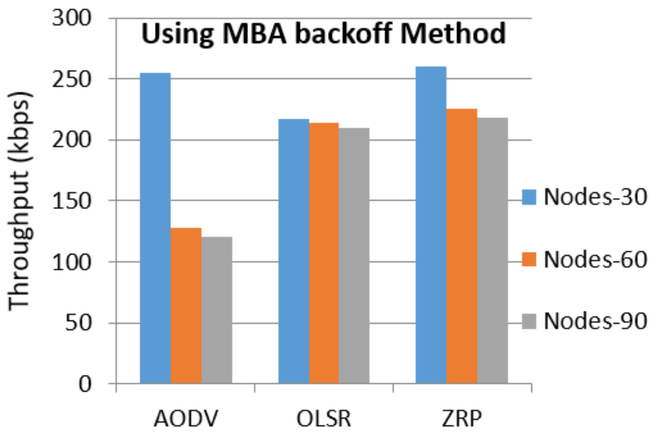


Figure 6. Throughput vs. Number of Nodes

Figure 6 shows the throughput of AODV, OLSR and ZRP with node density variations. In case of 30 nodes, AODV and ZRP both have highest throughput as compared to OLSR. In case of 60 nodes, AODV has downfall in throughput but OLSR and ZRP both have the average throughput. In case of 90 nodes, AODV has throughput lower than OLSR and ZRP.

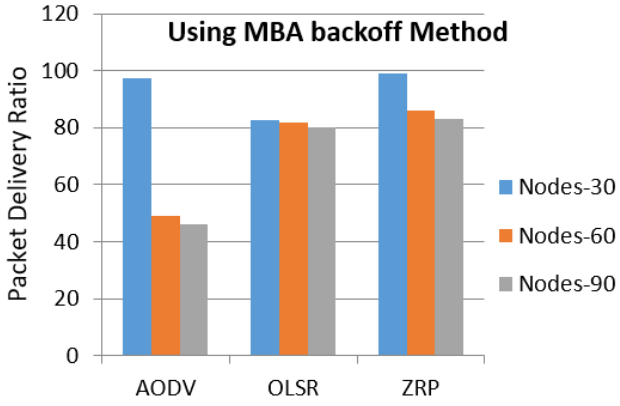


Figure 7. Packet Delivery Ratio vs. Number of Nodes

Figure above shows the PDR of AODV, OLSR and ZRP protocols with node densities of 30, 60 and 90. In case of 30 nodes, AODV and ZRP both have highest PDR as compared to OLSR. In case of 60 nodes, AODV has downfall in PDR but OLSR and ZRP both have the average PDR. In case of 90 nodes, AODV has the lowest PDR and ZRP has highest PDR as compared to AODV and OLSR.

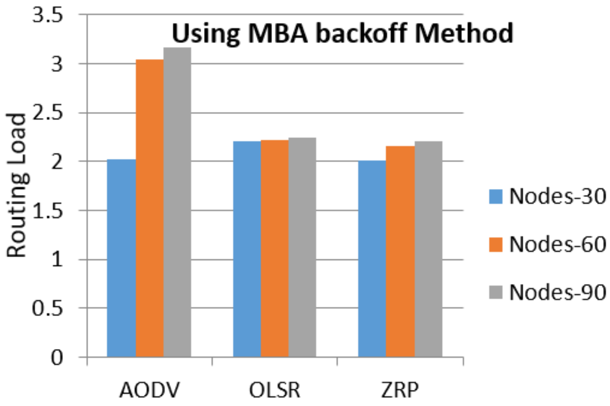


Figure 8. Routing Load vs. Number of Nodes

Figure 8 displays the routing load over AODV, OLSR and ZRP protocols. In case of 30 nodes, AODV, OLSR and ZRP all have the minimum load but in case of 60, 90 nodes, there are variations in load for AODV but it is stable for OLSR and ZRP.

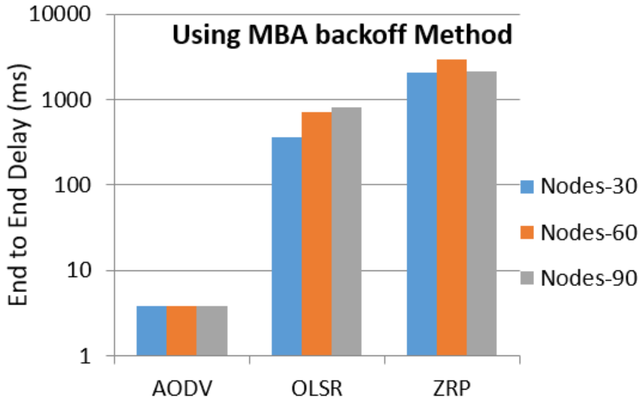


Figure 9. End to End delay vs. Number of Nodes

Figure above represents the end-to-end delay of AODV, OLSR and ZRP with different vehicle density. In case of AODV, there is no variation in delay but OLSR and ZRP both have the highest delay as per node density variation.

2) Scenario 2

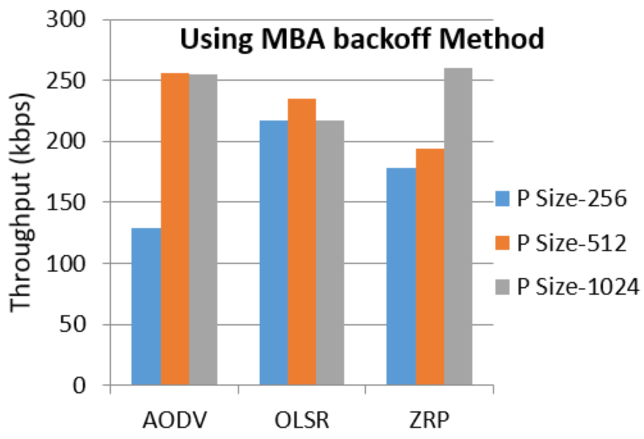


Figure 10. Throughput vs. Packet Size

Figure illustrates the throughput of different protocols with packet Size variations of 256 Bytes/512 Bytes/1024 Bytes. Results show that there are little bit variations in throughput using all packet sizes but with packet size 1024 Bytes, ZRP has the highest throughput among all.

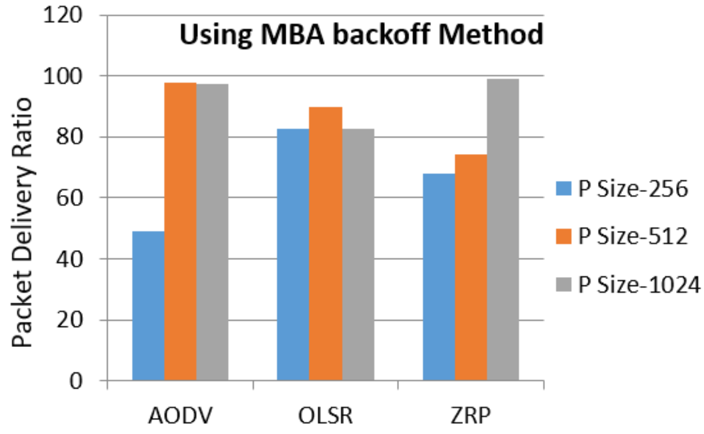
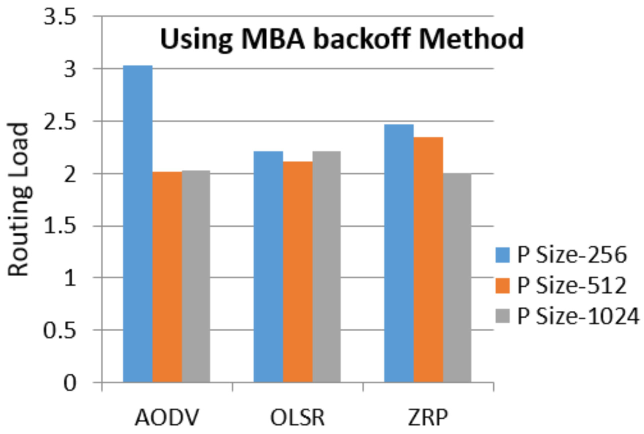


Figure 11. PDR vs. Packet Size

Figure 10 shows the PDR of different protocols with different packet sizes.Results show that there are little bit variations in PDR using all packet sizes but with packet size 1024 Bytes, ZRP has the highest PDR among all.



Fogure 12. Routing Load vs. Packet Size

Figure above shows the routing load in case of different protocols. Results show that there are little bit variations in routing load using all packet sizes but with packet size 256 Bytes, AODV experiences the highest load among all.

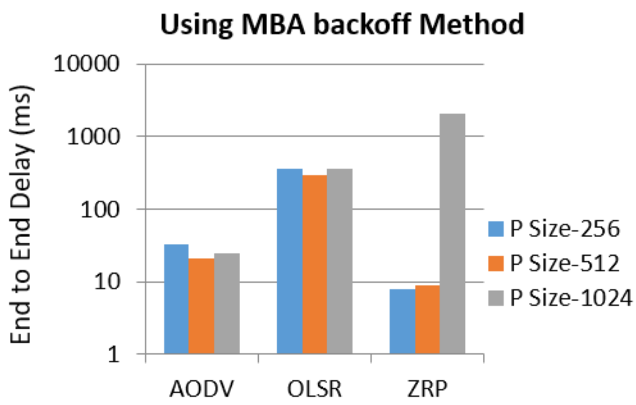


Figure 13. End to end delay vs. Packet Size

Figure above shows the variations in delay as the packet size changes. In case of packet size 256 bytes, AODV has the minimum delay and it is increasing with the increase in the packet size. In case of OLSR, there is no impact of packet size over delay, it is almost constant but delay for ZRP is minimum with packet size 256/512 bytes but it is increasing up to the peak level with packet size 1024 bytes.

3) Scenario 3

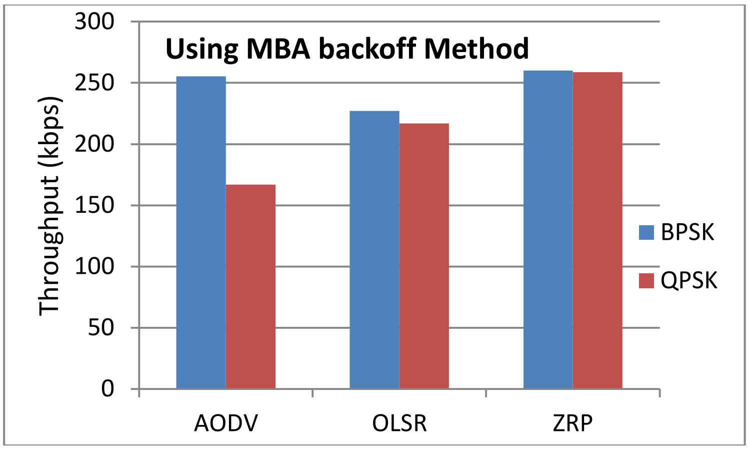


Figure 14. Throughput vs. Modulation

The figure above show the variations in throughput using BPSK and QPSK modulation schemes with AODV, OLSR and ZRP. As per the results we can observe that proposed method has better performance using BPSK modulation scheme and ZRP has the highest throughput followed by OLSR.AODV has the lowest throughput using QPSK.

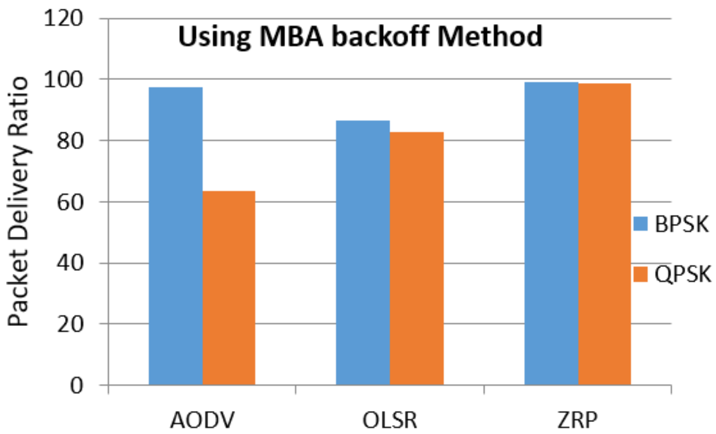


Figure 15. Packet Delivery Ratio vs. Modulation

Figure 15 shows the variations in packet delivery ratio using two different modulation schemes with various routing protocols. As per the results we can observe that proposed method has better performance using BPSK modulation scheme and ZRP has the highest PDR followed by OLSR and AODV has the lowest PDR using QPSK.

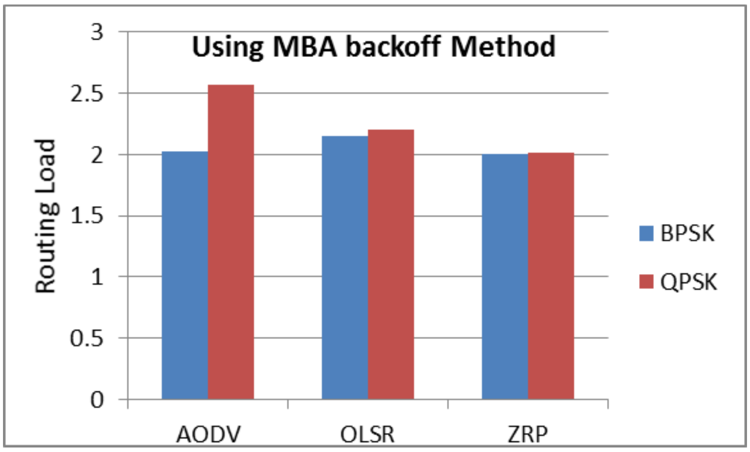


Figure 16. Routing Load vs. Modulation

As per the results shown in above figure we can observe that using QPSK, AODV has the highest routing load and there is average routing load for OLSR and ZRP has minimum routing load using both BPSK and QPSK schemes.

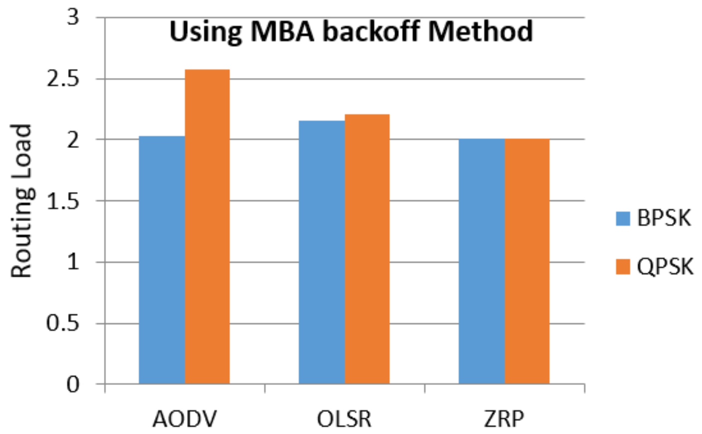


Figure 17. End-to-End Delay vs. Modulation

Figure above shows the variations in end-to-end delay using BPSK and QPSK modulation schemes with the routing protocols AODV, OLSR and ZRP. As per the results it is observed that both modulation schemes have average impact over delay but AODV has minimum delay using BPSK and QPSK followed by OLSR, which has idle value in each scheme and for ZRP, BPSK scheme has slightly more delay as compared to QPSK scheme.

6. Conclusion

In this paper, we enhanced the existing MAC 802.11p back-off method and introduced a modified back-off method and binary exponential method. After that we analyzed the behavior of routing protocols (those fall in reactive, proactive and hybrid category), using different modulation schemes, different node density and with different packet sizes. Results show that default back-off method being used by MAC 802.11p did not perform well as compared to BEB and MBA methods in terms performance parameters of throughput, PDR, routing load and delay. Packet Size variations have small effect over protocol performance but in case of density variations, with 30 nodes, AODV and ZRP performed well as compared to OLSR. With 60, 90 nodes, AODV did not perform well and has lowest throughput with 90 nodes. ZRP's throughput slightly falls down with 60 and 90 nodes. OLSR has an average and similar performance with node variation. PDR has same variations like throughput. In case of routing load, AODV has highest load as compared to OLSR and ZRP, it also has minimum load. However in case of delay, ZRP has the highest delay and AODV has minimum delay and OLSR has average delay. In modulation schemes, BPSK shows better results than QPSK. So finally, we can conclude that performance of routing protocols also depends upon the selection of MAC layer protocols as well as the back-off method used by that MAC protocol. Other factors such as packet size variations have almost negligible effect over performance parameters but node density can degrade the performance of protocols.

Acknowledgements

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