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Beaconless Packet Forwarding Approach for Vehicular Urban Environment

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Abstract

Existing wireless technologies provide communication and information services to all fields of life. The one of the emerging and popular field is vehicular ad hoc networks, with its unique characteristics and highly mobile environment. Different types of routing protocols have been proposed to address the routing issues in network and one of the most efficient types is geographical routing. In this type of protocols, the beacon messages are using to update the node locations and positions. However, these protoocls have been suffered with high channel congestion issue in the network. To this end, we propose a beaconless packet forwarding strategy based on modified handshake messages mechanism. The protocol uses some realistic metrics to select the next forwarder node such as forward progresss and link quality. The protocol performance is evaluated with existing beacon and beaconless geographical routing protocols. The simulation results showed the better performance of the proposed protocol in terms of packet delay and data delivery ratio in realistic wireless channel conditions.

Keywords: *packet forwarding, routing, mobility, handshake, beaconless*

1. Introduction

Vehicular ad hoc networks (VANETs) are expected to support the large spectrum of commercial and safety applications range from safety to comfort for travelers. The main objective of vehicular communication is providing real-time road information of dangerous situations in advance to drivers such as accident detection, weather information. However, due to high vehicle mobility, the vehicle nodes are frequently changing their positions and its impact in the shape of link disconnection, network overhead, high transmission delay and low data packet delivery ratio issues [1]. In order to incorporated these issues, geographical routing protocols are more suitable solutions to ensure forward progress toward the destination by flooding messages with node position information such as greedy perimeter stateless routing (GPSR) [2], greedy perimeter coordinator routing (GPCR) [3], vehicle assisted data delivery (VADD) [4]. In these protoocls, the beacon messages are periodically broadcasted to inform one-hop neighbors location and presence by global positioning systems (GPSs). The result of regular beaconing messages, the wireless channel is more congested and packet collisions with communication overhead occur in the network. Although, the recovery strategies have been proposed to solve these issues, but these approaches are based on planner graph traversals, which are not suitable for high-velocity and urban environment. Without an effective multi-hop routing, these features are limited and have several complexities. Therefore, an effective routing protocol requires for in-time data delivery in vehicular netwokrs.

To solve the frequent beaconing challenges in the network, various beaconless forwarding approaches have been proposed such as CBF [5], BRAVE [6], CoopGeo [7]. These beaconless approaches contain own and destination position in the data packet header and broadcast it to next one-hop neighbors. Afterwards, these approaches determine different routing metrics to find optimal forwarder in the network and deal with unique vehicular environment. The important point in beaconless protoocls is to select the appropriate routing metric to deal with vehciualr envirnemnt in their handshacke mechanism. In this paper, we proposed a beaconless packet forwarding (BPF) protocol, which is based on score function and self-election among vehicle nodes. The beaconless self-election forwarding is made in a way to

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maximize the network overhead and satisfying the quality of services in terms of packet delivery ratio and end-to-end delay in the network. The proposed routing protocol uses forward progress, link quality metrics in order to improve the data packet delivery in the network. In addition, the proposed protocol is suitable for different applications such as for file sharing, chatting, and other infotainment applications.

The rest of this paper is arranged as follows: Sec. 2 discusses the related literature review. Section 3 provides an overview and brief detail about proposed protocol. In section 4, the performance evaluation of the proposed protocol is elaborated, where we highlight the feasibility of proposed protocol by considering a realistic city environment. Finally, Section 5 contains out with concluding remarks.

2. Related Work

For Neighbor discovery, geographical routing protocols send periodic beacon or hello messages to update its own and neighbor information in the network. Through these beacon periodic messages, the vehicle nodes update and maintain its neighbors list. If the neighbor list is outdated the vehicle node faces problem to select optimal node as a next candidate or may select a node, which is near with radio range and will move out from radio range. To address these issues, beaconless approaches have been proposed. In this section, we discuss existing beaconless routing approaches for vehicular ad hoc networks.

Mohit et al. [8] was proposed guaranteed delivery beaconless forwarding (GDBF) scheme, where next candidate node selects through RTS/CTS (Request-to-send/Clear-to-send) control frames at MAC layer and waiting time function to select best next hop. GDBF uses greedy and recovery modes, where the closest node with destination selects and respond first to the source node. In the case of recovery mode, if the source node has shortest route toward the destination compared with direct neighbor node, source node selects contention winner node, which is near with the source node. The source node establishes a link and other nodes exit from contention phase, which are overheard CTS frames. The protocol performance is better in terms of packet delivery ratio compared with existing beaconless approaches. Most of the existing beaconless approaches retransmited the entire data and lead to duplicate packets and redundant retransmission issues in network.

Another positive step is taken by the authors in [5, 9], by proposing a contention based forwarding (CBF) scheme to select next hop through distributed contention process with real time location of present neighbors. Protocol does not maintain routes, because protocol is working without proactive transmission with beaconless manner and greedly route the data packet toward the destination. In CBF scheme, forwarding node sends control frames to neighbor nodes and neighbor nodes take decision for forwarding the data packet. Then the next forwarder relay node selected by distributed timer and self-election in the contention period and decide about relay node, which has shortest reply time and more geographical progress toward the destination. The selected node reply CTS frame to the source node and other candidates nodes cancel and exit from contention process when they hear CTS frames. The forwarding node sends complete message, which is representing that its neighbors shall forward the message or not. The CBF considers movement, direction and power signal strength and neglected instability and unreliability issues in packet forwarding and may lead to sub-optimal issues in wireless channels.

The new direction toward routing protocol is taken by [10], where authors proposed road based routing with the help of navigation system to establish a route between source and destination. The author used a sequence of intersections with high network connectivity for forwarding the packets toward destination. Furthermore, the author eliminates the beacon packet and enhances the receiver based self-election to solve the network overhead issues. Moreever, for beaconless forwarding author used optimization between intersections for packet forwarding and does not consider packet forwarding decision at intersection. In addition, they concentrated on three routing metrics for packet forwarding: distance, optimal transmission range and power signal with route maintenance.

Denis et al., [11] proposed a beaconless opportunistic routing (LinGo) protocol based on link quality and beaconless approach for mobile multimedia internet of things. The protocol works with multiple routing metrics such as link quality, geographical location and energy. Author proposed a cross layer approach include MAC and forwarding functionalities and assumed that the CSMA/CA mechanism relies on beaconless method with two operational modes: contention and back bone forwarding. For data forwarding, protocol uses DFD function including link quality, geographical information and remaining energy. The energy is not an issue in vehicular networks and LinGo is designed for mobile applications.

Pedro et al., [6] was proposed a beaconless routing protocol for vehicular environment (BRAVE) based on spatial awareness and beaconless geographic forwarding. The spatial awareness refers to allow intermediate nodes to change their initial plan based on view of street map and local information. The trajectory of the packet computes at every forwarding node and next junction selection is based on Dijkstra shortest path algorithm. Protocol uses four types of messages: date, response, select and acknowledgment. In addition, the protocol adopts store and forward strategy to recover the route. The protocol performance is better in terms of packet delivery ratio in high traffic density. On the other hand, in the less traffic density situation protocol has high end-to-end delay and caused of network overhead.

The comprehensive literature illustrated that receiver self-election is significant for multi-hop routing especially for the city environment. To this end, we propose an opportunistic beaconless packet forwarding strategy (BPF) for vehicular ad hoc networks.

3. Beaconless Packet Forwarding Strategy

For testing the proposed routing protocol some assumptions are taking into account, where all vehicle nodes are equipped with Global Positioning systems (GPSs) to obtain their geographical position and speed information. Vehicles are installed with pre-loaded digital map for detailed road topologies such as own position, road segments and coordinates of the junctions. For simplicity, the dead end road are not considered during the simulations.

The one of the main purpose of proposed protocols is to forward the packet between vehicle nodes without beacon messages in the network. Figure 1, shows the packet forwarding process of BPF, where preferable neighbors node are A, B, C and E. Source node broadcast RTS frame to preferable candidate nodes within its radio range and carries source and destination node location and duration of communication sessions. The candidate nodes calculate the score function with two metrics: forward progress and link quality. According to first metric forward progress, the node C is near with destination compare to node B but it has low link quality compare to node B. Finally node B has short reply time in terms of forward progress and high link quality and select as a relay node and send back CTS frame to source node. Source node sends the data packet to node B and node B again start the same process with node F and G and calculate score function.

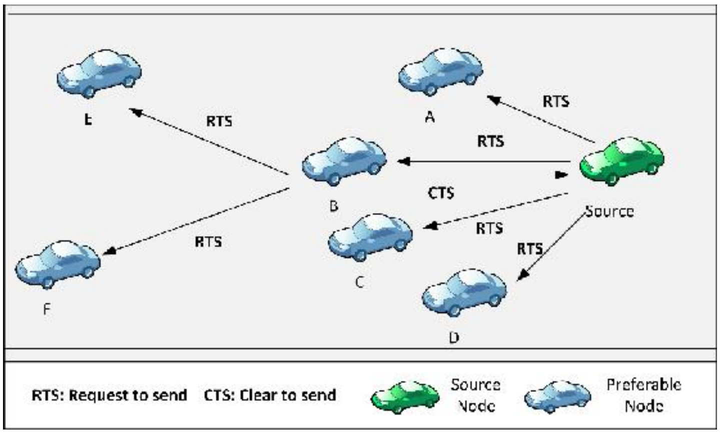


Figure 1. The illustration of proposed protocol, where node B select as a forwarder node after calculate score function with forward progress and lquality

Proposed beaconless packet forwarding protocol is a source based routing protocol capable of finding the robust route in the urban environment. Protocol is based on receiver self-election to suppress the effect of frequent hello or beacon messages and next hop self-election is based on modified RTS/CTS frames of IEEE 802.11 protocol. The IEEE. 802.11, DFC (distributed coordination function) [12] is designed to implement the CSMA/CA (carrier sense multiple access/collision avoidance) protocol with RTS/CTS (request-to-send/clear-to-send) sessions. Whenever, the vehicle source node want to send the data, it senses the wireless channel for a specific time called short inter-frame space (DIFS). If the channel is suitable then it select random backoff timer in the range of 0, CW (contention window). When the time is expired the source vehicle node sends the request-to-send frame to projected receiver and receiver clear-to-send frame from its neighbors. Neighbors and receiver node update network allocation vector (NAV) for a time interval and all neighbors defer their transmission until session completed. When the source vehicle node receives CTS frame it forward data to the receiver node after ACK frame. In the case of transmission failure source nodes retransmit until the retry limit is reached.

The algorithm 1 demonstrates the beaconless routing protocol function in detail. Then, candidate nodes compute their reply timer and it depends on link quality and forward progress (line 3, 4). After determining the reply timer (ti) candidate node set the value according to ti (line 6 to 7). If reply timer is finished then a control CTS frame transmitted from carrier node and indicate about its best relay node state. Meanwhile, other neighbor nodes cancel their timer when they hear CTS frame. Then source node takes decision to forward data packet to elected node (line 14 to 15). If reply timer ti has a negative value the packet will be discarded from candidate node side. Algorithm 1 Beaconless packet forwarding at node n_i.

Table 1. List of main symbols used in BPF algorithm with description

Symbol	Description
t	Time to transmit data frame
RTS	Receive-to-send
CTS	Clear-to-send
ACK	Acknowledgment
SIFS	Short inter frame space
Li	Location of node ni
Ld	Location of destination node
Lc	Location of packet career node
C	Address of packet carrier node
ti	reply timer for node ni

t_{DATA}, t_{RTS}, t_{CTS}, t_{ACK}, t_{SIFS}, L_i

1: **if** RTS frame (L_i, L_d, l_c, ʃ, t_{DATA}) packet is received **then**
2: call the waiting function with
3: forward progress
4: link quality
5: calculate reply timer ti
6: Set timer to [ti]
7: defer transmission, for [$t_{DATA} + t_{CTS} + t_{ACK} + 3 \times t_{SIFS}$]
8: **else**
9: **if**
10: CTS frame is received from n_k before the timeout **then**
11: cancel the timer
12: defer transmission, if any, for [t_{DATA}, $t_{ACK} + 2 \times t_{SIFS}$]
13: **else**
14: **if** ti is runs off then
15: broadcast CTS (n_i, c, t_{DATA})
16: **end if**
17: **end if**

3.1 Protocol Metrics

The reply timer is based on multi-metric score function to select an optimal forwarder node. For qualify the forwarder node, we set some parameters including link quality, forward to progress of RTS frame.

Forward progress metric is used for geographical advancement of forwarder node towards the destination node with respect to the source node. The forwarder node FNi (subset of forwarder nodes consider as a relay node) and select with high progress toward destination and compute ϵ [0, 1] according to Eq (1).

$$Forward\ Progress = \begin{cases} \frac{2R-P(FN_i,S)}{2R} & if\ D(FN_i,D)>R \\ 0 & if\ D(FN_i,D)>R \end{cases} \quad (1)$$

We denote D(FNi D) ϵ [0, R] as the Euclidian between FNi (subset of forwarder nodes consider as relay node) and D (destination node), R as radio range and 2R denote to maximum progress. The sum of two segment (P1 (FNi) + P2 (FNi)) composes the geographical advancement P(FNi,S) ϵ [0, 2R] of a given FNi toward the destination node D. We define P1(FNi) ϵ [0, R] as the projection of the distance travelled from S to any FNi, On the other hand, the projection of line FNi–FNi on line S-D defines P2(RNi) ϵ [0, R].

Through link quality metric, we analyze reliable transmission such as high packet delivery in the network. Existing beaconless routing protocols work on circle transmission range and assume that nodes are within transmission range. However, the vehicular environment is dynamic and wireless links are asymmetric [13]. In this context, we consider link quality between two vehicle nodes as part of dynamic forwarding delay (DFD)[29]. DFD is a timer between vehciles for forwarding decisions in beaconless routing protocol, by using the following Eq. (2) in the interval (0,1).

$$Link\ Quality = \begin{cases} 1 & if\ LQA_j > LQA_{Optimal} \\ - \quad \frac{LQA_{Max}-LQA_j}{LQA_{Max}} & if\ LQA_{Worst} < LQA_j < LQA_{Optimal} \\ 0 & if\ LQA_j < LQA_{Worst} \end{cases} \quad (2)$$

Links are classified according to values of packet reception ratio (PRR) into three regions of connectivity with different percentage ranges such as connected (PRR>90%) transitional (PRR is between 10 to 90%) and disconnected (PRR<10%). In this context, we present the bounds of disconnected and connected regions by mean of two LQA thresholds: LQA-Optimal and LQA-Worst .Based on these thresholds, we can classifying a link ej as disconnected, when receiver vehicle node RVi received a packet with LQAj and lower than LQAWorst; or as connected when LQAj is higher than LQAOptimal; or as transitional for LQAj ranging between LQAoptimal and LQAWorst.

According to Eq. (1), the FNi (subset of forwarder nodes consider as relay node) with connected link to S (source node) has higher probability for forward the packet faster (Link quality =0), consider a high reliability in network. For disconnected links, LinkQuality returns 1 and consider as a low quality for forward the packet. Transitional link generates ranging from 0 to 1 as an unreliable LinkQuality.

Now we describe the score function trade-off between forward progress and link quality, which is given by:

$$g\ (FPi,\ LQAi) = A \times FP_i^{\alpha_1} \times LQA_i^{\alpha_2} + Bmax \quad (3)$$

where α_1 and α_2 are weights for FP and LQA routing metrics and variable Bmax denotes the maximum time delay after receiving RTS frame. A id defined as follows:

$$A = \frac{-B_{max}}{FP_{max}^{\alpha_1} \times LQA_{max}^{\alpha_2}} \quad (4)$$

To compute the score function in Eq.3, essential to find the maximum values of FPi, LQAi , where the FP value depend on the simulation setting such as area and communication range. On the other hand the maximum value of link quality LQ set to 0 for higher probability to forward the packet faster.

After all routing metrics has been defined, there is a need to combine these criteria into one function. We used an aggregation function for make score function into one single ranking measure. The basic purpose of score function is to determine a single value with the help of different parameters in protocol. The final decision is based on final value of score function.

4. Simulation Results

In this section simulation setup and related parameters are discused in detail and give the outcomes of the simulations for evaluating the proposed protocol performance.

The performance of BPF has been analyzed using the most popular NS-2.34 network simulator with model mobility generator for vehicular networks (MOVE). The mobility generator is used for realistic vehicular movement generation in the urban environment. MOVE is based on open simulation of urban mobility (SUMO) simulator. It is an open source micro-traffic simulator [14]. MOVE has two modules for built a vehicular environment called vehicle movement editor and road map editor. The road map editor gives essential features of roads such as number of lanes, roads, and junctions, traffic lights setup, etc. Vehicle editor used to set the speed of vehicles, number of vehicles and probability of right or left turning. To set all required parameters in two editors the trace file generated by MOVE and directly used in NS-2. Then map is input in MOVE to incorporates further information in the map. Afterwards, the trace files and other configuration have been generated to analyze BPF protocol. The simulation parameters are summarized in Table 2 based on realistic measurement between vehicles nearby vehicles [15]. To avoid effects of transient behavior in results, we set the settling time 30s in the simulation. For accurate simulation results, the average of 25 simulations runs for each metric.

Table 2: Simulation Parameter

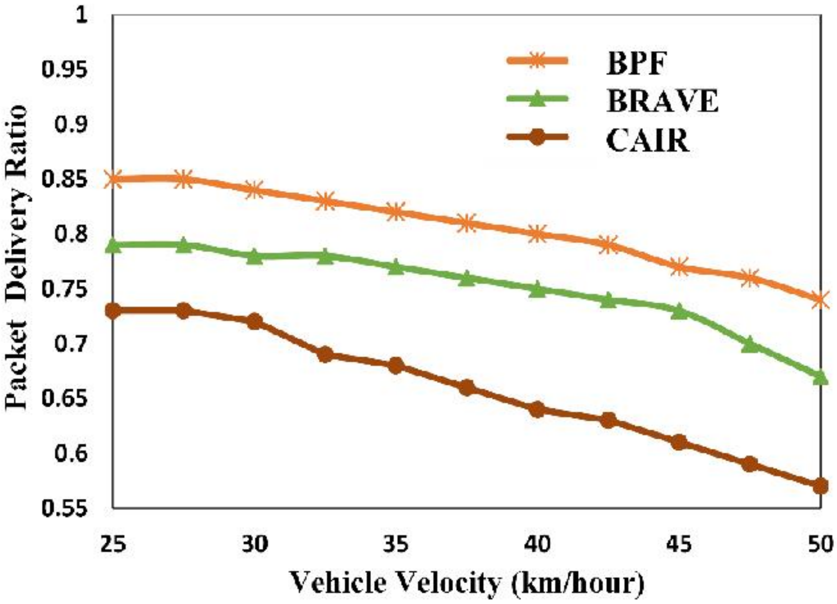
Parameters	Value
Simulation Area	2500m × 1500m
Simulation Time	350 s
Number of Vehicles nodes	100 to 250
Vehicle velocity	25-50 km/h
Transmission range	250 m
Mac Protocol	IEEE 802.11p DCF
Data Packet size	512 bytes
Channel Bandwidth	3 Mbps
Maximum packet generation rate	0.5-5 packets /second

To evaluate the performance of BPF protocol, we compared it with state of the art one beaconless geographical routing protocol BRAVE [6] and one beacon based routing protocol CAIR [16]. We check packet delivery ratio, end-to-end delay of relay nodes, which are participating in to forward the packet from source to the destination node. To test these metrics, we conducted various different parameters such as with obstacles environment and without obstacles, with different vehicle velocities in the urban environment.

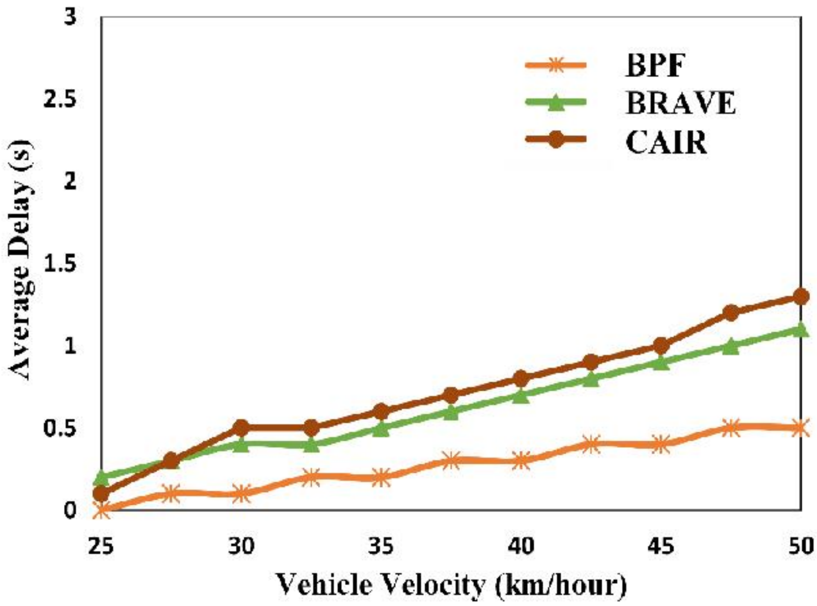
For first experiment the total number of vehicles nodes are 250, where 8 of them are set as a source nodes in the network. To determine the impact of vehicle velocity, we set vehicle velocity between 25 to 50 km/h in an urban environment and beacon interval set to 0.5 ms for BRAVE and CAIR protocols. Figure 2 (a) presents the packet delivery ratio of BPF protocol with BRAVE and CAIR protocols in terms of different vehicle velocity. Through these experiments, we determine that if the vehicles speed is increased the successful packet delivery ratio is decreased. But the BPF protocol performs better with high speed because of RTS frames instead of beacon messages for update the neighbor information in the network. The beacon messages take more bandwidth compared to RTS frames and lead to network overhead. Beaconless approach consumes less bandwidth and the percentage of link utilization will enhance the packet transfer rate. Multi-metric based election is favorable to make an optimal route between source and destination. Whenever, we increase the speed of vehicles and set at 50 km/h the BRAVE, and CAIR drop packets up to 70.3%. Then, we calculate the mean of these three protocol through Analysis of Variance in excel and results shows the BPF has lower variance than other two protocols. BPF has more reliable in urban environments, where we increase PDR and single factor validation method reflects the credibility of proposed protocol.

On the other hand CAIR, protocol uses beacon messages to update the possible information about its neighbor nodes. These periodic beacon messages are staleness because of high mobility of vehicles nodes in the network. The trend of CAIR protocol drops 50 to 55 % packets when the vehicles speed set as 50 km/h in network. BPF, BRAVE protocols suffered less in packet dropping compared to CAIR. The proposed protocol shows better results and one of the main reason for this efficiency is beaconless approach in the protocol compared with other beacon oriented protocol.

The Figure 2 (b) shows the average packet delay in terms of vehicle velocity. The proposed protocol has the smallest delay compared to other two protocols.



(a)



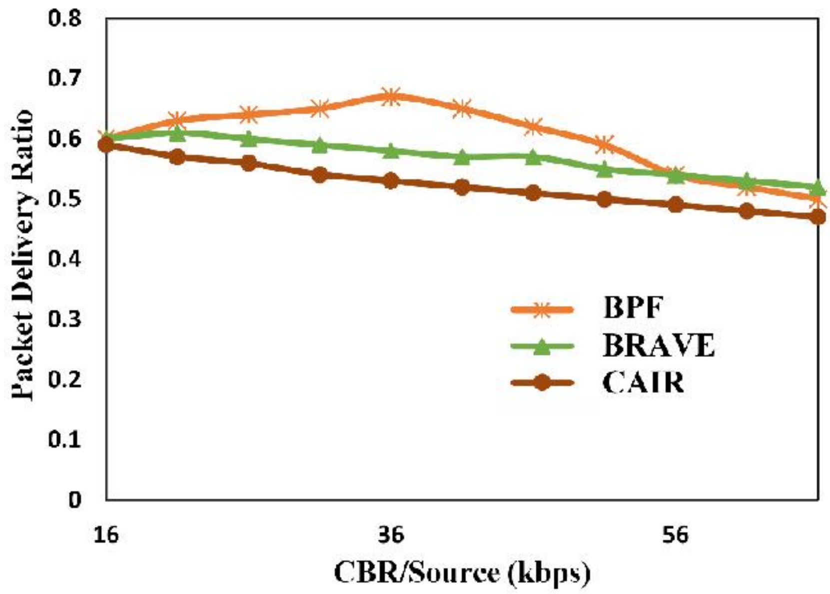
(b)

Figure 2. Effect of varying vehicle velocity of BPF protocol compared with BRAVE and CAIR routing protocols, (a) packet delivery ratio (b) average delay

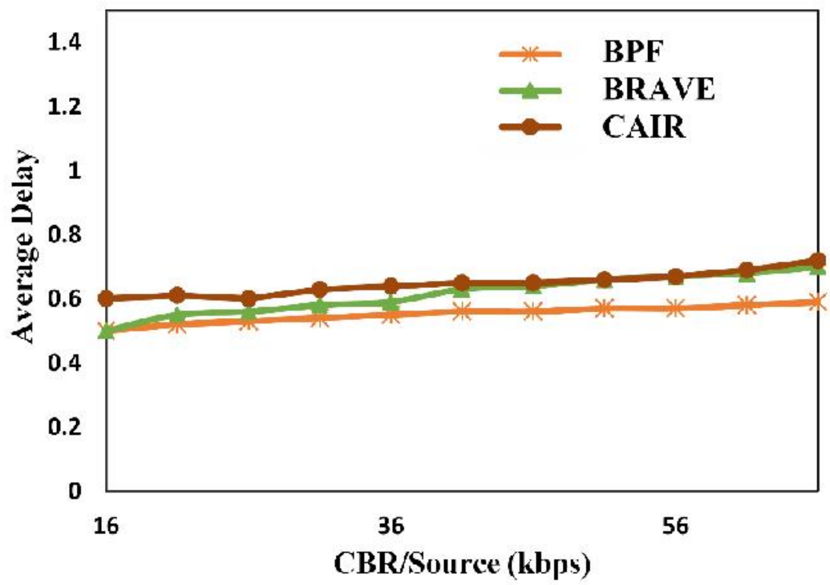
The modified RTS/CTS frames are used in proposed protocol to determine an optimal route in network and this method is more reliable and effective to reduce the traffic load on MAC layer and leads to improve delay in network. Through modified handshake mechanism the less transmission and exponential backoff happen in MAC layer. The CAIR protocol average packet delay increases drastically with high velocity because of the predictive nature of the protocol at intersection and beacon message broadcasting. In contrast, the BRAVE protocol also suffered in average packet delay compared to BPF protocol. This can be attributed to the fact of beacon messages to update neighbor information and relay node contend the access channel based on improve greedy forwarding where one transmission advance (EOA) metric is used and relay node selects itself as a next packet forwarder.

The second scenario of experiment is based in the presence of radio obstacles and without obstacles in an urban environment to evaluate the proposed BPF protocol performance. We set the vehicles speed at 30 km/h and set traffic density at 150 vehicles where 8 of them are source nodes in the network. We ran the simulation and set different packet generation rate and set building obstacles through mobility generation model. In some streets, we set scenario without obstacles to interface with the radio signal and set street numbers in road segment file. We captured the obstacles free street vehicles packet delivery ratio and with obstacles street ratio and delay and compared with each other. We also modified attenuation value between trimester and receiver.

Figure 3 shows that proposed BPF routing protocol better performance and increase up to 8% compared with the state of the art protocols. The one of the main reason behind these results is beaconless approach and link quality instead of transmission range to select next relay node in the network. On the other hand in Figure 3 (b) the average packet delay plotted with respect to packet generation rate of protocols. Whenever arrival time of inter-packet is large, the average packet delay increases and different with each protocol. The BPF protocol average delay is about 520 ms and fluctuates between 520 to 700 ms at 72 kbps. When vehicles are in streets without obstacles the average delay time is short and in the presence of obstacles it will high. The performance of BPF is better than other protocols.



(a)



(b)

Figure 3. Effect of radio obstacle on the performance of BPF protocol compared with BRAVE and CAIR routing protocols, (a) packet delivery ratio (b) average delay

5. Conclusion

In this paper, we proposed opportunistic beaconless packet forwarding strategy for vehicular ad hoc networks to optimally route the data packets toward destination. The proposed forwarding protocol is based on distributed self-election through modified 802.11 RTS/CTS frames with link quality, forward progress metrics. The protocol designed for an urban environment and considering the real traffic and realistic wireless channels. The experimental results show that proposed protocol performance is better in terms of packet delivery ratio, end-to-end delay, when we compared with existing BRAVE and CAIR protocols.

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