Beacon Adaptive Update for Interference Reduction in Mobile Ad hoc Networks

Abstract

Mobile Ad hoc Networks are Self-Configuring Multi-Step Networks consisting of Wireless Nodes without infrastructure or a default topology in which nodes can work together to communicate and exchange, in which nodes will be able to connect and exchange data with each other. Nodes in mobile networks have limitations in communication resources such as bandwidth, buffer space, and battery power. The formed topology will rarely remain static because the mobile nodes are mobile. Therefore, each node must broadcast its updated position to neighbor nodes. These updates will reduce power consumption and the risk of collisions at the Media Access Control layer, and increase wireless bandwidth. There is a need to adapt the Beacon transmission to the node's movement and traffic conditions instead of applying the Beacon static updating policies concerning the costs associated with Beacon transmission. Therefore, in this research, a method of adjusting the bacon sending ratio that is compatible with the speed of movement of the nodes has been used to reduce the interference. On the other hand, the link life factor is considered to increase the reliability to deal with the dynamics of the Mobile Ad hoc Networks environment. The simulation results show that the proposed method reduces the collision ratio (67 and 57%), normalized overhead (32 and 43%), and the number of packages (49 and 44%) compared to the GBR-CNR-LU and GBR-CNR-LN protocols, energy consumption (3 and 4%). It also increases End-to-End Latency (43 and 32%), Throughput (8 and 15%).

Keywords: *Mobile Ad hoc Networks, Position-based Routing, Lifetime, Beacon message, the Movement speed of nodes*

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Introduction

Mobile Ad hoc Networks are Self-Configuring Multi-Step Networks consisting of Wireless Nodes without infrastructure or a default topology in which nodes can work together to communicate and exchange, in which nodes will be able to connect and exchange data with each other.

These networks will generally be created in places where it is not possible or difficult to deploy infrastructure and nodes will be able to routine and provide services and Application Management by collaborating and organizing themselves. Mobile networks are connected through wireless connection devices with common and limited media and form a network if necessary. All wireless nodes can act as a router or host to send data. Nodes in mobile networks have limitations in communication resources such as bandwidth, buffer space, and battery power. These networks will be used in a wide range of applications, including battlefields, natural disasters, training, Multi-user applications, and Peer-to-Peer applications (P2P). The node's mobility makes routing difficult when transmitting data including the frequent interruption of communication links and topological changes, as a result of which the routes will be permanently lost. This will increase the packet loss ratio and latency to search and find a new route. Nodes may transmit their packets simultaneously to increase efficiency in mobile networks, resulting in synchronization, interference, collision, and packet loss. In these networks, collision and interference can have a significant and serious effect on network performance due to the dynamic nature of mobile networks and simultaneous transmission operations, interference, and collision in mobile networks because a receiver node is placed in the vicinity of the other sensors carrier. High overhead and communication interference will be problems because, in wireless communication, neighboring nodes exchange competitively messages. In addition to the above-mentioned, packet loss and buffer overflow can lead to excessive end-to-end delays in the network and reduced throughput and loss of connections between nodes, if there is interference in any route and any node, packet loss, and buffer overflow will occur.

Sun et al (2010) have proposed an AODV-Based routing scheme called LSB_AODV. The purpose of this technic is to select the most stable route based on topological changes. Hu et al (2010) have presented a routing protocol called ST-EN based on the Ad hoc On-Demand Distance Vector (AODV) routing protocol. It uses the LET route expiration and an asynchronous method to detect changes in neighboring nodes. The route expiration parameter calculates the link validity between nodes based on the speed, direction, and distance between nodes in the transmission radius, and the asynchronous process will perform its operations independently without the need to synchronize with neighbor nodes.

Mohammadzadeh et al. (2011) have proposed a protocol called S-ODMRP based on minimum latency and multicast mechanism. In this method, a weighted function is used to select the most stable route from origin to destination according to the route level energy and delay. De Rango et al. (2012) presented a protocol called Interference Aware-AODV by path selection interference to improve wireless system performance. In this technic, two criteria are presented separately, that the former is based on the global interferences from the neighboring nodes.

Bose et al. (2001) have proposed a routing protocol called Great Barrier Reef (GBR), taking into account the length of the path and the bonding's lifespan to achieve high route stability. In this method, the initial route is created based on the Greedy Transmission Mechanism and the local alternative route is presented based on the link's longevity. The method proposed by Li et al. (2003) is based on a probabilistic pattern for modeling neighbor nodes. Wang et al. (2011) proposed a new protocol called LEARN, which is an energy efficiency awareness protocol, to further develop and modify the GBR. The present structure assumes that the energy required to transfer a packet from a node u to a neighboring node v is equal to E (|| UV ||). Therefore, LEARN protocol selects the next step in the route discovery process according to the Transition Radius criterion r_0, which is a distance d with a maximum value of d⁄(E (d)).

The GBR-CNR-LU is a modified GBR-CNR protocol used to optimize the performance of nodes that are less commonly used in communication. It was proposed by Abdulmutallab and Fionz (2016). In this procedure, a node with the least amount of participation in previous communications will be selected as the NODE Next Step. They have proposed a modified GBR protocol using the CNR or Neighborhood Protection Range by eliminating the need for backup paths while maintaining stability called the GBR-CNR-LN.

The present study presents a new criterion for dealing with the bond dynamics between nodes due to the high speed of nodes as one of the challenges of Ad Hoc mobile networks, which is a combination of Euclidean distance and bonding lifespan. Interference and energy consumption for sending control packets massively and periodically in Ad Hoc mobile networks are the main factors. The competition between nodes will increase to the control channel with the periodic submission of these control packets and this will cause interference and network congestion. On the other hand, sending these packages periodically, regardless of the changes and conditions of the nodes, will reduce energy consumption and network lifetime. Therefore, the present study presents a comparative method for sending Beacon messages to solve interference and energy constraint challenges in mobile nodes.

Proposed method

A node may be present in a range of neighbors at regular intervals because the nodes are constantly moving at different speeds in various directions. A node may be in the neighbor's area at an interval time and may be out of this area at another time. The topology will rarely remain static due to the node's mobility in Mobile Ad hoc networks. As a result, each node needs to share its updated location with its neighbor nodes. Beacon messages will be redisplayed periodically to maintain an accurate list of neighbor nodes for each node. These updates are expensive in many ways. Each update will decrease power consumption and collisions at the media access layer, and increase wireless bandwidth. Packet collisions lead to packet loss, which will affect routing performance. Simultaneous transmission of Beacon messages will cause interference between nodes. Permanent changes in nodes will cause a permanent disconnection between them, which will reduce system reliability.

Therefore, it is necessary to consider network reliability as an important factor when choosing the next step for sending data packets to deal with the dynamics of the environment in mobile networks (Abdulmutallab and Fionz, 2016). For this purpose, in this study, the proposed method is presented in the following sections, focusing on the compatibility of the sending ratio of bacon messages and choosing the next step with a long lifetime.

In the proposed method, the update interval of sending Beacon messages is set based on the sending interval and the node's speed as well as nodes' density in the environment. The interval for sending a Beacon message is set based on the node's speed. In this case, sending messages based on the movement pattern of the nodes is considered using the proposed method, which reduces the routing overhead. Equation 1 shows the interval between sending Beacon messages (Haysen Butel et al., 2007).

$$\rho = a + (b - a).\left(\frac{v_{max} - v}{v_{max} - v_{min}}\right)^{n} \quad (1)$$

Where [a, b] is the Beacon messages predefined interval, Vmin and Vmax are the minimum and maximum allowed node speeds, and v is the node speeds calculated using the GPS. The n is a value defined in network conditions that can be adjusted based on node density and has been calculated experimentally (Haysen Butel et al., 2007). Each node broadcasts Beacon packets every second. The receiving node checks its neighbor's table, and if the path already exists, new position values, including node coordinates and speed, will be updated. Otherwise, it adds a link to the neighbor's table based on its information. According to Equation (1), the sending ratio of Beacon messages is adjusted according to the network characteristics. This reduces overhead and prevents congestion, and interference, thus reducing energy consumption. On the other hand, the value of the network attributes should be updated periodically after ρ second because the position of the nodes may change every time. Figure 1 shows the pseudocode of the proposed method.

Algotithı Sending Beacons based on Speed of Vehicl
Input: velocity
Output: Beacons Period Value

Notation

ρ: Beacon Period Value
i: Sender Vehicle
N: Neighbor List
a: Minimum Interval for Sending Beacons
b: Maximum Interval for Sending Beacons
V: Velocity of Node
NH: Next Hop

initializa

```
each node broadcasts Beacon to inform its nei
based on the Beacon received by each node cre
While (1) do
    For (each node(i) in the Network) do
        Calculate Time Interval for Sending Beacc
− 1)
        Calculate Life Time and Distance between
− 4)

Select the node as NH with Highest Lifetime an
        toward destination
        set a timer based on ρ
        If (BPV == 0)THEN
            node I send a Beacon for its neighbors
            based on Beacon received from node I
        Endif
    Endfor
End
```

Figure 1: Ratio adjustment algorithm for sending Beacon

In this study, estimating the lifetime of the link between nodes along with the Euclidean distance was used as a new criterion in the GIS protocol to increase the reliability of the selected links to select the next step. n the proposed method, this metric will be used to reduce route failure in a dynamic environment. This criterion is according to transmission range and the relative speed between nodes.

$$d = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (2)$$

$$\Delta v = v_i - v_j \qquad (3)$$

The relative speed between nodes is equal to Δv (Equation 3).

$$T_{ij} = \frac{R-d}{\Delta v} \qquad (4)$$

Therefore, in the proposed method, the bond lifetime between the nodes, in addition to the distance between the sender node and the node, will be considered in the selection of the next step. Therefore, the next step in the node should have a longer lifetime in addition to a long distance. So, each node involved in the routing process will be selected as the best neighbor node for the next step (5).

$$n_{max} = \arg_{min} \text{Distance}(n_i, dest) \text{ and } \arg_{max} \text{LifeTime}(n_i, n_j) \qquad (5)$$

Where n_i is the sender and n_j is the neighbor node for all neighbors nodes such that j = {1,2, 3…., n}. For example, the neighboring nodes are S A), B, C, and (E) (figure 2-3). The first expression in 〖arg〗_min Distance (n_i, dest) will give priority among the neighbors to the node that is further ahead (closer to the destination), and 〖arg〗 _max LifeTime (n_i, n_j) will choose a node with maximum lifetime. The reason for this is that the node that has the longest lifetime and the most further ahead toward the destination, will improve network characteristics such as delivery ratio and latency in the network if selected as the next step. Therefore, in the proposed method, the node with the n_max among the neighboring nodes is selected as the next step when sending packets. This strategy will be implemented by sending a packet from one node to another, and this process will continue until the packet reaches its destination. Figure (2) clearly shows this strategy.

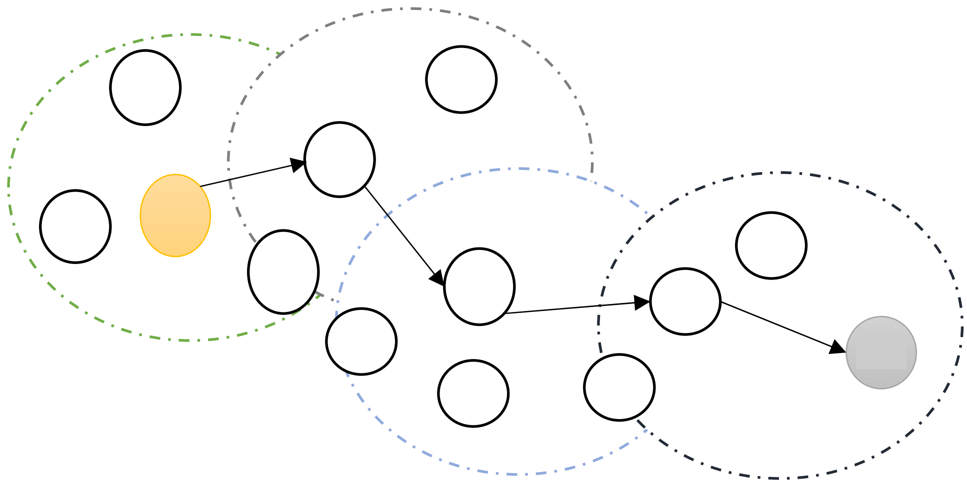

Figure 2: Proposed method Strategy

Node S needs to send data to node D. The transmission radius of node S surrounds nodes A, B, C, and E with dashed circles. According to the proposed method, node S sends the data packets to the neighboring node as the next step, which has the longest travel distance in its transmission radius and the longest link lifetime. Node E In the list of neighbors, node S (as shown in Table 1) is the closest node to destination D and has the longest bond life (figure 2).

Table 1: List of S Node Neighbors

Neighbors	Node ID
$A(x_1, y_1)$	A
$B(x_2, y_2)$	B
$C(x_3, y_3)$	C
$E(x_4, y_4)$	E

Node S sends the data packet to node E as the next selected step and node E sends the packet to G and node N to node D. Therefore, the transmission path will have more reliability in addition to shorter distances using this mechanism.

The network simulator NS-2 (M. Malathi et al, 2016) has been used to implement the protocols. The proposed protocol is compared with GBR-CNR-LU and GBR-CNR-LN routing protocols. The GBR-CNR-LN routing protocol selects nodes as the next step nodes with fewer neighbor nodes, and the GBR-CNR-LU routing protocol selects nodes as the next step with less involvement in packet sending. This strategy will reduce the overhead and the collision probability in the network. The bond lifetime has also been used to select stable bonds with long life to increase reliability.

Finding

1. Simulation parameters

Table 4-1 shows the parameters used to evaluate the protocols. The simulation is performed in 1000 by 1000 areas with an execution time of 200 seconds and 50 nodes in this limited area, which has been obtained randomly using the Random Way Point motion model and the Setdest command in NS-2 software. In the relevant scenario, nodes' movement is limited to a minimum and maximum speed in the range of [0,30] m/s. The simulation parameters for GBR-CNR-LN, GBR-CNR-LU methods, and the proposed method are shown in table 2.

Table 2: Simulation parameters

Parameter	**Value**
Number of Nodes	50
Wireless Range	400 meter
Simulation Area (m*m)	1000 * 1000
Mobility Generator	Random Way Point
MAC/PHY	IEEE 802.11
Packet Ratio	4 packets per second
Channel Ratio	8 Mbps

Data Packet Size	512Byte
Buffer size	50 Packets
Propagation Model	Two Ray Ground
Minimum Node Speed	0 m/s
Connection Type	CBR
Maximum Node Speed	30 m/s
Simulation Time	200 s
Initial Energy	10 Joule
Pause Time	15 s
Min. Hello Interval	1 s
Max.Hello Interval	5 s
n	2

2. **Evaluation criteria**

The proposed method is compared with GBR-CNR-LN and GBR-CNR-LU methods in terms of collision ratio, end-to-end latency, normalized routing overhead, throughput, number of packages produced, and average electricity consumption in the Network in scenarios with different node speeds. The minimum and maximum speed ranges in this test are 0 and 30 m/s, respectively.

Normalized Routing Load: the fraction of all routing control packets sent by all nodes over the number of received data packets at the destination nodes. Equation 6 indicates this variable mathematically (Oliveira et al., 2017).

$$NR = \frac{\text{Number of Control Packets}}{\text{Number of Received Data Packets}} \quad (6)$$

The number of packets generated: Number of control packets generated in the network at simulation time. This variable can indicate routing cost, concerning that the proposed method uses a speed-compatible ratio to schedule the Beacon message sending time.

End-to-end delay: Time is taken for a packet to be transmitted across a network from source to destination (Equation 7).

$$E2E = \frac{\sum_i^N (\text{recieve time}_i - \text{send time}_i)}{N} \quad (7)$$

Average energy consumption: The average amount of energy consumed by all nodes during the simulation time.

Throughput: The number of bits successfully transmitted in a channel in an interval that is usually expressed in bits per second.

Collision ratio: The number of packets collides in the media access layer with the number of packets sent in the network. is clear that the lower the collision ratio, the better the network performance. The collision ratio is calculated as Equation 8.

8)

The average in each method and improvement percentage will also be calculated (Equation 9)

$$\text{Improvement percentage} = \frac{A-B}{B} \times 100$$

Where A is the average in the proposed method and B is the average of the methods compared to the proposed method.

Figure 3 shows the collision ratio per 50 nodes that are randomly placed in the simulation dimensions and are moving at variable speeds. The collision ratio in the proposed method has improved by 57 and 67% compared to GBR-CNR-LN and GBR-CNR-LU protocols.

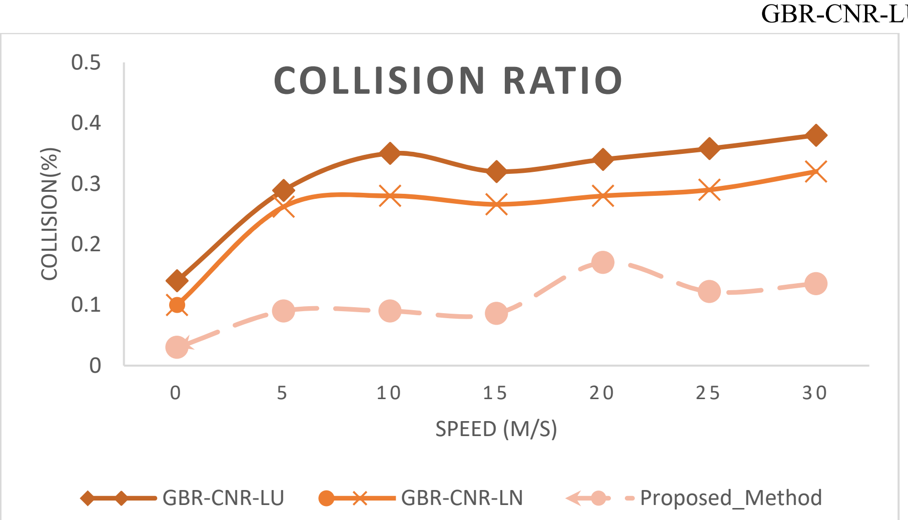

Figure 3: The collision ratio for different speeds

Figure 4 indicates the end-to-end latency for all three routing methods. As it can be, the proposed method has a longer delay than the other two methods, because more stable bonds are considered. On the other hand, the proposed method will reduce the Link availability considering the setting of the Hello transmission ratio, which in turn will increase the delay compared to other methods. The end-to-end latency has increased by an average of 40% and 25% compared to GBR-CNR-LN and GBR-CNR-LU methods. The proposed delay method has two behaviors: first, the delay increased with a rapid slope, which is due to network congestion and more delay in buffering packets. However, the proposed method has an almost constant delay with a fairly gentle slope - at a speed of 15-30 m/s. Since the proposed method uses the bond lifetime in selecting the next step, this has led to the selection of stable bonds (latency reduction), because routes with fewer speed changes have higher priority.

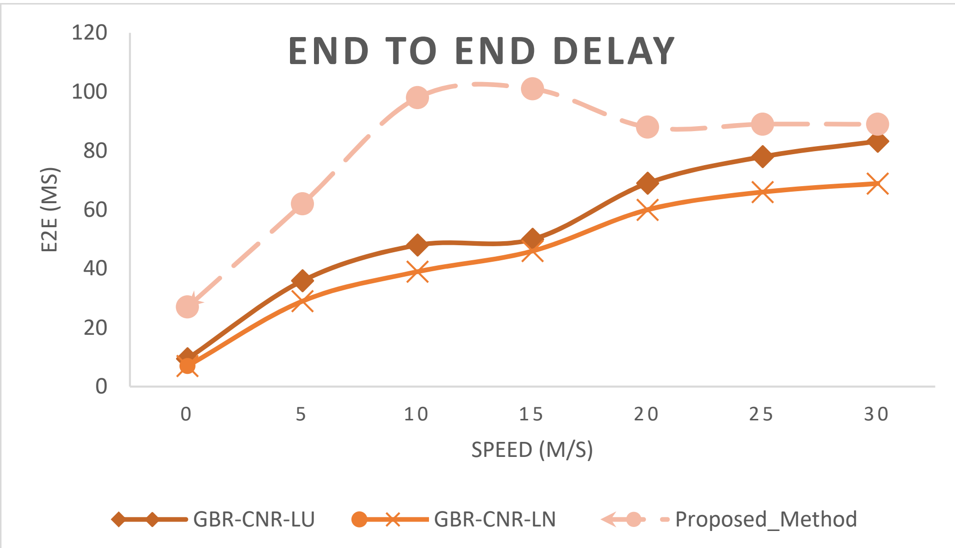

Figure 4: Average end-to-end latency for different speeds

Figure 5 shows the normalized overhead for 50 nodes with different speeds in the network. Control packets in all three methods include Hello packets on the network, which are exchanged as a condition of having neighbor nodes. GBR-CNR-LU and GBR-CNR-LN routing protocols use a fixed rate of sending Hello control packets, however, the proposed method uses a rate compatible with the nodes in the network. The use of the Hello packet delivery time setting method reduces the normalized overhead in the proposed method. The average normalized overhead in the proposed method is 43% and 32% lower than the GBR-CNR-LU and GBR-CNR-LN methods, respectively (figure 5).

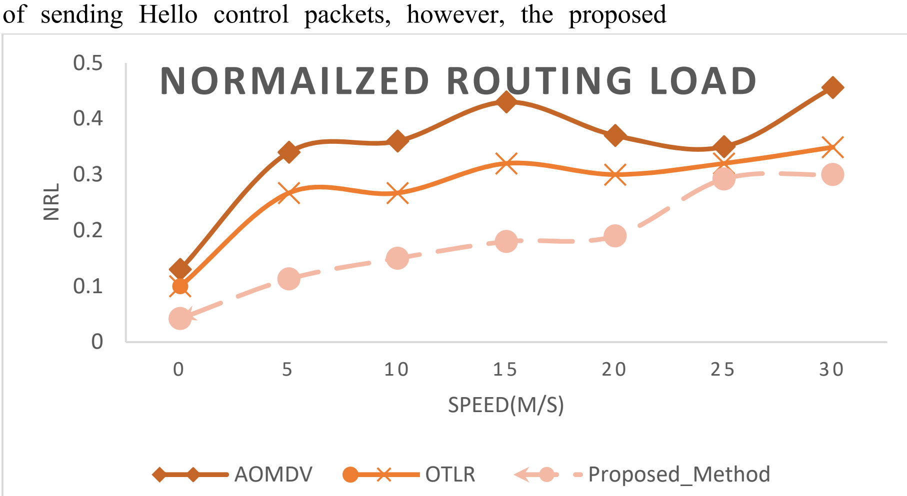

Figure 5: Normalized overhead for different speeds

Figure (6) shows the Throughput of the three compared methods for different speeds and with about 50 nodes randomly distributed in the network. The proposed method improves the throughput compared to other methods by considering bonds with longer bond lifetimes. The proposed method showed about 8% improvement compared to the GBR-CNR-LN method and 15% improvement compared to the GBR-CNR-LU method.

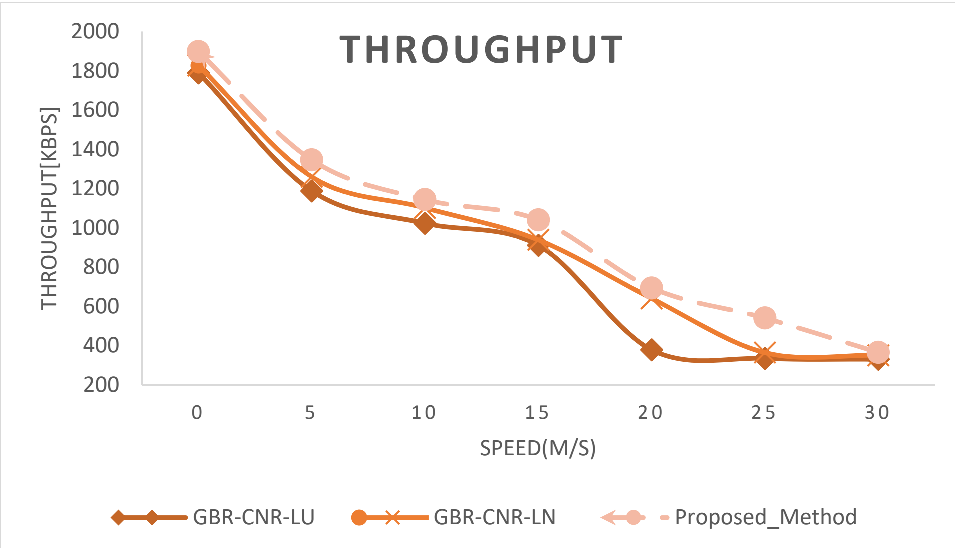

Figure 6: Throughput for different speeds

The electric power consumption for the proposed protocol is lower than other methods (figure 7). Since the proposed method has reduced the packets sent in the network compared to other protocols, the electric power consumption in the network will be reduced. GBR-CNR-IN and GBR-CNR-LU routing protocols have more overhead than the proposed protocol. However, it has reduced energy consumption due to reduced transmission and interception operations, as the GBR-CNR-LN routing protocol selects nodes with fewer neighbors as the next step. The proposed method has increased by 3% and decreased by 4% on average compared to GBR-CNR-LN and GBR-CNR-LU protocols (figure 7).

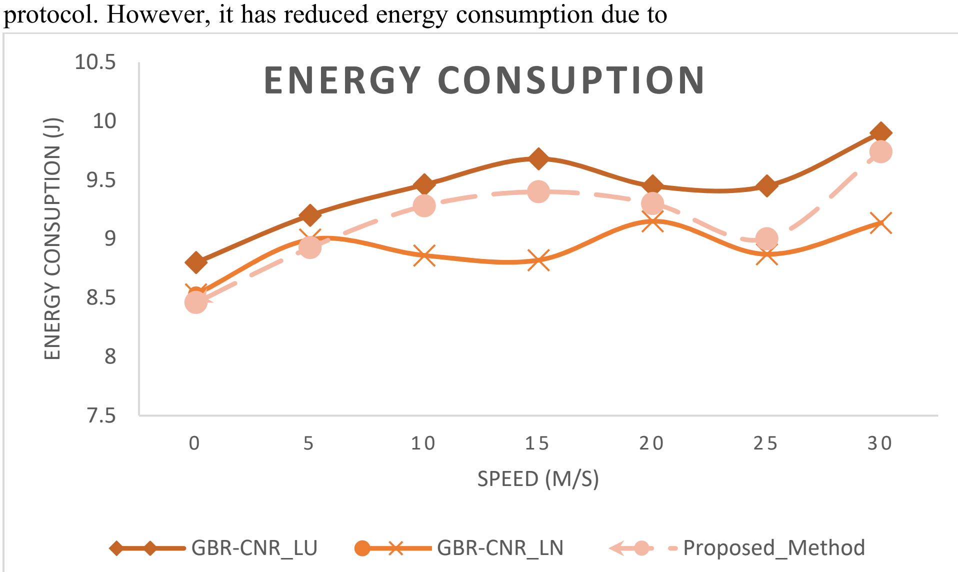

Figure 7: Average energy consumption for different speeds

Figure 8 indicated the number of Hello packets in all three routing methods for different speeds. according to this figure, the number of control packets in the network has increased in exchange for increasing the node's speed. The proposed method has a reduction of 44 and 49% compared to GBR-CNR-LN and GBR-CNR-LU in terms of the number of Hello packets in the network (figure 8).

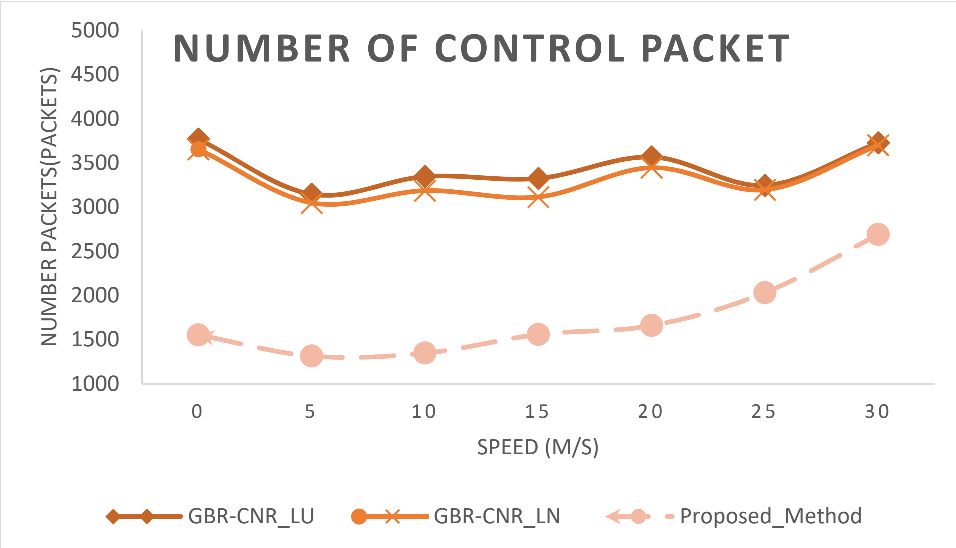

Figure 8: number of control packets

Conclusion

In this research, a Beacon transmission method for Geographical routing protocols is proposed to reduce interference between nodes and improve Throughput with emphasis on location-based routing protocols in Ad Hoc mobile networks. The results obtained from the simulations performed show that the proposed method has a better performance in terms of closed collision rate, throughput, power consumption, and normalization overhead. According to the simulation results, the research has proven that adjusting the Beacon sending rate can reduce collisions and improve Throughput, along with a routing criterion for selecting highly stable links.

Many early researches did not address the mobility control problem and the inherent characteristics of Ad Hoc mobile networks that reduce the effect of adjacent-channel interference. This causes the network throughput to be lower than the desired value. Among the routing protocols offered for mobile networks, position-based routing is a suitable alternative for this type of network due to the use of node location and the increasing popularity of positioning systems such as GPS. However, since the nodes are mobile, the formed topology will rarely remain static. As a result, each node should broadcast its updated position with its neighbor nodes. This upgrading is costly in many ways. Each upgrade will decrease power consumption and increase wireless bandwidth and the collision risk at the media access layer. Packet collision causes packet loss, which will affect routing performance. There is a need to adapt the delivery of Beacon-based content to the node's movement traffic conditions instead of applying the policy of static update of Beacon-based content, concerning the costs associated with the transmitting Beacons. On the other hand, mobile nodes have a dynamic topology and relatively high speed of transfer. In the greedy strategy, the next step will have the farthest distance from the sender node. The next step may be outside the transmission range of the sender node due to the constant changes of the nodes and as a result, the packet loss probability will increase. Therefore, it is necessary to consider network reliability as an important factor when choosing the next step for sending data packets to deal with the dynamic environment in Ad Hoc mobile networks. Therefore, in this study, the challenges and their effect on Ad Hoc mobile networks were investigated and a method is proposed to control the Beacon transmission rate in the network. The bond lifetime along with the Euclidean distance is used to select the appropriate next step in the network. The results of the simulations performed with Simulator 2 (NS2) show that the strategies used in the proposed method reduce the overhead and thus the interference of nodes and increase the network characteristics such as delivery rate and network latency.

In this study, a new criterion was presented while selecting the next step in position-based routing. It has also been used as an alternative for selecting links with longer lifetimes in the greedy strategy in position-based routing to select the appropriate next step for sending data on the link's lifespan along with the Euclidean distance. The proposed method also reduces the interference between nodes in the transmission area and thus improves the packet delivery rate and reduces the delay due to the reduced competition for channel acquisition due to the reduction of sent Beacon packets.

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Conflict of interest

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Ethics statement

None.

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