Mobility-based Opportunistic Routing for Mobile Ad-Hoc Networks

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ABSTRACT
Opportunistic Routing (OR) is an effective and enhanced routing scheme for wireless multihop environment. OR is an approach which selects a certain number of best forwarders (candidates) at each hop by taking the advantage of the broadcast nature of the wireless medium to reach the destination. When a set of candidates receive the packet, they coordinate with each other to figure out which one has to forward the packet toward the destination. Most of the researches in this area have been done in mesh networks where nodes do not have mobility. In this paper, we propose a new OR protocol for mobile ad hoc scenarios called as Enhanced Mobility-based Opportunistic Routing (EMOR) protocol. To deal with the node mobility, we have proposed a new metric which considers the geographical position of the candidates, the link delivery probability to reach them, the number of the neighboring nodes of the candidate, and the predicted position of nodes using the motion vector of the nodes. We have compared EMOR with five other well-known routing protocols in terms of delivery ratio, end-to-end delay, and expected number of transmissions from source to the destination. Our simulation results show that proposed protocol improves delivery ratio and number of expected transmission in terms of different type of mobility models.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design|Wireless Communication

Keywords
Opportunistic routing; mobile ad hoc networks; candidate selection; candidate coordination.

1. INTRODUCTION
Traditional Mobile Ad hoc Networks (MANETs) routing protocols select the next hop forwarders before data transmission and packets are traversed on pre-specified path toward the destination [1]. In such manner, wireless links have been treated as point-to-point wired links and broadcast nature of the wireless medium has been ignored. In contrast, Opportunistic Routing (OR) uses broadcast feature of wireless environment to enhance the performance of routing. Generally, the basic idea of OR is overhearing of transmission of the nodes in wireless medium and coordination of them in such a way that the packets reach the destination. Due to this fact, OR is a suitable technic for wireless multihop networks such as mobile ad hoc network, vehicular ad hoc network (VANET), and sensor network. Increasing the network reliability and reducing the number of transmissions are main advantages of using OR. Both of the analysis results [2][3] and recent experiments [4][5][6] show that OR has the potential to perform better than traditional routing in most of scenarios [7], especially in the environments with high percentage of packet loss.

OR has three main parts: metric calculation, candidate selection and prioritization, and candidate coordination. Metric calculation mechanisms generally are divided into local and end-to-end methods. Local or hop-by-hop metrics consider only the information of the local neighboring nodes to forward the packets. On the other hand, in end-to-end approaches, the information and states of the all nodes are considered to select the best route from source to the destination. Although end-to-end method is more efficient and lead to the optimal result, it is difficult to carry the information and state of the whole topology in a mobile scenario which have frequently topology changes. Therefore, it is obvious that local trend is more suitable for dynamic networks. In the local approaches, beacon messages are broadcasted regularly so that each node gets some information about its neighbors. In this case, nodes only consider the information of their local neighbors for making decision to select the candidates.

As we have mentioned above the other part of OR is candidate selection. In this phase, the sender node specifies a set of capable nodes as the candidates set to forward the data packet and sorts them according to a metric. The sender puts the candidates set in the header of the data packet and broadcasts it. Note that the selected candidates can be prioritized based on expected transmission count (ETX) [8], hop count to the destination, geo-distance and so on (see [9][30] for more information). When the data packet is received by the candidates, it checks the packet header to figure out whether its ID exists in header of data or not. In case of existence, it will enter the coordination phase. Several coordination methods have been proposed to handle this part such as timer-based, Acknowledgement-based, RTS-CTS, and network coding [9]. One of the most used approaches for the candidate coordination is the timer-based coordination which each candidate waits for a specific time before forwarding the packet. Each candidate then will transmit the packet if it does not hear the same packet from other higher priority candidates during the waiting time. Otherwise, the candidate simply discards the data packet. This procedure continues till the data packet received by the destination.

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Most of the works on OR have been done for static mesh networks where nodes do not have mobility. When nodes are mobile, candidates set changes frequently with dynamic topology and updating the whole topology information is so costly in dynamic scenarios. Therefore, a fast and efficient candidate selection and coordination algorithm is needed in the mobile scenarios in order to adapt rapidly with the frequent topology changes. In addition, choosing efficient metric which consider the mobility properties has great impact on the performance and complexity of an OR protocol. In this paper we use NS-2 simulation to display the enhanced performance of our proposed protocol in terms of delivery ratio and expected number of transmission in mobile scenarios.

The rest of this paper is organized as follow: first a brief related work is provided in Section 2. Then, the proposed protocol (EMOR) will be introduced in Section 3, and finally in Section 4 several comparisons are done to show the performance of EMOR compare to the other well-known routing protocols.

2. RELATED WORK

First idea of OR routing was proposed in [8] which considered the overhearing of the nodes in wireless medium. Generally, recent studies in field of OR have been divided into two areas. Most of the protocols such as ExOR [8], OAPF [10], and MORE [11] consider end-to-end or topological approach which are suitable for static networks. As an illustration, in Extreme Opportunistic Routing (ExOR) [8], shortest path first algorithm uses ETX metric to find out the best path to the destination, or In Opportunistic Any-Path Forwarding (OAPF) [10], EAX metric is employed which is more suitable for OR concept but it needs the information of whole paths. On the other hands, there are some OR protocols like POR [12] and DPOR [13] that use local neighbors information to route the packets. For example in POR [12] just geographically closeness to destination has been considered as a geed metric, or in DPOR [13] both of the closeness to destination and delivery ratio up to neighbors have been used for calculating metric.

OPRAH [14], LAOR [15], GOSR [16], and TO-GO [17] are some of the most well-known protocols that have proposed for mobile ad hoc scenario and VANET. In OPportunistic Routing in dynamic Ad Hoc networks (OPRAH) [14] relay nodes creates set of downstream path toward the destination and also upstream paths toward the source by sending on-demand route requests and route replies. Although it is more suitable for dynamic wireless networks, it selects only one forwarding node as transmitting node, and it does not take advantage of transmissions that reaching nodes other than the previously selected forwarder. Simulation results show that end-to-end forwarding reliability of packets have been increased by using this method. However, it seems that receiving duplicated packet at the destination is unavoidable. Owing to this fact that the route set may contain spatially or partially disjoint paths from the intermediate nodes toward the destination.

Location-Aided Opportunistic Routing protocol (LAOR) [15] is another geographical protocol that uses the location information of nodes in order to select and prioritize candidate set. Furthermore, LAOR minimizes resource consumption and duplicated transmissions by reasonable choosing forwarding nodes to prevent routes from diverging. In addition, it employs retransmission mechanism for local recovery issue if the sender does not get the ACK of the sent packet in specified time slot. The base idea of this protocol is similar to the other routing protocols such as POR [12] and GeRaF [18]. The only differences is related to coordination part that LOAR uses acknowledgment-based method. The main drawback of this proposed protocol is the poor results of the experiments in terms of comparing with other good routing protocols. Moreover, high rate of control messages is another concern regarding to this protocol.

Geographical Opportunistic Source Routing (GOSR) [16] is initially proposed for VANET environment. It is a combination of opportunistic concept and Geographical Source Routing protocol (GSR) [19]. First, GSR algorithm is done in an on-demand way. It generate a graph from the topology, and the cost of the links are considered as the length of the road segment. Then, the Dijkstra algorithm is run to find the shortest path to the destination. After that protocol enters opportunistic phase, and it tries to find a scope near the best path that contains the eligible forwarders. In coordination phase, after receiving the packet by the forwarders, they transmit the packet on specific time according to their distance to the destination if they do not receive the same packet from other forwarders. Simulation results show that employing GOSR can reduce the number of hop count and end-to-end latency.

TOpology-assisted Geo-Opportunistic routing (TO-GO) [17] is a geographic OR protocol that is introduced for VANET. TO-GO tries to find effective candidate set between the sender and the farthest node in the same road, and it also takes the road information topology in order to calculate effective candidates. First of all, the sender predicts that the target node whether is at junction point or not. It is assumed that the nodes at junction can transmit the packet in any direction. Then, the sender chooses a set of candidates that can hear the target and other candidates. After receiving the packet, each candidate waits for a period of time based on its distance to the target node and forwards the packet if it does not hear the packet from other forwarders. The results of this protocol illustrate that using prediction in an environment with loss and fading model can be lead to a good throughput. However, TO-GO only considered grid mobility model in its experiments and did not examine other mobility models.

In terms of improving the performance of geographical routing on lifetime of links and place prediction, some works such as MOPR [26] and GPSR-L [27] have been done. The results of these methods indicate that being aware of the movement pattern of the nodes can increase the efficiency of geographical routing. In addition, in [28] and [29] authors focus on some mobility specifications of the nodes to raise the packet delivery ratio in VANET environment. Thus, combination of OR concept with mentioned enhancements on mobile scenarios seems to perform well.

The new proposed metric in this paper covers not only geographical position of forwarders but also link delivery probability to reach them. Moreover, it considers the number of the neighboring nodes of the relay nodes as density of the relay nodes, and position prediction of the neighboring nodes by using the motion vector of the nodes once the packet will be received by them. In coordination part, timer-based approach is employed in such a way that source and the forwarders can overhear each other to avoid duplicated transmissions.

3. MOBILITY-BASED OPPORTUNISTIC ROUTING

In this section, we explain our Enhanced Mobility-based Opportunistic Routing protocol (EMOR). As we have mentioned before, geographical hop-by-hop protocols are used mostly in mobile scenario because handling the states of the end-to-end paths are so difficult and costly while the topology is always changing.

EMOR is a hop-by-hop OR protocol which consist of two phases: candidate selection and candidate coordination. To obtain the local information in EMOR, each node broadcasts its ID, current position, velocity, and the number of neighbors, which we refer to as density of node, by broadcasting hello message every $T_{interval}$. Once the hello messages are received by a node, it has the local information of its neighbors and can select some of its neighboring nodes as its candidates set.

In the candidate selection phase, EMOR uses the predicted position of nodes and the link delivery probability between the sender and neighboring nodes to select the candidates set. It also considers the number of neighbors of its neighbor which we refer to as density as another parameter to select the candidates. Once the candidates are selected the sender puts them in the header of data packet and broadcasts it. In the second phase of EMOR (candidate coordination), each candidate that has received the packet coordinate with each other to decide which one has to forward the packet. In the following we explain each of the candidate selection and coordination phases in more details.

To maintain the neighboring list information up to date, each node keeps the list of its neighbor during a specific period of time called dead time (represented by T_{dead}). If it does not receive any more hello messages from the neighbor during this period, it will consider it as dead one and will remove it from its neighbor list.

3.1 Candidate Selection

In the candidate selection phase EMOR considers different parameters to select some of the neighboring nodes as the candidates set. In OR, the nodes which are closer to the destination that the current node are considered as the potential candidates. Using the hello message information including the current position, velocity, and direction of nodes, each node can estimates the future position of its neighbors. Based on Equations (1) and (2) the position of neighboring nodes will be predicted for a short period of time. Note that in Equations (1) and (2), θ is the angel of the motion vector of the adjacent node with horizon line, $V_{current}$ is the current velocity of the neighboring node, and X & Y are the predicted and current coordinate position.

$$X_{next} = V_{current} * \cos\theta + X_{current} \qquad (1)$$

$$Y_{next} = V_{current} * \sin\theta + Y_{current} \qquad (2)$$

Based on the predicted position of neighbors and also known position of destination, estimated distance of each neighbor to the destination will be calculated by using Pythagorean equation, and it represents by PD_i where i is the ID of node.

Although selecting the nodes which are close to the destination that the sender could increase the packet progress toward the destination, reaching the nodes far from the sender is more difficult. Therefore, the other factor that has to be considered in the candidate selection process is link delivery probability between the current node and its neighbors. The link delivery probability between a node and its neighbors can be calculated using the number of received hello messages in a predefined period of time. This probability can be calculated by dividing the number of received hello messages from the neighbor in specific period of time by the number of hello messages supposed to be received. We illustrate it by $P_{i,j}$ where i and j are the ID of two neighboring nodes.

Despite the fact having more number of candidates to forward the packet increases the chance of delivering the packet to the destination, there are some drawbacks for that. First of all, since all of the candidates have to mention in header, increasing the number of candidates will increase the size of packet header. Secondly, a large number of candidates causes that the candidate coordination be more complex since a lot of nodes might receive the sent packet. Therefore, it may raise the number of duplicate packets. In addition, in OR if at least one of the candidate receives the packet it can continue the forwarding the process. Therefore, there is a probability that when a source broadcasts a packet at least one of its candidates received the packet which can be calculated as shown in Equation (4):

$$P_1 \vee P_2 \vee P_3 \vee \ldots \vee P_n =$$
$$1 - \big((1-P_1) \wedge (1-P_2) \wedge (1-P_3) \wedge \ldots \wedge (1-P_n)\big) \qquad (4)$$

Where P_i is the link delivery probability between the sender and node i. As we can see in Equation (4) increasing the number of candidates does not improve the probability of reaching to the candidates set that much. Therefore, as shown in [20] having a small number of candidates can provide large enough probability to reach to at least one of the candidates and we have considered constraint on the maximum number of candidates in each node which is set to C_{max}.

Another parameter that has to take into consideration for calculating metric in candidate selection part is geographical progress of a transmitted packet which is defined as difference between distance of the source to the destination and predicted distance of the neighboring candidate to the destination (PD_i). We show it as Geographical Progress (GP). According to this definition, we define potential candidates as the nodes which their predicted position is closer to the destination that the current node. We have normalized the GP value by dividing it to the transmission range in order to use it in metric calculation. Equation (5) illustrates our Expectation Predicted Progress metric (EPP) over candidate set $\{C_1, C_2, \ldots, C_{max}\}$ which sorted based on their priorities and used in candidate selection algorithm.

$$EPP = \sum_{i=1}^{C_{max}} Normalized\big(GP_{C_i}\big) * P_{src,C_i} * \prod_{j=1}^{j=i-1} \Big(1 - P_{src,C_j}\Big) \qquad (5)$$

Note that in OR, the probability that i^{th} candidate forwards the data packet is equal to the probability that the packet is delivered to that node and the other higher priority candidates do not receive the packet successfully. Thus, the probability of sending a data packet by i^{th} forwarder is:

$$P_{src,c_i} * \big(1 - P_{src,c_1}\big) * \big(1 - P_{src,c_2}\big) * \big(1 - P_{src,c_3}\big) * \ldots * \big(1 - P_{src,c_{i-1}}\big) \qquad (6)$$

Algorithm 1 represents the pseudo code of candidate selection algorithm that EMOR uses. First of all, the neighbor list will be checked and updated which means that all of the farther, dead, out of coordination range, and under density threshold neighbors will be removed from the neighboring list. Note that the density of each neighbor is used in order to make sure that the selected candidate has enough neighbors such that it will not face the local maximum issue. That is the packet will not reach to a candidate that it cannot forward it anymore toward the destination because of lack of any neighboring node. The Expectation Predicted Progress (EPP) will then be calculated so that it maximizes the progress of sent packet. As a result, candidates set for forwarding the packet toward the destination will be provided.

Algorithm 1- Candidate selection

```
FOR (∀node_i ∈ neighbor_list[i])
    IF (dead neighbor , out of coordination range, GP_i < 0 ,
    Dens_i < Dens_threshold)
        remove node_i from neighbor_list[i]
    ENDIF
ENDFOR

FOR (i = 1 → C_max)
    sort the candidate_set[i] based on PD_i
    FOR (∀node_j ∈ neighbor_list[j])
        calculate EPP_j over candidate_set[i]
    ENDFOR
    candidate_set[i] ← node_j that maximize the EPP
    ignore node_j for next iteration
ENDFOR
```

3.2 Candidate Coordination

When a node selects its candidates, it puts them in the header of data packet and broadcasts it. Each node that receives the packet will check if its ID is exist in the header or not. In case of not existing, the node will simply drop the packet. Otherwise, the candidate will wait for a period of time according to its priority which is mentioned in the candidates set in order to transmit the packet. During this period of time the candidate will listen to the medium to see whether any other higher priority candidate is forwarding the packet or not. A candidate will forward the packet if it does not hear the transmissions of the same packet from other candidates during its waiting time. Note that the highest priority candidate will not wait and as long as receives the packet it will immediately forward it. This process continues till the data packet reached to the destination.

One of the challenging issue in OR is the amount of duplicated packets generated due to failure in coordination phase. In other words, more than one candidate will forward the same packet if they cannot overhear each other. To address this issue, the feature of Reuleaux triangle is used to make sure that the sender and the receiving candidates can overhear each other. The worst positions of nodes are displayed in Figure 1 so that the sender and two other forwarding candidates can coordinate together around the triangle vertexes. Thus, all of the nodes in Reuleaux triangle can overhear each other. Note that R represents the radius of transmission range.

In EMOR, when a node sends a packet it waits for a period of time to see if any of its candidates forwards the packet or not. In another words, acknowledge of receiving the packet in EMOR is done hop-by-hop by overhearing the broadcast signal of one of the candidates. In case that the sender does not hear any transmission of the same packet from one of its candidates, it will retransmit it for at most N_{retry} times.

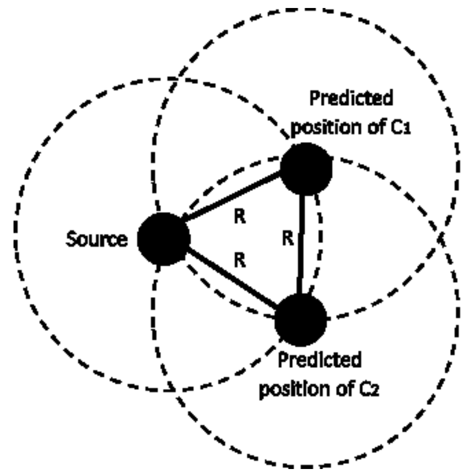

Figure 1- Coordination zone

4. EXPERIMENT RESULTS

4.1 Simulation Environment

In our NS-2 simulation, we assume that the position of the destination is known to all of the nodes via location server. Moreover, some random traffics are generated by the nodes to emulate more realistic scenario in case of congestion. Also, five candidates are chosen in the simulations in practical manner.

An environment with a high rate of packet loss is used for simulating in order to illustrate the performance of OR concept rather than other routing protocols in such of these environments. The two-ray model predicts the received power as a deterministic function of distance, and it represents the communication range as a circle. But in reality, the received power at certain distance is a random variable due to multipath propagation effects, which is also known as fading effects. Shadowing propagation model is employed to address these conditions.

Random Direction, Random Waypoint, and Manhattan Grid mobility models are used to examine the behavior of the routing protocols in different mobile scenarios. In Random Waypoint mobility model each node chooses a target position randomly and start moving toward the target with randomly selected speed between defined minimum and maximum speed. Then, it will choose another random point after reaching the specified target. This model is used widely as a reference for mobile scenarios.

On the other hand, Random Direction mobility model [21] is basically similar to Random Waypoint model, but it does not suffer from the density waves in the center of the simulation area that Random Waypoint model does. In this model each node keeps going up to edge of the simulation area border with random direction. Once the simulation boundary is reached, the node pauses for a specified time, and it chooses another angular direction between 0 and 180 degrees for its path.

Finally, in Manhattan Grid mobility model [24], the simulation area divided into arbitrary grid segments. Nodes have to go straight forward; only at the junction points they can choose whether they turn right, left or keep going straight. The grid of 5x5 with probability of 0.5 for going straight and 0.25 for turning right and left has been considered to evaluate the performance of mentioned protocols in an environment such as VANET. We will show in following sections the behavior of mentioned protocols in these different mobility models.

In comparison part, we compare AODV [22] as a traditional routing protocol, POR [12] and DPOR [13] as geographical and hop-by-hop OR protocols, CBF [23] as a receiver based OR protocol that does not use hello packet to discover the network, and finally GPSR [25] which is a well-known geographical protocol for wireless mesh networks.

End-to-end packet delivery ratio, latency, expected number of data transmission, and expected number of effective data transmission are measured for evaluation part. Delivery ratio shows the general throughput of a protocol, which is the number of sent packets at the source node divided by the number of successfully received packets at the destination. Latency or End-to-End delay displays the time of transmission of the packet from the source to the destination. Expected number of data transmission is defined as the number of all data transmissions over the network divided by successfully received data packets at the destination, and it logically shows how many data transmissions are required over the entire network to deliver a data packet from the source to the destination. On the other hand, expected number of effective data transmission only illustrates the number of transmissions of the received data packets over the network.

Table 1- Simulation 1 parameters

Playground size	500m x 500m
Propagation model	Log-normal Shadowing mean=0, stdDev=6, path loss=2.2
MAC layer mode	802.11 g (2.412e+9Hz)
Mobility model	RandomDirection
Speed	5,10,15,20,25,30 (m/s)
Hello pkt interval	Every 1 sec
Data pkt interval	Every 0.1 sec
Data traffic type	Constant Bit Rate
Number of nodes	40
Number of forwarding candidates	5

4.2 Simulation-1

The purpose of first simulation is to show the behavior of each of the mentioned routing protocols in different speeds. The parameters of simulation-1 are mentioned in Table 1. Number of nodes is considered so that they can cover the playground of the simulation. Figures 2, 3, 4, and 5 display the performance evaluation and comparison of the mentioned protocols in terms of packet delivery ratio, latency, expected number of data packet transmissions, and candidate forwarding status.

As expected, AODV as a traditional routing has a low and unstable performance (large confidential interval) in mobile scenario with high percentage of packet loss. Hence, another small graph is considered at Figure 2 to illustrate the delivery ratio of the other protocol in better way. Generally, as indicated in Figure 2, packet delivery ratio decreases as the speed raises. Although CBF has the best delivery ratio, it suffers from high latency and high number of data transmission over the network. On the other hand, all of the opportunistic routing protocols have better packet delivery ratio than GPSR in simulation-1 environment.

Figure 2- Delivery ratio

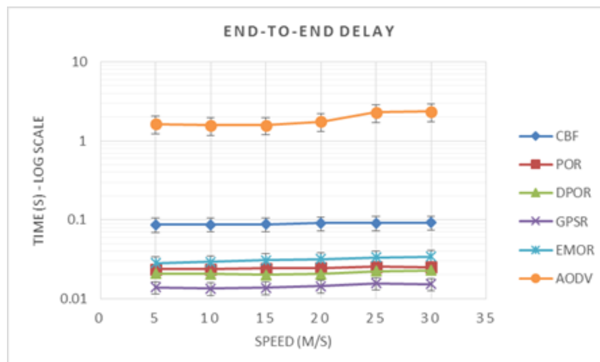

Figure 3- End-to-end delay

Figure 4- Expected number of all data transmissions

As illustrated in Figure 2 and 3, Enhanced Mobility-based Opportunistic Routing protocol (EMOR) has higher delivery ratio in compare to the other OR protocols and even GPSR with approximately having reasonable latency. Note that logarithm scale is used to display the different times of these protocols in Figure 3. In addition, the low rate of expected transmission of EMOR in Figure 4 indicates the performance of proposed coordination algorithm, which reduces the number of duplicated data packets.

Although GPSR has lower delivery ratio than OR protocols, according to Figure 3 it has less delay in compare to the other OR protocols that use timer-based coordination approach. In fact, the only drawback of timer-based method can be considered as the high latency due to waiting time of the low priority candidates for forwarding. Figure 5 displays the role of each candidate in forwarding the data packets among all of the OR protocols. As indicated, almost half of the transmission are done by middle candidates. Since, as a proposal for future works these portions can be considered in such a way that transmission priority will be given to middle candidates in order to enhance the total end-to-end latency.

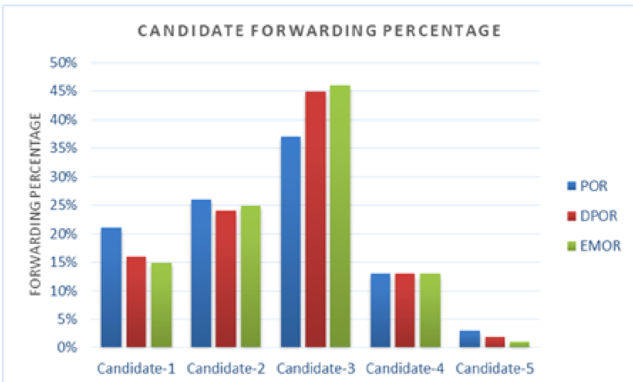

Figure 5- Candidate forwarding percentage

Table 2 - simulation 2 parameters

Playground size	500m x 500m
Propagation model	Log-normal Shadowing mean=0, stdDev=6, path loss=2.2
MAC layer mode	802.11 g (2.412e+9Hz)
Mobility model	RandomWaypoint, RandomDirection, ManhattanGrid
Speed	5 ~ 30 (m/s)
Hello interval	Every 1 sec
Data pkt interval	Every 0.1 sec
Data traffic type	Constant Bit Rate
Number of nodes	20, 30, 40, 50
Number of forwarding candidates	5

4.3 Simulation-2

The aim of second simulation is showing the effect of number of nodes and role of different mobility models over performance of the mentioned protocols. The parameters of simulation 2 are stated in Table 2. Figures 6 and 7 display the behavior of the considered protocols in different mobility models. As illustrated in charts of Figure 6, in terms of delivery ratio, CBF has a linear increasing behavior which is totally depended on the number of nodes. On the other hands, AODV has a considerable exponential decreasing trend owing to the fact of incomplete ARP packets as the simulation results shown. The effect of fading, loss, collision, and high movement of nodes cause this issue. Besides, OR protocols and GPSR have almost stable and good trends regarding to the number of relay nodes. Note that among all of these protocols, EMOR has higher packet delivery ratio and steadier performance even in sparse networks. Furthermore, as displayed in Figure 6, there are little differences between delivery ratios of charts in terms of various mobility models. However, packet delivery ratio of Manhattan Grid mobility model is generally lower than two others.

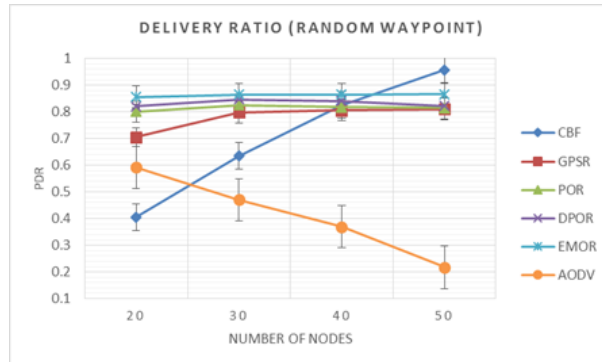

Figure 6 (a) - PDR in RandomWaypoint mobility model

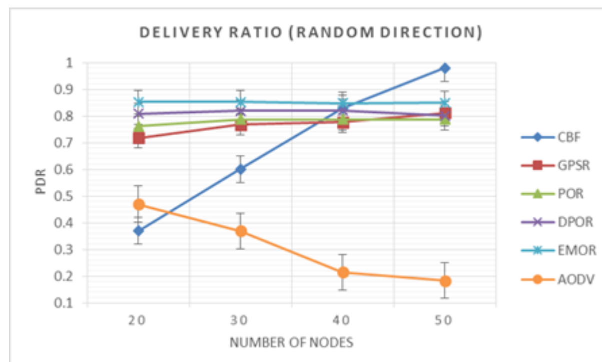

Figure 6 (b) - PDR in RandomDirection mobility model

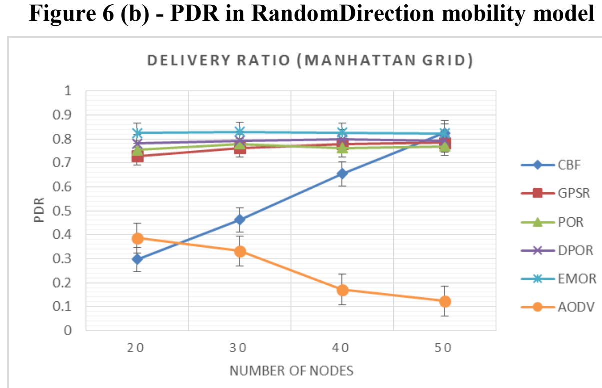

Figure 6 (c) - PDR in Manhattan mobility model

In charts of Figure 7, total latency of these routing protocol are shown. All routing protocols except AODV have the same behavior in different mobility models. The proposed protocol has higher latency in compare to the GPSR, POR, and DPOR due to its complexity in candidate selection phase. Nonetheless, the total end-to-end delay of all mentioned routing protocols can be consider stable in various number of forwarding nodes.

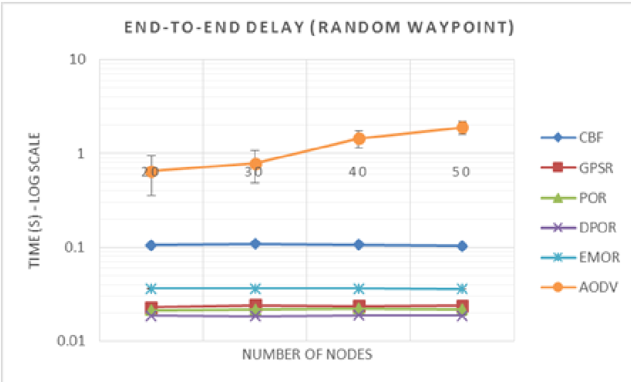

Figure 7 (a) - Latency in RandomWaypoint mobility model

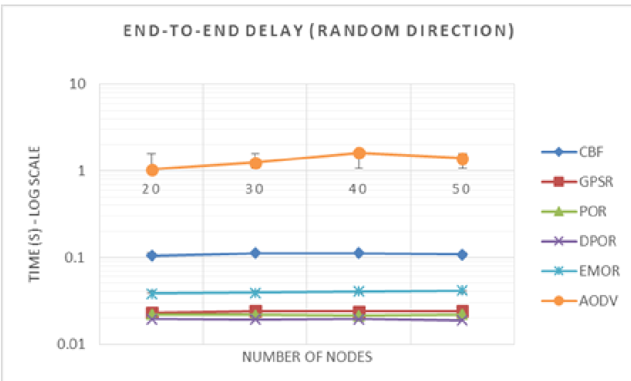

Figure 7 (b) - Latency in RandomDirection mobility model

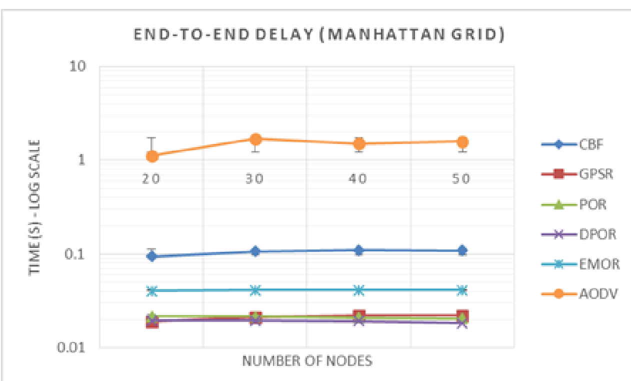

Figure 7 (c) – Latency in Manhattan mobility model

5. CONCLUSION

Opportunistic routing has a considerable potential to be employed over wireless environment with high rate of packet loss and noise. It uses broadcast nature of transmission to avoid extra re-transmissions; and as the result, it enhances latency and delivery ratio. The proposed EMOR protocol defines a new metric that adapted for mobile scenario. It covers not only geographical position of forwarders but also link delivery probability to reach them. In addition, it considers the density of the relay nodes, and position prediction. Moreover, timer-based coordination algorithm is employed so that source and the forwarders can overhear each other to avoid duplicated transmissions.

Results of the simulations show that proposed protocol has more stable performances in high speed, and it improves delivery ratio and number of expected transmissions in terms of different type of mobility models.

As future works, we can consider these evaluations with an environment with physical obstacles and observe the performance of prediction procedure. Also, similar to the most of the OR protocols, some modifications need to be done in MAC layer to increase the efficiency of the coordination part. In addition, to avoid latency and starvation caused by timer-based approach, we can give weighted priority to the candidates in such a way that the middle priority nodes that transfer in most of the times get higher priority to transmit the packets. Consequently, this approach will reduce the total end-to-end delay.

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