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Energy Consumption Analysis of modified AODV Routing protocol under Random Waypoint and Reference point Group Mobility Models

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***Abstract*—A Mobile Ad hoc Networks (MANET) is a non-infrastructure network that consists of a collection of nodes that can communicate each other independently. MANET is characterized by mobile with portable and limited power sources. A lot of protocols proposed to improve and optimize AODV performance. Our previous work, we have proposed a modified AODV routing protocol called RAODV+. RAODV+ combines two mechanism such as gateway mode and reverse route mechanism with the aim to improve the performance of the hybrid protocol. In this paper, we will discuss and analyze our modified AODV routing protocol in term of energy consumption analysis in mobility models, random waypoint and reference point group mobility. In this work, we use network simulator NS-2 to perform some scenarios of simulation. We used mobility models random waypoint and reference point group with various speed and number of source node to evaluate the energy consumed by each node. The simulation result shows that our modified protocol has lower energy consumption for random waypoint movement compare to the reference point group mobility model.**

I. Introduction

A Mobile ad hoc Networks (MANET) steadily developed in a tremendous space. Many routing protocol for Manets had been developed and proposed. Ad hoc On-demand Distance Vector (AODV) is the most widely used protocol in this field of research. Research in the early 2000s only focused on the development of services or functions of the AODV routing protocol, such as route discovery mechanism, shared channel, and counter dynamic nodes. The aim of last decade studies were to manage an ad hoc network topology that always change and solve the problem of link failure or route error caused by the mobility of ad hoc node that cannot be predicted.

Our previous research, we have already proposed a modified AODV routing protocol [1]. We have performed some comparison with others AODV routing protocol also.

In this paper, we continue our previous work and measure the performance and analyze the energy consumption of our modified protocol under some circumstances of mobility models and rates. The research question is how many energy will released by mobile node which using our modified protocol under random waypoint and Reference Point Group Mobility (RPGM) models. We choose these mobility models because the movements of mobile node are almost similar to the real world [2], especially for low speed mobility.

In the random waypoint movement model, nodes choose a random location on the simulation area and go there with the speed drawn from a uniform distribution with a minimum and maximum value. When the node has arrived, it will wait a random amount of time, and then continue with the same routine. One feature of the random waypoint model is that when it has reached a steady state, the nodes are not uniformly distributed on the simulation area.

The Reference Point Group Mobility (RPGM) model represent the random movement of a group of mobile nodes their random individual movement within a group. RPGM model determines the next position by calculating group motion vector in order to define velocity and destination position of mobile nodes. This group mobility can be used in military battlefield communication or emergency environment.

This paper will be presented as follows. In Section II we will discuss the existing related research. Next on Section III we will discuss about our contribution. Section IV contains the simulation of the protocol. Finally, Section V describes the conclusions and future work.

II. Related Work

The concept of optimized AODV routing protocol in Manets was treated in several research. Most of these research works are to optimize and create efficient energy consumption of mobile node in MANETs. Developing and optimizing routing protocol for mobile ad hoc networks could be done from any point of views.

Kim et al. proposed R-AODV [3] to optimize the standard AODV routing protocol. AODV protocol only built a single path for finding the destination node in the network. If a node that has received RREP no longer in the line of communication because of rapid changes of network topology, then the source node will established path again from the beginning to initiate communication with the destination node. This causes inefficiency in the network. R-AODV algorithm provides a solution by spending the cost of flooding the entire network. RREP message is replaced with Route Reverse Request (RRREQ) message to send back to the source node, and distributed to all neighboring nodes. Consequently it will build multi-path towards the source node. This will reduce the possibility of failed connection in case of topology changes because there are some alternative paths for communication.

Hamidian proposed AODV+ [4] to cover the communication problem between ad hoc network and infrastructure network. Gateway module was extended to standard AODV algorithm. The Gateway helps nodes in ad hoc network to be able to connect with infrastructure network. In this scenario, several nodes have ability to act as gateways between ad hoc network and infrastructure network. A node in ad hoc network can be connected to each other and even with a node in infrastructure network through these gateways.

Energy and load are become the most important factors to support routing protocol in MANET since mobile nodes use wireless communication. Ding and Wan [5] proposed mathematical models which concern about sustainable energy, consumed energy and bandwidth estimation. Their aim was to improve AODV routing protocol by choose the minimum paths or hops with no problem in energy and bandwidth availability.

Khelifa [6] proposed an energy conserving routing protocol in mobile ad hoc network, called ER-AODV (Energy Reverse Ad hoc On-demand Distance Vector routing). ER-AODV is a reactive routing protocol based on a policy which combines two mechanisms used in the basic AODV protocol. First mechanism is using multiple route replies to cover the problem when the route reply could not arrive to the source node. The second mechanism proposes a new adaptive approach which seeks to incorporate the metric "residual energy" in the process route selection, Indeed the residual energy of mobile nodes were considered when making routing decisions.

Tolba et al. [7] used a variable transmission range in order to save energy and to keep the connectivity between nodes. They proposed an algorithm that implemented at data link layer. The main aim is to propose a generic solution that can be used by other protocols such as AODV.

Abdule et al. [8] had investigated the effects of pause time setting for AODV routing protocol on RPGM mobility model in MANETs. The result has shown that the value setting of pause time can be affecting the performance of AODV routing protocol. The experiments found that the lower pause time give better performance rather than the higher one.

Huan et al. [9] performed the research to find out what pattern each mobile node will have significant impact on the performance of ad hoc network. Through analyzing and comparing the performances of four mobility models such as Random Waypoint, RPGM, Free Way, and Manhattan, in sparse ad hoc networks. It indicates that the impact on the performance of networks is remarkably different when the nodes move in different mobility models. In order to realize the effective communication between the fixed node and mobile nodes in sparse ad hoc networks in a large area, they also proposed a chain mobility model which mobile nodes could move as a chain and fixed node serves as a relay node. The results show that their proposed mobility model is suitable for communication in the sparse ad hoc circumstance.

III. Our Contribution

In this section, we present an overview of our proposed protocol. A new variant of AODV routing protocol called RAODV+ [1]. AODV routing protocol only builds one path to find the destination node on the network. Inefficiencies occur in AODV protocol when the path is lost. Source node will repeat the process from initial discovery to find the destination node.

To solve this weakness, Kim et al. [3] developed a method of reverse request and proposed R-AODV protocol. Reverse mechanism provides an alternative path when the discovery process is done. As the consequence, it will build an alternative path of communication. The path that is used to establish communication is the shortest path. When one path of communication is broken, the alternative route will be used directly without reinitiating discovery procedure.

Our proposed protocol uses this mechanism to improve its communications performance. Our proposed protocol also used gateway mode, adopted from AODV+ [4] for hybrid environment. The gateway helps nodes in ad hoc network to be able to connect with infrastructure network. RREP is replaced with RRREQ to build a multi-path ways towards the source node. If the node receives RREQ which broadcast to the network, then node will check if it ever receives the same RREQ. If yes, the packet will

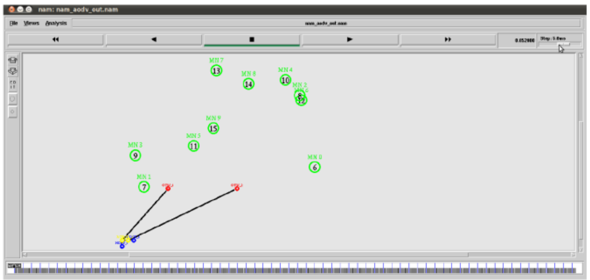

Fig. 1. Network animator for simulation scenario

be ignored. If the node which received the RREQ packet is not the destination node, then the RREQ will be updated, and request time will be set and then forward the RREQ again to all neighboring nodes.

If the destination node receives RREQ, it will check whether the gateway mode on. If the gateway mode is on then the packet will be forwarded to the network infrastructure. If the gateway mode is not on, more RRREQ will be generated and then it will broadcast to all neighboring nodes to look for the source node. If RRREQ found the source node, the packet transmission between nodes will start immediately. When R-RREQ is broadcasted, every node will check again its redundancy. If R-RREQ has been received then the packet will be ignored. Otherwise it will be forwarded to the next node.

In this simulation, we evaluate our proposed protocol in term of energy. We use following formula to calculate the energy parameter:

$$Ei_{\Delta t} = power\ i \times \Delta t \quad (1)$$

$$Ei_{(t+\Delta t)} = Ei_{(t)} Ei_{\Delta t} \quad (2)$$

IV. Simulation and Result

The simulation is done with network simulation tools, NS-2 version 2.34. The topology is an ad hoc hybrid network with contains 10 mobile nodes, 2 gateways, 2 routers and 2 hosts in an infrastructure network. The topology dimension is 1000 x 800 meter area.

We made some scenarios with different number of source nodes, speeds and mobility models. For these scenarios we used only random waypoint and RPGM mobility models. We choose these mobility models because the movements of mobile node are almost similar to the real world especially for low speed mobility like pedestrian. We also assume that every mobile node has the initial energy of 100 Joules. Traffic model used in this simulation is Constant Bit Rate (CBR) with 512 bytes in packet size. The simulation time is 500 seconds. Table 1 shows the parameter simulations. Fig. 1 shows the network animator (nam) for the simulation scenario.

TABLE I
PARAMETER SIMULATIONS

Parameter	Value
Host	2
Gateway	2
Routers	2
Mobile Nodes	10
Area Topology	1000 x 800 m
Mobility Model	Random Waypoint, RPGM
Speed	10,20,30
Traffic type	CBR
Packet size	512 bytes
Time simulation	500 s
Initial Energy	100 Joules
Tx Power	3.53E-002
Rx Power	3.13E-002
Idle Power	7.12E-004
Sleep Power	1.44E-007

In this simulation we evaluate the energy consumption of proposed protocol with two different mobility models. The total average energy after communication is the total of energy that used in each node divide total event during communication. For total of average energy remaining is difference between initial energy with total average energy after communication. The formula to calculate the energy parameters as follows:

$$Avg\ e_{\gamma} = \frac{\sum e_{\gamma}}{\sum Event} \quad (3)$$

$$Avg\ e_{\tau} = \sum EI - \sum Avg\ e_{\gamma} \quad (4)$$

Variables definition:

e_{γ} : Average used energy at each node.
$Avg\ e_{\gamma}$: Average remaining energy after communication.
$Avg\ e_{\tau}$: Average energy remaining.
Event : All events that occurred during communication between nodes.
EI : first initial energy in each node.

The energy consume for each state are as follows:

- Transmit power (Tx Power) is 3.53E-002,
- Receive power (Rx Power) is 3.13E-002,
- Idle power is 7.12E-004, and
- Sleep power is 1.44E-007.

Fig. 2, 3, 4 showed that the average remaining energy when mobile nodes play as sources which transmit cbr packet type under different mobility models (random waypoint and RPGM), and also in various speed of mobile node. The average remaining energy (Joules) by 2, 4, and 6 source nodes when the maximum speed is varied as 10 m/s, 20 m/s, and 30 m/s. We can observe from the simulation scenarios with different mobility models and different speed that, RPGM consumed more energy when the speed

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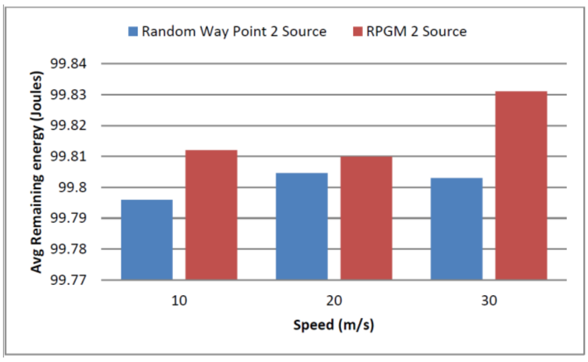

Fig. 1. Average remaining energy with 2 source nodes.

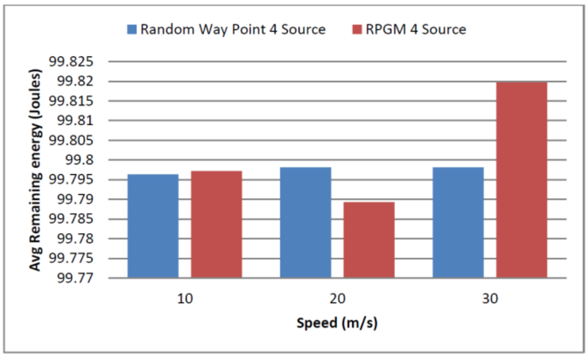

Fig. 2. Average remaining energy with 4 source nodes.

of node increases. However our proposed protocol is stable under random waypoint model in any circumstances of speed and number of source node that access the gateway. In general, almost all mobile nodes have the same level of remaining energy after 500 seconds of simulation even while in different speeds. The ranges of remaining energy of all mobile nodes are 99.75 to 99.85 Joules.

Our modified protocol has more minimum average energy consumption while using random waypoint mobility when the speed and the number of source is increase. In contrast, energy consumption of RPGM with speed bellow 30 m/s and less number of sources is lower than random waypoint mobility model.

Next, Fig. 5, 6, 7 showed that the result of remaining energy from number of mobile node which act as source node that communicate with gateway at infrastructure network. We will show the effect of the

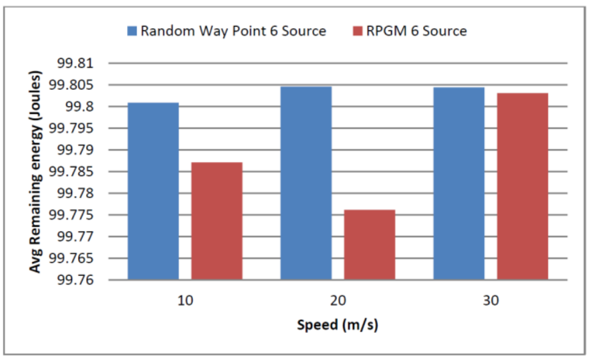

Fig. 3. Average remaining energy with 6 source nodes.

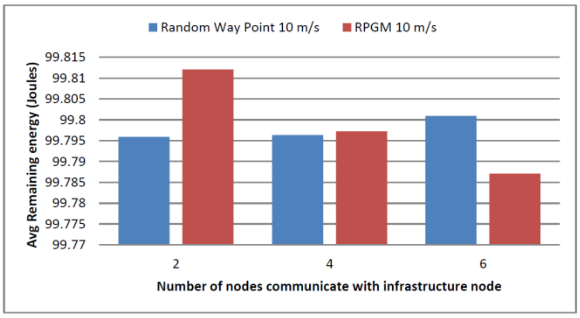

Fig. 5. Average remaining energy with speeds 10 m/s.

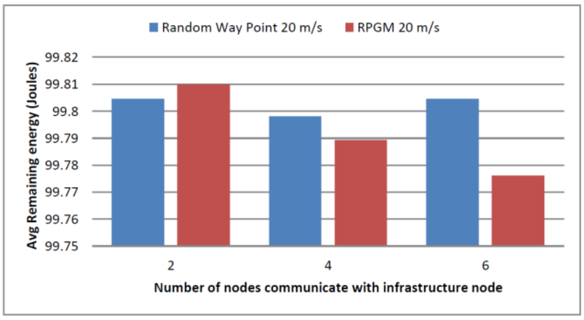

Fig. 6. Average remaining energy with speeds 20 m/s.

number of node communicates with gateway against average energy remaining in different speed. Based on the graph, we can observe that in RPGM, the energy consumption increases when the number of node that access gateway increases. With RPGM, our protocol will consume low energy in condition low speed and low number of nodes accesses the gateway. In contrast with the random waypoint mobility, energy consumption becomes stable. The energy consumption decreases when the speed of mobility and the number of node access gateway increases.

We can conclude that the energy consumption of our modified protocol is lower despite the high speed and many nodes access gateway when using random waypoint mobility model. This phenomenon caused by the route reverse mechanism which applied in our proposed protocol. When the link is broken during communication, the nodes do not need to perform discovery mechanism to find new path. In that way, it reduces the energy consumption of each node.

Overall, our proposed protocol is suitable for random waypoint mobility model. Due to the different movement models between RWP and RPGM. The movement model in rwp, each node move randomly by its self. However the characteristic of rpgm is nodes move together with same direction and speed in order to keep distance between each node in one group. It caused the broken link in RPGM more than when we use RWP mobility models. As consequence, when broken link increases, the route discovery mechanism needs to re perform. It can increase the energy consumption of the protocol communication.

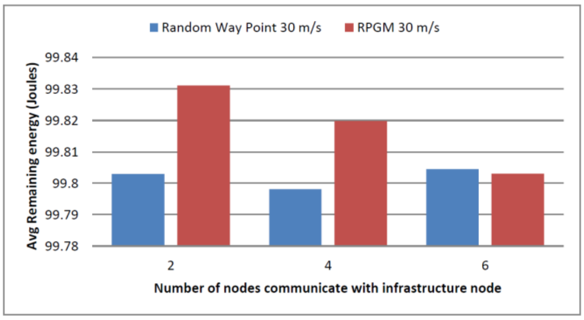

Fig. 7. Average remaining energy with speeds 30 m/s.

V. CONCLUSION

In this work, we evaluate the energy consumption of our proposed protocol. We conduct a simulation with NS-2 to find out the energy consumption in ad hoc network scenario with different number of source nodes, different maximum speeds, and also different mobility models. We use random waypoint and Reference Point Group Mobility (RPGM) models in order to know our protocol in low speed environment. The simulation result shows that our modified protocol is more stable in random waypoint mobility model with any different number of sources node and maximum speed. Under random waypoint mobility model, our proposed protocol consumes small energy when the speeds and number of nodes access the gateway increase.

In the future works, we plan to design an algorithm that has a capability to determine which nodes is an intermediate node with energy as a parameter and we will develop a trust mechanism communication between each node to increase the security of the proposed protocol.

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