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A Routing Protocol for Throughput Enhancement and Extend Network Lifetime in MANET

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Abstract: - Unlike a cellular network, MANET(Mobile Ad-hoc Networks) is constructed only by mobile nodes without access point. Since MANET has certain constraints, including power shortages, an unstable wireless environment, and node mobility, more power-efficient and reliable routing protocols are needed. Namely, it is very important that we consider Residual Battery Capacity and also Link Stability at the same time in MANET. Accordingly, this paper proposes RPTnE(A Routing Protocol for Throughput Enhancement and Extend Network Lifetime in MANET). The RPTnE considers Residual Battery Capacity and Link Stability. The RPTnE is based on AODV(Ad-hoc On-demand Distance Vector Routing). We use ns-2 for simulation. This simulation result shows that RPTnE is able to enhance throughput and extend network lifetime through the reduction of power consumption and distribution of traffic load that is centralized into special node.

Key-Words: - Throughput, Network Lifetime, Residual Battery, Signal Strength, Distance

1 Introduction

MANET is a network where no fixed infrastructure such as a base station or an AP(Access Point) exists, and nodes having a routing function communicate with each other [1], [15]. MANET is applicable for emergency situations like natural or human-induced disasters, military conflicts, emergency medical situations etc. It is featured by dynamic topology (infrastructureless), multi-hop communication, limited resources (bandwidth, CPU, battery, etc.) and limited security. These characteristics put special challenges in routing protocol design [2].

The one of the most important objectives of MANET routing protocol is to maximize energy efficiency, since nodes in MANET depend on limited energy resources. Several routing protocols for MANET's have been suggested in late 90's: DSR, AODV, DSDV, TORA and others [3], [4], [5], [6]. The classical MANET settings assume that neither node locations nor relative locations of other nodes are available.

The primary objectives of MANET routing protocols are to maximize network throughput, to maximize energy efficiency, maximize network lifetime, and to minimize dely. The network throughput is usually measured by packet delivery ratio while the most significant contribution to energy consumption is measured by routing overhead which is the number or size of routing control packets. The general consensus based on simulations is that reactive protocols, i.e., those finding routes on fly by request with no work in advance, perform better than proactive routing protocols, which try to maintain the routs for all source-destination pairs [7].

In hop-by-hop reactive routing protocols (e.g., used in Ad-hoc On-demand Distance Vector routing (DSR, AODV) can reduce end-to-end delay, since they consider mainly shortest path based on hop distance. But the lifetime of network is shortened by inefficient consumption of battery. To solve this problem, protocols such as MTPR, MCBR and BECT which consider power consumption have been introduced [8], [9]. However, those protocols can meet with good results just only one side (i.e., reduction of total power consumption or balanced consumption of energy). Accordingly, there is need for a new protocol solving these disadvantage.

In this paper, we propose the RPTnE(A Routing Protocol for Throughput Enhancement and Extend Network Lifetime in MANET). RPTnE is able to increase Network Lifetime through minimizing the whole energy consumption and distributing traffic load. In Section 2, describes proposed idea RPTnE in detail. Section 3 presents the efficiency of RPTnE through performance evaluation. Lastly, Section 4 presents the conclusion of this paper.

2 Proposed Idea

Until now, most of researches in routing protocols of MANET have been focused on only one aspect(e.g., a reduction in End-to-End delay, battery consumption, balanced energy consumption and Signal Strength [10], [11], [12], [16], [17], [18].

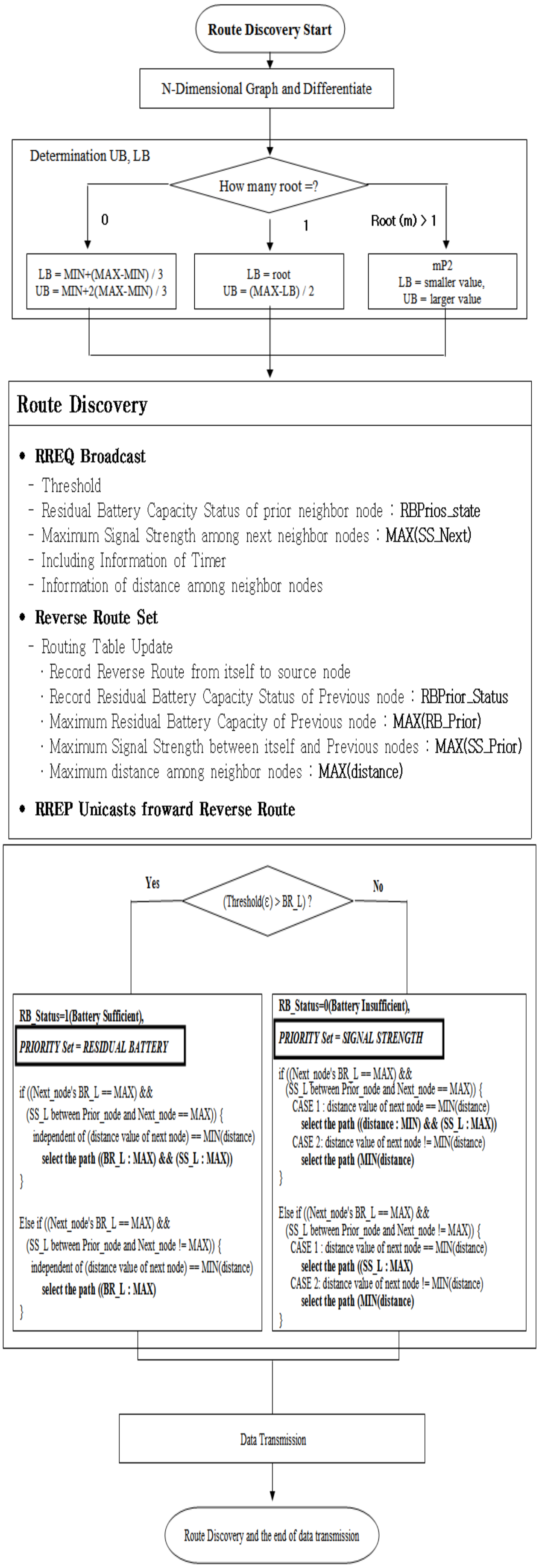


Fig 1. Route Discovery process of RPTnE

This paper proposes RPTnE(A Routing Protocol for Throughput Enhancement and Extend Network Lifetime in MANET). RPTnE chooses the node having the high Residual Battery and being more close and select the route with high Signal Strength. RPTnE applies threshold on Residual Battery Capacity and is based on AODV. Route discovery process of RPTnE is described in **"Fig. 1"**

2.1 Determination of Threshold

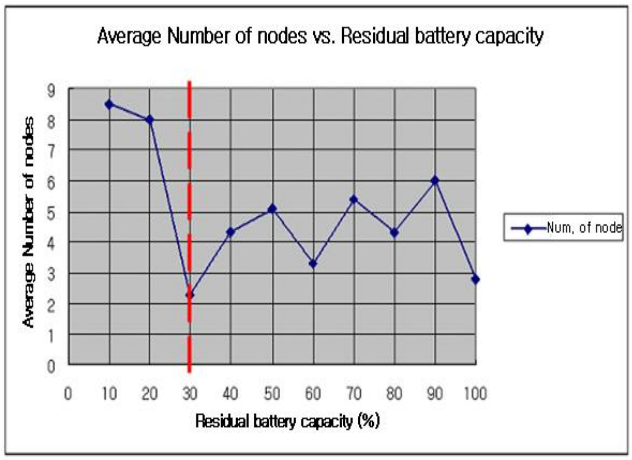


Fig 2. Average Number of nodes vs. the Residual Battery Capacity in AODV-based in MANET

We simulate 500 times in condition of distributing 50 nodes in a general MANET environment (i.e., an area of 1000m ×1000m). We compute the residual battery capacity per node whenever the simulation is complete. And then we can draw a graph about average number of nodes vs. residual battery capacity. In this case, threshold is determined by a variation of the inclination in the graph.

"Fig. 2", represents average Residual Battery Capacity of each node based on AODV in MANET. The point of inflection value on the graph is regarded as being a reference point at which data characteristic values change, and thus, the point of reflection value is able to be set as a threshold for determining the level of Residual Battery Capacity. We assign the minimum point of inflection value(=30) to default threshold.

2.2 Route Discovery

RPTnE uses three vector as a main metric during Route Discovery, (***Residual Battery, Distance, Signal Strength***). Assuming that a routing table is initialized, a source node broadcasts a RREQ message to neighbor nodes in order to detect a route from the source node to the destination node, the RREQ message contains fields follow as **Table 1**.

Table 1. RREQ Message Format

Packet Field	Description
Type of Packet	Type of packet RREQ packet(1)
Hop Count	Number of hops from source node to node receiving RREQ
Source IP Address	Address of node first generates RREQ
Source Sequence Number	Sequence number used to generate RREP by source node
Broadcast ID	Sequence number used to generate RREQ
Destination IP Address	Address of node to which RREQ will be delivered
Destination Sequence Number	Sequence number used to generate RREP by destination node
MAX(SS_Next)	Maximum signal strength between Source node and next node
Threshold	Threshold corresponding to battery capacity
RB_oneself	Battery capacity of source node

Threshold is included in RREQ message and it is used for determination of the Residual Battery Capacity level. And also the own Residual Battery Capacity***(RB_Oneself)***, maximum signal strength between the source node, the neighbor nodes***{MAX(SS_Next)}*** and ***MAX(distance)*** metric are included in RREQ message.

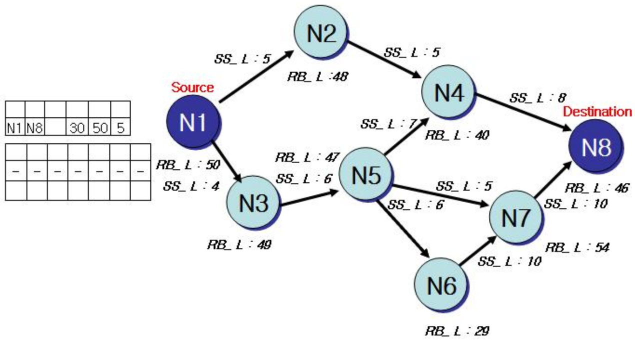
If an intermediate nodes receiving the RREQ message are not a destination node, the intermediate nodes based on the received RREQ message record or update a reverse route from oneself to the source node, the Residual Battery status***(RBPrior_Status)***, the maximum Residual Battery Capacity of previous node***{MAX(RB_Prior)}***, the maximum Signal Strength between the intermediate node and the previous nodes***{MAX(SS_Prior)}***, ***MAX(distance)*** and ***priority*** information in the routing table.

Since the RREQ message may be redundantly received from more nodes, the redundantly received messages are only used to determine whether the routing table is updated or not through comparing field values of the own routing table with field values of the redundant RREQ message. And then the redundant RREQ messages are not forwarded and discarded.

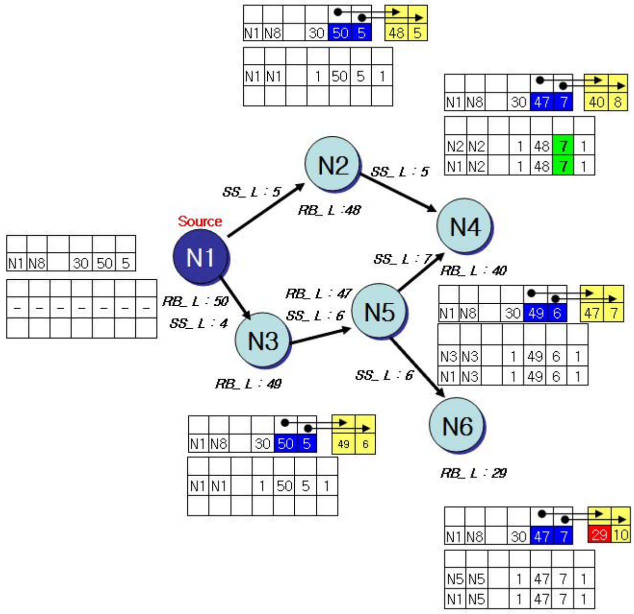
After updating the routing table, the intermediate node respectively updates the residual battery capacity field value and the signal strength field value in the received RREQ message with its battery capacity and the maximum signal strength between the intermediate node and neighbor nodes, and then broadcasts the RREQ message.

If the RREQ message is delivered to the destination node in this way, each node acquires information regarding the reverse route to the source node and the maximum Residual Battery Capacity and Signal Strength of each of neighbor nodes that are spaced one hop distance in the network.

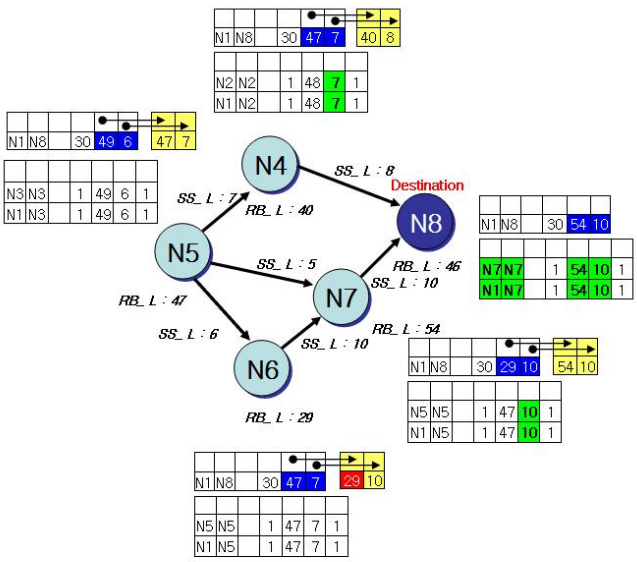
"Fig. 3" represents route discovery from source node N1 to destination node N8. A routing table is initialized, the source node N1 inserts ***Threshold=30***, ***RB_Oneself=50***, ***MAX(SS_ Next)=5*** into an RREQ message and broadcasts the RREQ message.



(a) Initialization of Network Topology



(b) Procedure for RREQ Forwarding(1)



(b) Procedure for RREQ Forwarding(2)

Fig. 3. Procedure for RREQ Forwarding

Node N2 receiving the RREQ message from the source node N1 records in the routing table information regarding a reverse route(N1,N1) from node N2 to the source node N1, ***RBPrior_Status=1, MAX(RB_Prior) = 50, MAX(SS_Prior)=5***. Since Residual Battery Capacity of the node N2 is sufficient, priority is assigned to Residual Battery Capacity, and thus, Priority=1 is recorded. Node N3 receives the same RREQ message with node N2 from the source node, and therefore node N3 records the same information with routing table of node N2.

Next, the nodes N2 and N3 forward the RREQ messages. In detail, each of them updates the field values of its Residual Battery Capacity and the field values of Signal Strength between itself and a neighbor node on the basis of itself and then forwarding the RREQ message. That is, the node N2 updates the RREQ message with ***RB_Oneself=48, MAX(SS_ Next)=5*** and forwards it to a neighbor node N4, and the node N3 updates the RREQ message with ***RB_Oneself=49, MAX(SS_Next) =6*** and forwards it to a neighbor node N5.

The node N4 receiving the RREQ message from the node N2 records information regarding a reverse route{(N2,N2), (N1,N2)} from the node N4 to the source node N1, ***RBPrior_Status=1, MAX(RB_ Prior)=48, MAX(SS_Prior)=5 and Priority=1*** in the routing table. The node N5 receiving the RREQ message from the node N3 records information regarding a reverse route{(N3, N3),(N1,N3)} from the node N5 to the source node N1, ***RBPrior_Status=1, MAX(RB_Prior=49, MAX (SS_Prior)=6 and Priority =1*** in the routing table.

Next, the node N4 updates the RREQ message with ***RB_Onself=40, MAX(SS_Next)=8*** and forwards it to the neighbor node N8, and the node N5 updates the RREQ message with ***RB_Oneself=47, MAX(SS_ Next)=7*** and forwards it to neighbor nodes N4, N6, and N7. The destination node N8 receiving the RREQ message from the node N4 records information regarding a reverse route{(N4,N4), (N1,N4)} from the destination node N8 to the source node N1, ***RBPrior_Status=1, MAX(RB_Prior)=40, MAX(SS_ Prior)=8, Priority =1*** in the routing table. The node N4 receives the RREQ messages from node N2 and N5.

The node N4 receives redundant RREQ message from node N5. At this time node N4 respectively compares the values of RB_Oneself and MAX(SS_Next) fields in the RREQ message received from the node N5 with the values of the ***MAX(RB_Prior)*** and ***MAX(SS_Prior)*** fields recorded in the routing table, and update the values of the ***MAX(RB_Prior) and MAX(SS_Prior)*** fields in the routing table only when they are greater than the values of the ***MAX(RB_Prior)*** and ***MAX(SS_Prior)*** fields in the RREQ message.

The node N7 records information regarding a reverse route{(N5,N5),(N1,N5)} from the node N7 to the source node N1, ***RBPrior_Status=1, MAX(RB_Prior) =47, MAX(SS_Prior)=7 and Priority=1*** in the routing table. The node N6 records information regarding a reverse route{(N5,N5),(N1,N5)} from the node N6 to the source node N1, ***RBPrior_Status=1, MAX(RB_ Prior)=47, MAX(SS_Prior)=7 and Priority =1*** in the routing table.

Thereafter, each of the nodes N4, N6, and N7 updates the values of the ***RB_Oneself*** and ***MAX(SS_Next)*** fields in the RREQ message and forwards the updated RREQ message to its neighbor node. In this case, the RREQ messages redundantly received by the node N4 are used only as information to update the routing table and discarded. Thus, only the nodes N6 and N7 forward the RREQ messages from the node N5. That is, the node N6 updates the RREQ message with ***RB_Oneself=20*** and ***MAX(SS_Next)=10*** and forwards it to the node N7, and the node N7 updates the RREQ message with ***RB_Oneself=54*** and ***MAX(SS_Next)=10*** and forwards it to the destination node N8.

The node N7 redundantly receives the RREQ message from the node N6, and compares the values of the ***RB_Oneself*** and ***MAX (SS_Next***) fields in the RREQ message with those of the existing ***MAX (RB_Prior)*** and ***MAX(SS_Prior)*** fields in the routing table. Since ***MAX(RB_Prior)=47*** in the routing table is greater than ***RB_Oneself=29*** in the RREQ message, ***MAX(RB_Prior)=47*** is not updated. However, ***MAX(SS_ Prior)=7***, which is the value of the signal strength field in the routing table, is less than ***MAX(SS_Next)=10*** in the RREQ message, the signal strength field in the routing table is updated with ***MAX(SS_Prior)=10***. The RREQ message that the node N7 receives from the node N6 is redundant, and thus, it is used only as reference information to update the values of the Residual Battery Capacity and Signal Strength fields in the routing table of the node N7 and is not further forwarded.

The destination node N8 receives the redundant RREQ message from both the nodes N4 and N7. In the redundant RREQ message that the node N8 receives from the node N7, ***RB_Oneself=54*** and ***MAX(SS_Next)=10*** are greater than ***MAX(RB_ Prior)=10*** and ***MAX(SS_Prior)=8*** in the routing table, and thus, ***MAX(RB_Prior)=10*** and ***MAX(SS_Prior) =8*** are respectively updated with ***MAX(RB_Prior)=54*** and ***MAX(SS_Next)=10***.

The destination node N8 receiving the RREQ message unicast an RREP message to the RREQ transmitter. The RREP message is unicasted based on the reverse route in the routing table of each node. If the source node N1 finally receives the RREP message, the overall route is set. To set the route, both the Residual Battery Capacity and Signal Strengths of each node are considered, and whether priority will be allocated to Residual Battery Capacity or Signal Strength is determined according to a threshold for the residual battery capacity.

Table 2. RREP Message Format

Packet Field	Description
Type of Packet	Type of packet RREP packet(2)
Hop count	Space storing hop count needed to transmit RREQ from source node to destination node
Source IP address	Address of node which generates RREQ and will receive RREP
Destination IP address	Address of node generating RREP
Destination sequence number	Sequence number used to generate RREP by destination node
Life time	Determination of effective time of route generated by RREP

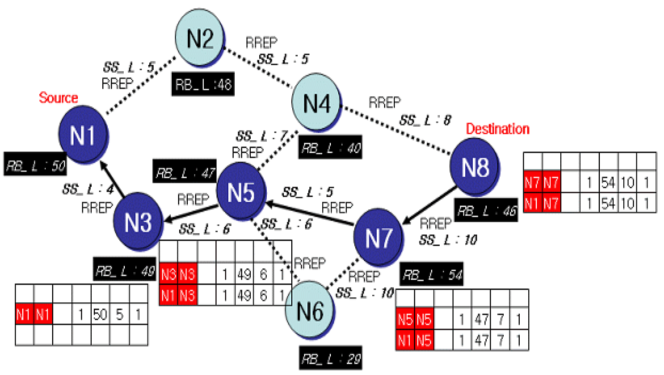


Fig. 4. Procedure for RREP Message Reply

Assume that the distance between node N5 and node N7 is more close than other distance, (between node N5 and node N4, between node N5 and node N6). If two neighbor is far from other node, the link is liable to be broken because the node is apt to move out of the Signal Strength range. For that reason, the node that is far from other node isn't participated in setting up route. Referring to **"Fig 4"**, while the RREP message is unicasted from node N8 to node N1 like this N8-N7-N5-N3-N1 based on information regarding a reverse route in a routing table of each node, finally a route from a source node N1 to a destination node N8 is set.

2.3 Packet Forwarding

First, RPTnE acquires information regarding the maximum Residual Battery Capacity and Signal. Next, accordance to the Residual Battery Capacity, Signal Strength and distance, the route is settled.

2.3.1 When the Residual Battery Capacity of All nodes is sufficient (the Residual Battery Capacity > Threshold(30))

- **Case 1 : When both the Residual Battery Capacity and the Signal Strength are maximum**

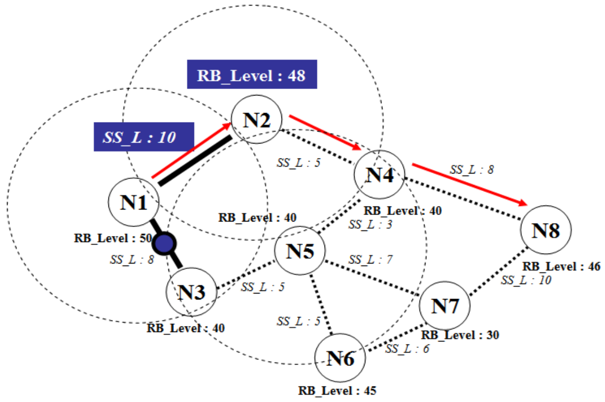


Fig 5. When the Residual Battery Capacity is sufficient

Since the Residual Battery Capacity of neighbor nodes that are spaced one hop distance from itself is sufficient, priority is assigned to the Residual Battery Capacity. Referring to **"Fig 5"**, the Residual Battery Capacity of node N2(48) is greater than that of node N3(40). The distance between source and node N2 is longer than that between source and node N3. Since the node N2 is at the edge of the Signal Strength range, the link participating node N2 is apt to be broken. If node N2 is selected to route, more transmission power will be consumed to data packet. But source node select the node N2, since the Residual Battery Capacity of whole nodes in the network is sufficient and also the Residual Battery Capacity and the Signal Strength is maximum. Thus, a data packet is transmitted via nodes N1-N2-N4-N8.

- **Case 2 : When the Residual Battery Capacity is maximum but the Signal Strength is not maximum**

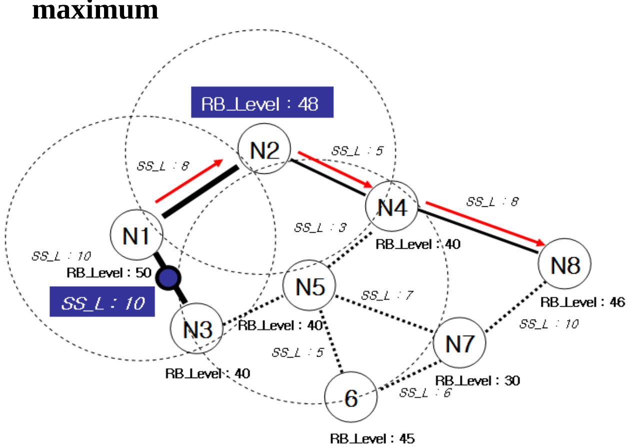


Fig 6. When the Residual Battery Capacity is sufficient

Since the Residual Battery Capacity is sufficient, a route is selected by assigning priority to the Residual Battery Capacity. Referring to **“Fig 6”**, a route is selected similarly in **“Fig 5”**. The Signal Strength of nodes N1-N3(10) is greater than that of nodes N1-N2(8) and the Residual Battery Capacity of node N2(48) is greater than that of node N3(40). Since the Residual Battery Capacity of whole nodes in the network is sufficient and priority is set by the Residual Battery Capacity, node N2 is selected. Accordingly, a data packet is transmitted via the nodes N1-N2-N4-N8.

2.3.2 When the Residual Battery Capacity of All nodes is insufficient (the Residual Battery Capacity < Threshold(30))

Since each node’s energy is insufficient, Link Stability by the Signal Strength information and distance are regarded more important factor. Namely, it can reduce the route reconstruction count through the link stability and avoid being turned off specific node that has the insufficient Residual Battery Capacity by using repeatedly.

- **Case 1 : When both the Residual Battery Capacity and the Signal Strength are maximum**

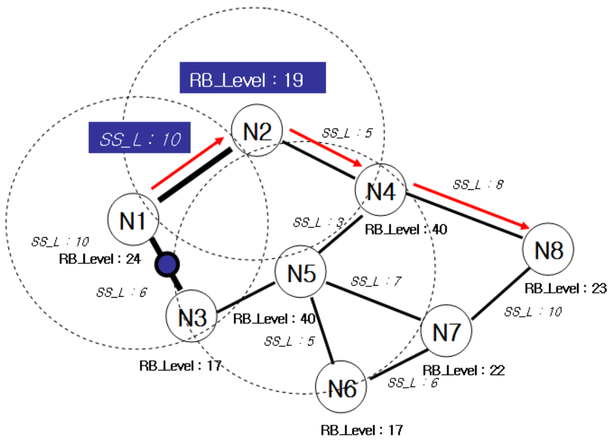


Fig 7. When the Residual Battery Capacity is insufficient

Since the Residual Battery Capacity of neighbor nodes that are spaced one hop distance from itself is insufficient, a route is set by assigning priority to Signal Strength. Referring to **“Fig 7”**, since the Signal Strength of nodes N1-N2(=10) is greater than that of nodes N1-N3(=6), the node N3 is selected. Thus, a data packet is delivered via the nodes N1-N2-N4 -N8.

- **Case 2 : When the Signal Strength is maximum but the Residual Battery Capacity is not maximum**

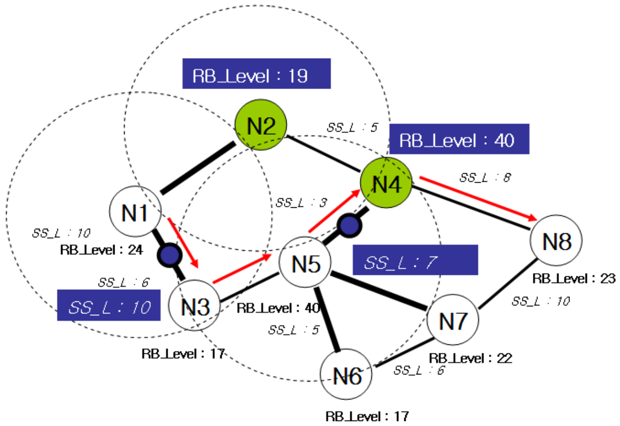


Fig 8. When the Residual Battery Capacity is insufficient

Since the Residual Battery is insufficient, a route is selected by assigning priority to Signal Strength. Referring to **“Fig 8”**, a source node N1 checks the Signal Strength of each neighbor node that is spaced one hop distance from itself, and selects a route having a maximum value. Although the Residual Battery Capacity of the node N2 is greater than that of the node N3, the node N3 is selected, since the Signal Strength of the nodes N1-N3 is greater than that of the nodes N1-N2. And also the distance of node N3 is shorter than that of node N2, so it is able to reduce the transmission power. Among nodes N4, N6, and N7, the node N4 having a Residual Battery Capacity(40) is selected, instead of the node N7 that has maximum Signal Strength(7). Since there is no node which has both maximum Residual Battery Capacity and Signal Strength, priority is changed into distance vector. Accordingly, a data packet is delivered via the nodes N1-N3-N5-N4-N8.

2.3.3 When the Residual Battery Capacity is Mixed Status (exist sufficient and insufficient node in network)

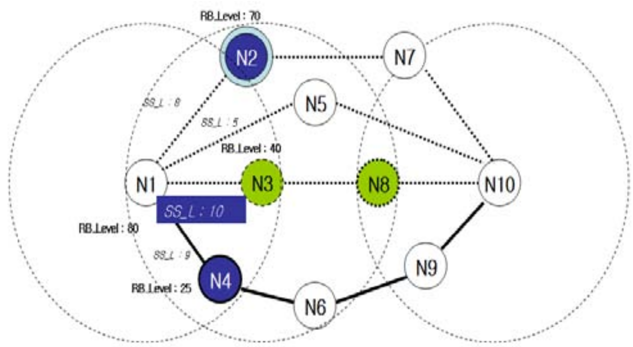


Fig 9. Routing when Residual Battery Capacity is mixed status(sufficient and insufficient)

The distance vector has priority on decision of route. Referring to **“Fig 9”**, the Residual Battery Capacity of node N2(70) is greater than that of node N3(40), node N4(25). The Signal Strength of node N1-N3(10) is greater than that of node N1-N2(8), node N1-N4(9). And the distance node N1-N4 is shortest. In that case, the route is selected by shortest distance vector. Thus, data packets are transmitted via nodes N1-N4-N6-N9-N10.

As described above, in RPTnE, a data packet is delivered via a route that is set by five cases.

2.4 Route Maintenance

During transmission of data packet, when one of nodes is moved or turned off, previous node transmits an RERR (Route Error) message and then transmits data via an alternative route. RPTnE reserves the alternative to use it when route is broken. Because RPTnE knows not only Signal Strength but also Residual Battery Capacity, so RPTnE is able to reserve the path that is a good condition of Residual Battery Capacity or Signal Strength.

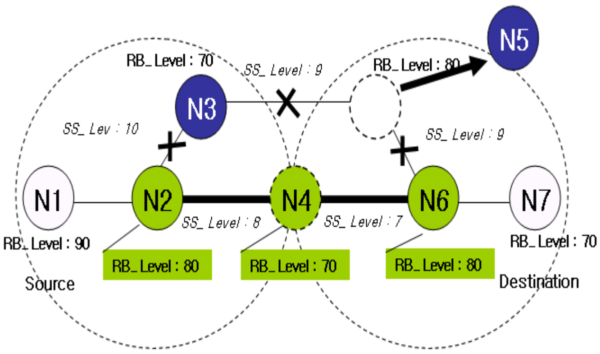


Fig 10. Route Recovery via Alternative Route

Referring to **"Fig 10"**, the alternative route N1-N2-N4-N6-N7 is selected. If there is no alternative route that is a good battery condition, data packets are transmitted through the shortest path no matter what it has insufficient Residual Battery Capacity.

3 Performance Evaluation

This section compares the performance of RPTnE with those of the existing protocols through NS-2 [13]. An energy model was based on the Lucent 2Mb/s WaveLAN 802.11 LAN card. For performance evaluation, transmission energy(1.4W), receiving energy(1.0W), listening/Idle energy(0.83W), and sleeping energy(0.043W) were used [14]. We assume that energy consumption in the idle mode is ignored and each node operates in a non-promiscuous mode. Simulation result shows that when pause time is 0 second, mobile nodes always move during the simulation time, and when pause time is 900 seconds, data is exchanged between mobile nodes at a fixed location. The simulation result was obtained and analyzed separately according to both the throughput and the efficiency of energy, and an evaluation environment is as **Table 2**.

Table 2. Simulation Environment

Simulation Time	900 sec
Terrain Dimensions	1000×1000
Number of nodes	50
Node placement	UNIFORM / RANDOM
Routing protocol	DSR / BECT / BRPSS
Traffic	. CBR . 10, 20, 30 sources . Packet size : 512 bytes . Packet Interval : 5 packets/s
Movement	. Random waypoint - pause time : 0 to 900 sec - speed : min 0, max 25m/s

3.1 Control Packet Overhead

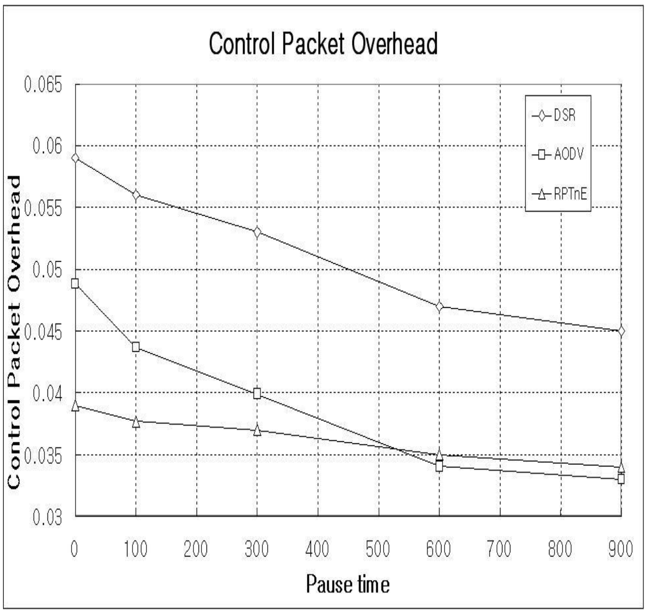


Fig 11. Control Packet Overhead vs. Pause

"Fig 11" represents a control packet overhead. Since AODV, DSR use the hop count as a main metric, performance is better than RPTnE and other power aware routing protocols in static environment. But in dynamic environment, route reconstructions happen frequently and much more special nodes are turned-off in case that the factor related to power is not considered. If there exist many route reconstruction, control packet overhead is increased. Since RPTnE considers the Residual Battery Capacity and Link Stability, it is able to reduce the count of route reconstruction much more than protocols that just only consider hop count(AODV, DSR). For that reason, the performance of RPTnE is best in dynamic environment.

3.2 Data Delivery Ratio

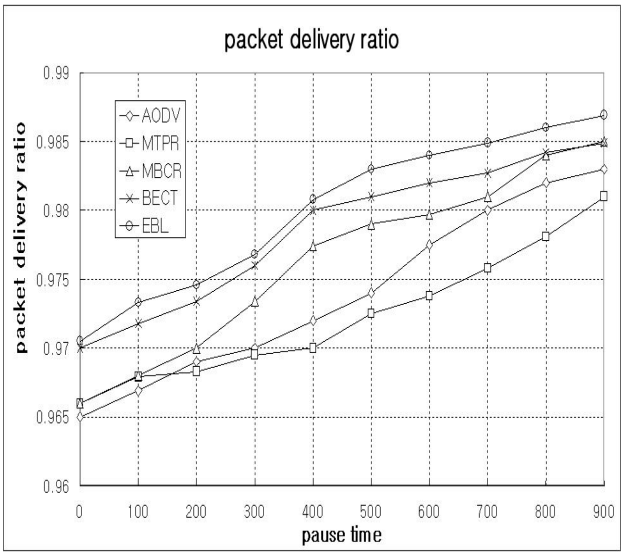


Fig 12. Data Delivery Rate vs. Pause time

Referring to **"Fig 12"**, the ratio of data delivery in all of AODV, MTPR, MBCR, BECT, and RPTnE is 96.5% or more. In particular, the ratio of data delivery in RPTnE is 97% or more. Also, the performance of BECT appears to be similar to the performance of RPTnE. This reason is that BECT use both the threshold about energy and shortest path, and then protect breaking link and maintain the load balancing. For that reason, data packet is able to be transmitted through the alternative path efficiently with reducing packet loss.

The ratio of data delivery in RPTnE and BECT becomes greater than in AODV, MTPR, and MBCR in more dynamic environment. In the case of RPTnE, the ratio of data delivery is high by maintaining a stable route in consideration of both Residual Battery Capacity and Signal Strength. That is, the ratio of data delivery is increased by realizing balanced use of battery power by participating all of nodes in a network in setting a route, and reducing the rate of data packet loss due to link break by forming a stable link according to Signal Strength. In the case of BECT, the rate of overall data delivery is good by realizing balanced use of energy according to a threshold.

3.3 Average Energy Standard Deviation

Whether the battery consumptions of nodes are balanced is determined by using a standard deviation of battery consumption of nodes after simulation for 900 seconds. If the standard deviation of the Residual Battery Capacity is great, it means that balanced battery consumption is not achieved since the number of times that specific nodes are frequently used for routing.

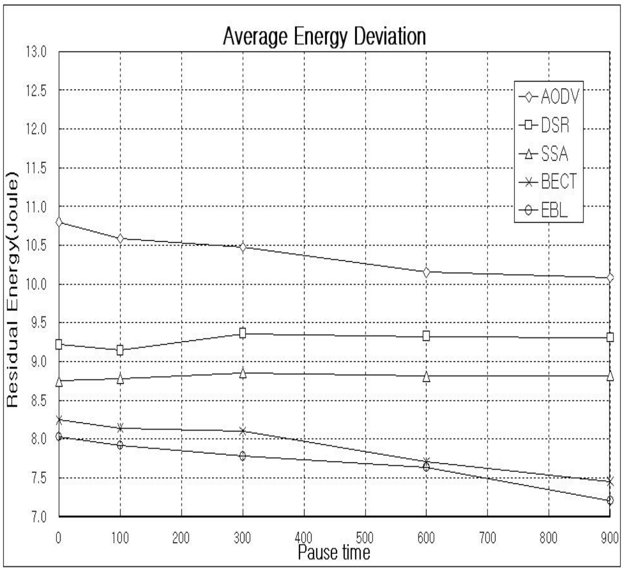


Fig 13. Standard Deviation of the Residual Battery Capacity vs. Pause

In contrast, if the standard deviation is small, balanced battery consumption is achieved since the number of times that the specific nodes are not frequently used for routing. **"Fig 13"** represents standard deviation of Residual Battery Capacity. In a dynamic environment, the performance of RPTnE is 35% higher than that of AODV, 14% higher than that of MTPR, and 9% higher than that of MBCR and 3% higher than that of BECT.

In a static environment, the performance of RPTnE is 40% higher than that of AODV, 30% higher than that of MTPR, 22% higher than that of MBCR and 3% higher than that of BECT. In BECT is lower than that of RPTnE because the Link Stability is not considered. In MTPR, since a major metric is to minimize the transmission power consumption, the Residual Battery Capacity is not considered, thereby increasing the number of times that specific nodes will be used for routing.

In conclusion, a protocol that considers both transmission power and Link Stability is able to achieve balanced battery consumption. In particular, RPTnE considers both Residual Battery Capacity and Signal Strengths allows balanced battery consumption more than protocols that consider hop count or a reduction of battery consumption.

3.4 Average Energy Consumption

"Fig 14" represents average rate of energy consumption versus pause time. In a dynamic environment, the performance of RPTnE is 8% higher than that of AODV, 2% higher than that of MTPR, 5% higher than that of MBCR, and 3% higher than that of BECT.

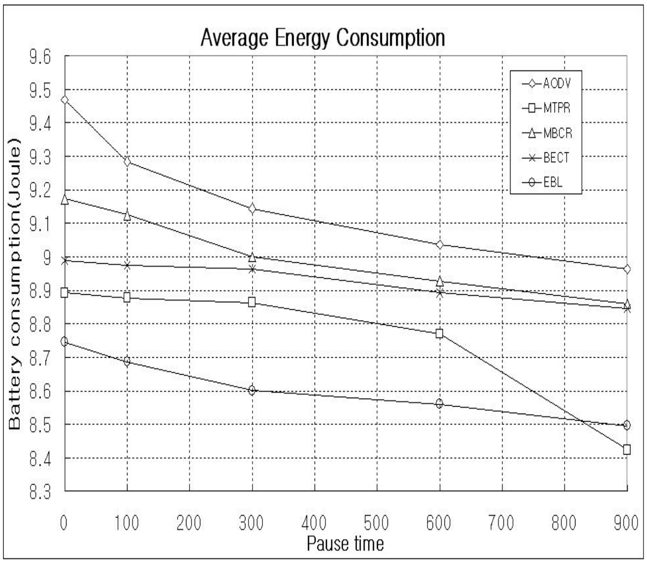


Fig 14. Average rate of Energy Consumption vs. Pause Time

In a static environment, the performance of RPTnE is 6% higher than that of AODV, 4% higher than that of MBCR, and 4% higher than that of BECT. However, the performance of RPTnE is 1% lower than that of MTPR. As a result, MTPR becomes substantially similar to a protocol that is aimed at a minimum of hop count, thus not significantly reducing energy consumption.

However, since RPTnE considers both Residual Battery Capacity and Link Stability, it reduces battery consumption through transmitting packet via a route having more shorter or the smallest amount of transmission power. That is, various information(i.e., the distance between two nodes, Residual Battery Capacity, and Link Stability) is preferably considered in order to reduce battery consumption.

4 Conclusion

This paper proposes RPTnE that is able to enhance throughput and extend network lifetime through the minimization of energy consumption and allowance of balanced energy consumption. RPTnE sets the approximate shortest route to minimize transmission delay. Also, a route is selected in consideration of Residual Battery Capacity, Link Stability and distance vector in order to prevent imbalanced energy consumption of nodes. The result of a simulation through NS-2 shows that the performance of RPTnE is better than those of protocols that use only hop count as a metric or consider only one of low-power aspects, in terms of energy consumption.

In conclusion, it is possible to use energy more efficiently by setting a stable route selected in consideration of both Residual Battery Capacity and Link Stability, and preventing specific nodes from being overused for routing by assigning a threshold for Residual Battery Capacity in MANET.

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