The Residual Battery Capacity and Signal Strength Based on Power-Aware Routing Protocol in Mobile Ad-hoc Network[1]

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Abstract: The shortest path is only maintained during short time and each mobile nodes communicate each other by depending on battery in Mobile Ad-hoc Network. So many researches that are to overcome a limitation or consider a power have executed actively by many researcher. But these protocols are considered only one side of link stability or power consumption, so we can make high of stability but power consumption is inefficient. And also we can reduce power consumption of network but the protocol can't make power consumption of balancing. For that reason we suggest Residual Battery and Signal Strength Based Power-aware Routing Protocol in Mobile Ad-hoc Network(RBSSPR). The RBSSPR considers residual of battery and signal strength so it keeps not only a load balancing but also minimizing of power consumption. Simulation result shows that RBSSPR can extend lifetime of network through distribution of traffic that is centralized into special node and reducing of power consumption.

Key-Words: Mobile Ad-hoc Network, Signal Strength, Residual Battery Capacity, Power-aware Routing Protocol

1 Introduction

A Mobile Ad-hoc Network(MANET) is a network where no fixed infrastructure such as a base station or an access point (AP) exists, and nodes having a routing function communicate with each other. The MANET is applicable for emergency situations like natural or human-induced disasters, military conflicts, emergency medical situations etc.

The MANET routing protocols are categorized into table-driven and on-demand protocol [1]. In the table-driven protocol, each node must update routing table whenever network topology changes. For that reason, transmission overhead about a control packet is increased. In contrast, in the on-demand protocol, a transmitter sets a route only if needed, thereby reducing the overhead due to the control packet. On-demand algorithms are Dynamic Source Routing (DSR) and Ad-hoc On-demand Distance Vector Routing (AODV). However, since the DSR and the AODV use as a metric only hop count representing the distance between nodes, the end-to-end distance may be short but the lifetime of the network is shortened by inefficient consumption of energy. To solve this problem, protocols such as MTPR, MBCR and BECT, which consider power consumption, have been introduced [2, 3]. However, they are focused on only one aspect of a reduction in energy consumption or balanced consumption of energy. If only energy consumption is considered, total energy consumption in the network can be reduced but balanced consumption of energy among all of nodes in the network is not achieved. If only balanced consumption of energy is considered, balanced consumption of energy among all of the nodes in the network can be achieved but total energy consumption in the network is not significantly reduced. Accordingly, there is need for a new protocol that provides a solution to this problem.

This paper proposes the Residual Battery and Signal Strength Based Power-aware Routing Protocol in Mobile Ad-hoc Network(RBSSPR) that minimizes whole energy consumption through consideration of both residual battery capacity and signal strengths and also increases the lifetime of network through applying a threshold to a residual battery capacity.

Section 2 describes proposed RBSSPR in detail. Section 3 presents the efficiency of RBSSPR through performance evaluation. Lastly, Section 4 presents the conclusion of this paper.

2 Proposed Algorithm

Until now, most of researches into MANET routing protocols have been focused on only one aspect (e.g., a reduction in End-to-End delay, a reduction in battery consumption, or balanced energy consump-

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tion), so this paper proposes RBSSPR that not only minimizes power consumption in consideration of both residual battery capacity and signal strengths but also realizes balanced power consumption by using a threshold related to residual battery capacity [4]. RBSSPR is based on AODV and route discovery process of RBSSPR is described in Fig. 2.

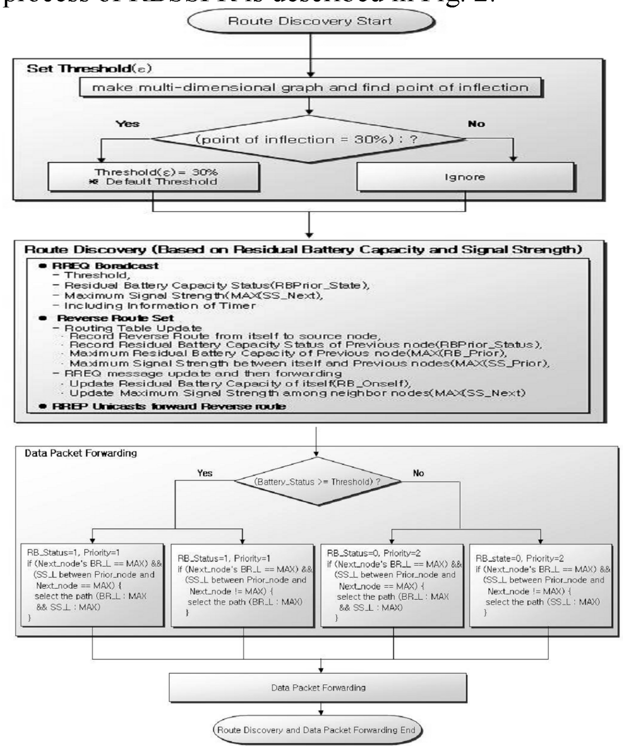

Fig. 2 Route Discovery Process of BRPSS

2.1 Determination of Threshold

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. Threshold can exist a large number and the minimum point of inflection value of 30% is set as a default threshold.

2.2 Route Discovery

Assuming that a routing table is initialized, a source node broadcasts an RREQ message to neighbor nodes in order to detect a route from the source node to the destination node, the RREQ message containing a threshold that is a reference value for determining the level of residual battery capacity (Threshold), the own residual battery capacity (RB_Oneself) and a maximum signal strength between the source node and the neighbor nodes {MAX(SS_Next)}. If 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 (Reverse Route), 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)} and priority information in the routing table.

Since the RREQ message may be redundantly received from other nodes, the messages received redundantly 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.

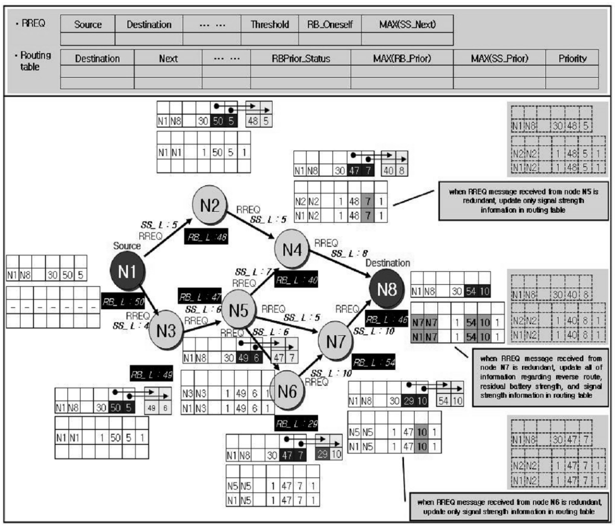

Fig. 3 Procedure for RREQ Forwarding

Fig. 3 represents procedure for RREQ Forwarding from source node N1 to destination node N8.

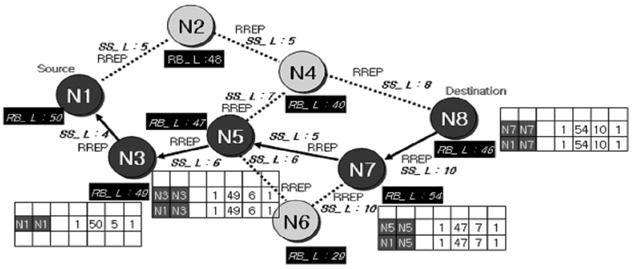

Fig. 4 Procedure for RREP Message Reply

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, RBSSPR acquires information regarding the maximum residual battery capacity and signal strength of nodes that are spaced one hop distance from itself. Next, whether the residual battery capacity of each node is sufficient is identified by using the residual battery capacity threshold of each node. If the residual battery capacity of a node is identified to be sufficient, a route is set by assigning priority to residual battery capacity. If the residual battery capacity of a node is identified to be insufficient, a route is set by assigning priority to the signal strength of nodes. That is, a data packet is transmitted via a route for four cases categorized according to residual battery capacity and signal strength determined by a threshold, as follows.

2.3.1 When the residual battery capacity of a node is identified to be sufficient

(1) Case 1: When both residual battery capacity and signal strength are maximum

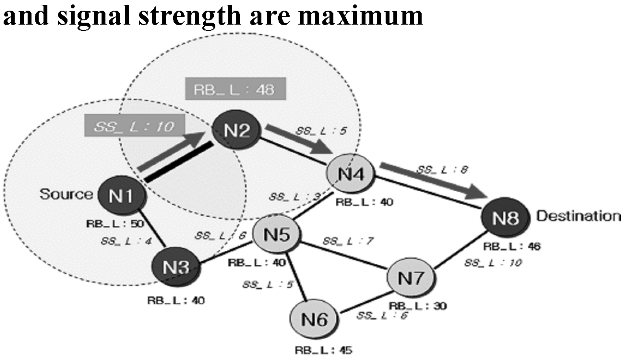

Fig. 5 Residual battery capacity is sufficient (1)

As described above, if the residual battery capacity is identified to be sufficient, priority is assigned to residual battery capacity. Referring to Fig. 5, two neighbor nodes N2 and N3 spaced one hop distance from a source node N1 are compared with each other. Since the node N2 having a residual battery capacity (=48) is greater than the residual battery capacity of the node N3, the node N2 is selected to route. Thus, a data packet is transmitted via nodes N1-N2-N4-N8. The signal strength of the nodes N1-N2 is greater than that the signal strength of the nodes N1-N3, and thus, the route is the most idealistic for the topology.

(2) Case 2: Residual battery capacity is maximum but signal strength is not maximum

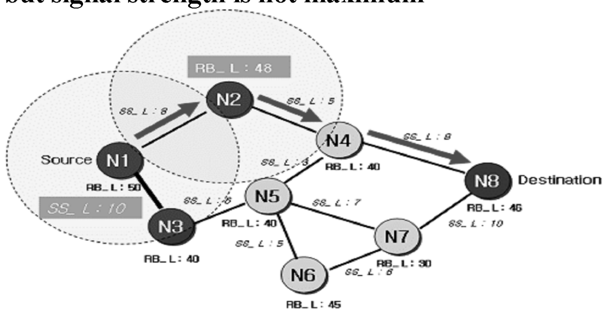

Fig. 6 Residual battery capacity is sufficient (2)

Since the residual battery capacity of node is identified to be sufficient, a route is selected by assigning priority to residual battery capacity. That is, referring to Fig. 6, a route is selected similarly in Fig. 5. Thus, although the signal strength of the nodes N1-N2 (=8) is smaller than the signal strength of the nodes N1-N3 (=10), the node N2 having a residual battery capacity (=48) is greater than the residual battery capacity of the node N3 (=40), so the 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 a node is identified to be insufficient

(1) Case 1: When both residual battery and signal strength are maximum

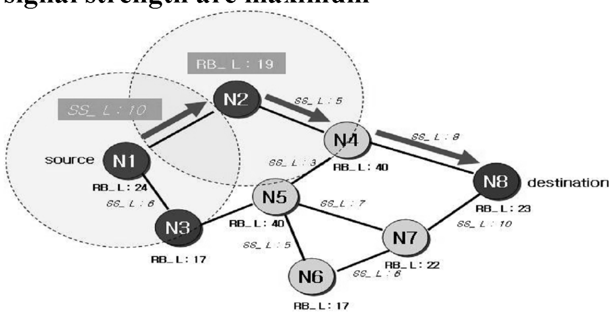

Fig. 7 Residual battery capacity is insufficient (1)

When 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 signals strength of nodes N1-N2 (=10) is greater than the signal strength of nodes N1-N3 (=6), the node N3 is selected. Thus, a data packet is delivered via the nodes N1-N2-N4 -N8. In Fig. 8, not only the signal strength is the largest but also residual battery capacity is maximum, and thus, the route is the most idealistic when battery capacity is not sufficient.

(2) Case 2: When residual battery capacity is maximum but signal strength is not maximum

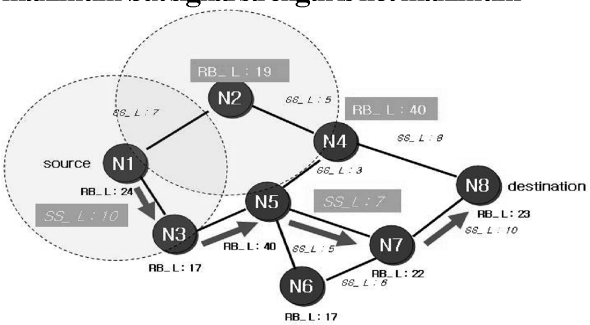

Fig. 8 Residual battery capacity is insufficient(2)

Since the residual battery capacity of a node 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. That is, 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 the signal strength of the nodes N1-N2. Since the node N3 has a single route, the node N5 is selected. Then, among nodes N4, N6, and N7 that are spaced one hop distance from the node N5, the node N4 having a residual battery capacity (=40) is not selected, instead, the node N7 is selected since the signal strength (=7) is maximum value. Accordingly, a data packet is delivered via the nodes N1-N3-N5-N7-N8.

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. The alternative route is selected based on priority assigned to residual battery capacity during routing. When a route was set by assigning priority to residual battery capacity, if there exist a route including the signal strength is the largest, the route is selected as the alternative route. On the contrary, when the route was set by assigning priority to signal strength, if there exist a route including the residual battery capacity is the largest, the route is selected as the alternative route.

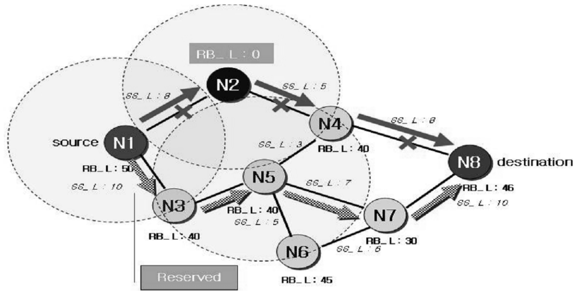

Fig. 9 Route Recovery via alternative Route

Referring to Fig. 9, node N3 was selected since priority is assigned to residual battery capacity by threshold. In this case, a source node N1 can select an alternative route including the node N3 since the signal strengths of the nodes N1- N3 is the largest. If the source node N1 selects the node N3, not an initial node N2, the alternative route N1-N3-N5-N7 -N8 is set by assigning priority to signal strength.

3 Performance Evaluation

This section compares the performance of RBSSPR with those of the existing protocols through NS-2. 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 [5]. We assume that energy consumption in the idle mode is ignored and an evaluation environment is as follows:

Table 1. Simulation environments

Simulation Time	900 sec
Terrain Dimensions	1000×1000
Number of nodes	50
Node placement	UNIFORM / RANDOM
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 End-to-End Delay

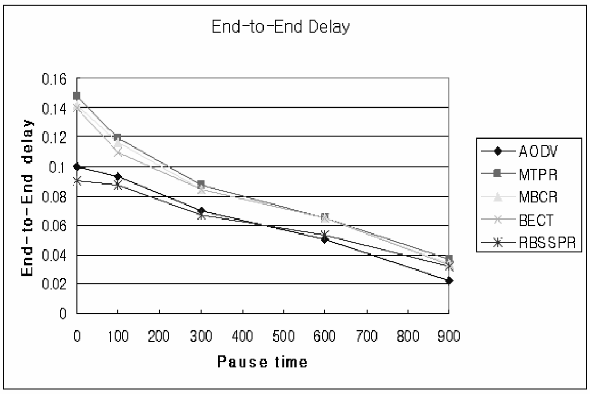

Fig. 10 End-to-End Delay vs. Pause Time

Fig. 10 represents an end-to-end delay. The graph shows that the performances of MTPR, MBCR, BECT, and RBSSRP that considering power are better than that of AODV. In particular, the performance of RBSSPR that considers both residual battery capacity and signal strength is best. However, the performance of AODV is best in the environment of the less mobility. Since AODV uses hop count as a major metric, it shows lower end-to-end delay in a static environment. In contrast, the more nodes that are turned off due to inefficient use of battery power and the more frequently a route is reset in the environment of large mobility, thereby increasing the end-to-end delay.

In the case of RBSSPR, when a node is turned off, route reconstruction count is reduced since link stability is higher than other protocols and the lifetime of each node are longer than other protocols, so end-to-end delay in dynamic environment. And also, since RBSSPR uses an alternative route without performing rerouting, thereby significantly reducing the end-to-end delay.

3.2 Data Delivery Ratio

Fig. 11 Data Delivery vs. Pause time

Referring to Fig. 11, in dynamic environment, the ratio of data delivery in RBSSPR and BECT becomes greater than in AODV, MTPR, and MBCR. 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 by forming a stable link according to signal strength.

The difference of data delivery ratios between protocols that consider battery power and protocols that consider hop count in a static environment is small than those in dynamic environment. That is, in the static environment, the ratio of data delivery is more significantly influenced by a link break due to a change of a route than by the number of nodes that are turned off due to power exhaustion.

3.3 Average Energy Standard Deviation

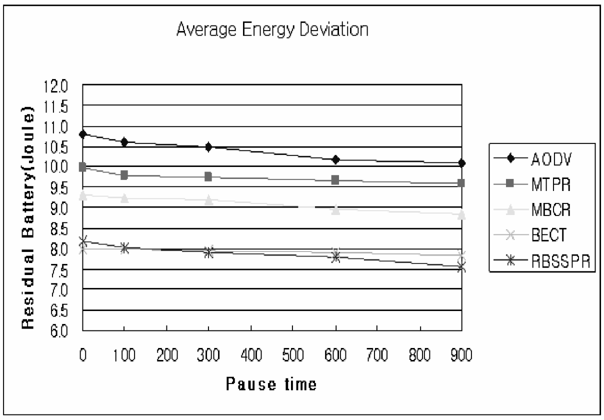

Fig. 12 Standard Deviation of Residual battery capacity vs. Pause Time

Fig. 12 represents standard deviation of residual battery capacity. In a dynamic environment, the performance of RBSSPR is 32.2% higher than that of AODV, 22% higher than that of MTPR, and 14.1% higher than that of MBCR, but is 3.2% lower than that of BECT. In a static environment, the performance of RBSSPR is 33.3% higher than that of AODV, 26.7% higher than that of MTPR, 17.2% higher than that of MBCR, and 2.9% higher than that of BECT. In static environment, the performance of BECT is lower than that of RBSSPR. because the stability of link versus signal strength 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 selects a route in consideration of transmission power enables balanced battery consumption of more nodes in a network than a protocol that selects a route in consideration of only hop count. In particular, RBSSPR considers both residual battery capacity and signal strengths allows balanced battery consumption more than protocols that consider either hop count or a reduction in battery consumption.

3.4 Average Energy Consumption

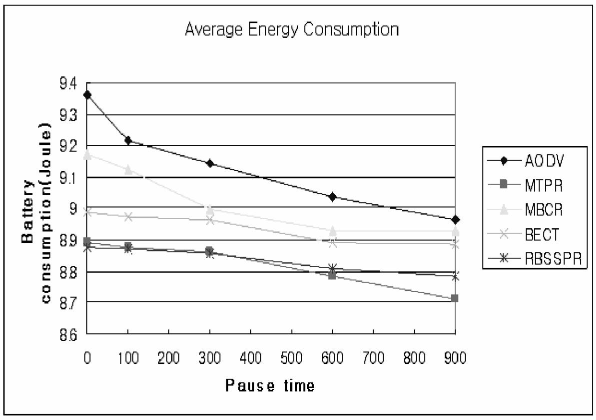

Fig. 13 Average rate of Energy Consumption vs. Pause Time

Fig. 13 represents average rate of energy consumption versus pause time. In a dynamic environment, the performance of RBSSPR is 5.5% higher than that of AODV, 0.2% higher than that of MTPR, 3.4% higher than that of MBCR, and 1.3% higher than that of BECT. In a static environment, the performance of RBSSPR is 2.1% higher than that of AODV, 1.7% higher than that of MBCR, and 1.2% higher than that of BECT. However, the performance of RBSSPR is 0.8% 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 RBSSPR considers both residual battery capacity and signal strength, 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, remaining battery capacity, and the difference between the signal strength of nodes) is preferably considered in order to reduce battery consumption.

4 Conclusion

This paper proposes RBSSPR that minimizes energy consumption and allows balanced energy consumption in the mobile Ad-hoc network. RBSSPR sets the approximate shortest route to minimize transmission delay. Also, a route is selected in consideration of both residual battery capacity and signal strength in order to prevent imbalanced energy consumption of nodes due to data transmission and minimize energy consumption. The result of a simulation through NS-2 revealed that the performance of RBSSPR 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 more efficiently use energy in a mobile Ad-hoc network by setting a stable route selected in consideration of both residual battery capacity and signal strength, and preventing specific nodes from being overused for routing by assigning a threshold for residual battery capacity.

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