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Power Aware Routing Protocol in Multimedia Ad-hoc Network Considering Hop Lifetime of Node

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Abstract

The purpose of this research is to extend Ad-hoc network system lifetime with the proposed routing protocol which has considered hop lifetimes of the nodes while guaranteeing QoS in the establishment process of Ad-hoc network communication paths.

Based on another power aware routing system that proposed in the advanced research [1], we are proposing an alternative power aware routing system in which nodes' hop lifetimes are compared in order to extend the lifetime of an Ad-hoc network system and delay factors have been considered for the assurance of QoS. The research of the routing protocol in this paper, which aims to maximize the system survival time considering power consumption status during the path searching in MANET and pursues the mechanism that controls hop delays for the same reason, can be applied to the study of WSN. The study concerning such phenomena is essential so that the proposed protocol has been simulated and verified with NS-2 in Linux system focusing on the lifetimes of the hops of the nodes.

Commercialization of smart devices and arrival of the ubiquitous age has brought about the world where all the people and things are connected with networks. Since the proposed power aware method and the hop delay control mechanism used to find the adequate communication paths in MANET which mainly uses batteries or in WSN, they can largely contribute to the lifetime extension of the network system by reducing power consumptions when utilized for the communications attempts among soldiers during military operation, disaster areas, temporary events or exhibitions, mobile phone shadow areas, home networks, in-between vehicle communications and sense networks, etc. This paper presents the definitions and some advantages regarding the proposed outing protocol that sustain and extend the lifetime of the networks.

Key Words: Ad-hoc Network, Power Aware Routing Protocol, Hop Lifetime of Node, NS2 simulation.

I. INTRODUCTION

This Nowadays, the usages of personal communication devices like mobile phones are expanding and have become a necessary in our daily life. Especially, high-performance devices such as smart phones have fast transmission speed and support various kinds of wireless communication options(e.g., CDMA, Wi-Fi and Bluetooth, etc.) so that they can connect to the networks all the time, and the connections to the other peripherals or mobile devices can easily and conveniently be established as well. However, in the cases of mountain regions, remote areas and shadow zones where telecommunications infra structures are not available, or the war, disaster and blackout zones in need of an urgent communication because such infrastructures have been destroyed, with that there exist grave inconveniences. Ad-hoc network is the communication method that can respond to such emergencies.

In multimedia transmission, the QoS(Quality of Service) should be guaranteed but some quality degradation problem might occur while passing through many nodes in the normal power aware Ad-hoc routing system. Major QoS-related factors of MANET routing for multimedia transmission are the bandwidth and the delay [2-4]. Bandwidth is the range of frequency used in wireless communications. The larger bandwidth, the amount of transmission increases but also it tends to involve greater packet loss possibilities. Transmission delay is the time taken for the data sent from the source node to arrive at the goal node. In this case, transmission time differs significantly depending upon how many nodes the data would pass through on the path starting from the source node to the goal node. For this reason, the routing system attempts to reduce delay time by cutting down the number of hops but if this is to be done, the transmission distance would become longer and therefore power consumption of the transmitting node tends to increase much. The study

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concerning such phenomenon is necessary in this aspect so that this power aware routing protocol considering the lifetimes of the hops has been proposed in this paper-simulating and verifying it with NS-2 in Linux system.

The research purpose of this paper is to extend the lifetime of ad-hoc network systems by proposing a routing protocol which takes several electric power-related factors into consideration while guaranteeing QoS in setting of communication paths for the system.

To extend the lifetime of ad-hoc network system, the first method [1] has been proposed as the power-aware routing in the advance researches and the delay-power aware routing as the second. The latter seeks a set of paths in which path's delay time is within a certain range and selects the path with the longest transmission lifetime among them to maintain the system's lifetime longer.

II. RELATED RESERARCH

2.1. Ad-hoc Network

Ad-hoc network is a kind of communication network composed of multiple-hop wireless links that depends upon data transmissions between several intermediate terminals, and of course, path routings, for the smooth communications among such terminals which do not have centralized full-time administrators or infrastructures like access points. Figure 1 shows the conceptual diagram of Ad-hoc network communication.

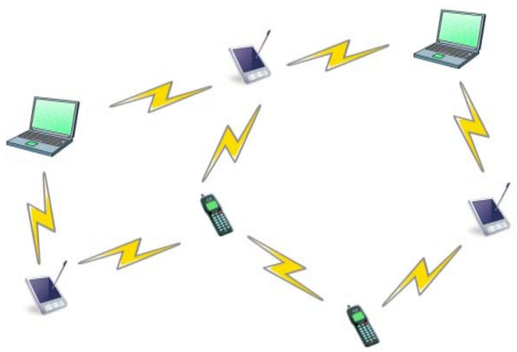

Fig. 1. Diagram of Ad-hoc network communication.

Ad-hoc network is a communication network which has an advantage of constructing communication network within a short period of time, and even though there are still some problems to be solved, it's the communication system that has already gotten into our daily lives deeply. Ad-hoc networks can be divided into two types, MANET and WSN [5-8].

2.2. MANET (Mobile Ad-hoc Network)

MANET (Mobile Ad-hoc Network) copes with frequent topology changes caused by the unpredictable or unplanned mobility of nodes and does not depend upon existing communication infrastructures. In order to deal with fast moving terminals, all leaf nodes act as the hosts, and at the same time, these nodes must be able to construct communication network by assuming the role of functions that are missing from the cooperation system - the role as a router.

The study concerning MANET initially started for the military purpose but a variety of commercial application areas are emerging owing to the technological development of networks. MANET is a wireless network that communicates via mobile terminals on a multiple basis when each mobile terminal communicates each other. And also, it's the network whose topology changes dynamically due to the fluid movement of mobile terminals. Since the main power supply of each mobile terminal is batteries, the network has experiences some limits in maintaining the network links.

2.3. MANET Routing Protocol

Since the MANET method needs to establish communications through other relay devices when direct communications are impossible, its own power consumption needed to support relay functions with other devices must be taken into consideration so that overall system lifetime will be extended. Thus, setting the communication path considering power supply is a critical matter connected to the lifetime of the network system in use.

Despite the fact that the most fatal problem regarding MANET is the power supply-related one but majority of studies related to power aware routing only consider overall transmission power or total remaining power of the nodes on the path - not for each node. To devise more complete power aware routing system, the method which considers both on-pathway and remaining powers is necessary, and the power status of each node and overall lifetime of the relevant path should also be considered evenly. In other words, when setting the Ad-hoc network's communication path, it is necessary to reflect each node's lifetime, set the path that has the longest lifetime reflecting path's average lifetime and consider QoS for the multimedia transmissions.

Since the bandwidth, which is one of the factors related to QoS in multimedia transmission, is an index related to power consumption and being set up independently, it is rather easy to find the path that minimizes power consumption while satisfying certain bandwidth. However, in case of the delay, the delay time increases when data arrives to the goal node via nearby nodes even though power consumption decreases. For this reason, it's necessary to devise a mechanism that negotiates such contradiction between the delay and power consumption.

Normal power aware routing protocol minimizes transmission power consumption of the chosen path during the set up process between the nodes. Nevertheless, if the node with a low remaining power is included in the path because the routing system discussed here does not consider remaining power of an intermediate node, there will be a problem that the lifetime of the path will be shortened. Accordingly, we are reflecting remaining power of the node in the path setting process as a necessary improvement. An advantage to be gained in such power aware routing method is to be able to maximize system survival time.

The power problem is the most fatal problem in MANET environment and yet most of the existing studies concerning the power-aware routing only consider the total transmission power or the sum of remaining powers over the nodes in the paths so that the power transmission lifetime of each node has not been contemplated. For a more complete power-aware routing, the method that considers both powers and that evenly reflects both the power status each node and the total lifetime of relevant path is necessary.

That is, in setting of the communication route of the ad-hoc network, the path with the longest lifetime should be established by reflecting the life time of each node as well as the average lifetime of the path. Additionally, QoS needs to be considered for multimedia transmission.

During the multimedia transmission, QoS should be guaranteed but the problem of declined transmission quality in a common power-aware ad-hoc routing could arise for it passes through many nodes. Mostly, the QoS-related elements considered in the MANET routing for multimedia transmission are the bandwidths and delays [3,7,8]. Bandwidth is the frequency range used for the wireless communications and larger the bandwidth, it tend towards increased data transmissions and packet losses.

The delay refers to a time lag arising from the transmission from the source node attempting to send the data to the goal node where the data should arrive at. As for the delayed delivery, the transmission time clearly differs depending on how many nodes in the path (from the source node to the goal node) have been passed through. For that reason, the routing method which reduces the delay time by decreasing the number of hops is often attempted but due to the nature of wireless communications, the transmission power consumption of transmitting node tends to increase greatly when the number of hops has been reduced resulting in greater transmission distance - the research over this problem is necessary.

Since the bandwidth, which is one of the QoS elements, is an almost independently established index, it's relatively easy to find the path that meets particular bandwidth and minimizes power consumption. However, as for the issue of the transmission delay, it reduces power consumption but lengthen the delay time. Such transmission delay and power consumption conflict each other so that the mechanism which negotiates this contradiction is also needed.

In establishing the paths that need communications between the nodes, a common power-aware routing protocol attempts to minimize the transmission power consumed over the paths. But in the event that the remaining power of intermediate node is not considered during the power-aware routing process, and thereby the node(s) with lesser remaining power has been included in the path, there could be a problem of shortened path lifetime so that we've improved this problem by making sure that the remaining power of each node is reflected in the path-setting process. A merit of such power-aware routing is that the system lifetime can be extended as long as possible.

III. PROTOCOL IN MULTIMEDIA AD-HOC NETWORK CONSIDERING HOP LIFETIME OF NODE

The topology is fixed in a normal wired routing and the routing table is set up by the metric numbers which are produced with the factors such as line speed, transmission delay, reliability of the line, line usage, the number of hops and maximum transfer unit, etc., and the data is transmitted after searching the table. Meanwhile, the main characteristic of MANET is that the network constituent nodes have mobility so that addition of new nodes, or escaping of one or more nodes from the network are accepted as a new network deployment. These changes in the node positions lead to the changes in connections or to the reconstruction of the network. Additionally, the constant changes could occur in the connection between two nodes due to the characteristics (e.g., noise or interference) of wireless communication. Thus, when discussing the connectivity in a certain moment in an Ad-hoc network, these factors cannot be ignored, and realistically, the problems of connectivity can be regarded as the problem of probability. Therefore, for the routings in MANET, On-demand method in which the path to the goal node is sought at the time of data transmission is much preferred over the method that utilizes pre-determined table. On-demand method announces a Path Request Message to find the goal node in the source nodes, and during this action, suitable path is chosen considering the power supply status or searching for the path that supports QoS.

In MANET, where batteries are being used as a main power supply, the most important consideration must be given to the power-related problems directly connected to the system's lifetime. The fatality is so devastating that once the power runs dry, all system functions and services will be terminated.

As mentioned above, the research purpose of this paper is to extend an Ad-hoc network system lifetime by proposing a routing protocol which has considered hop lifetime of the node while guaranteeing QoS in establishment process of the Ad-hoc network communication path.

In the advanced research [1], power aware routing system comparing the lifetimes in order to extend the lifetime of an Ad-hoc system has been introduced and used as a reference for our study to make additional improvements.

To limit hop delays in power aware routing, Delay-Power Aware Routing method calculates a set of paths whose delays are within a certain range and selects the path with the longest lifespan to extend the lifetime of the system longer [1,2,8].

In this paper, a dynamic hop delay control mechanism has been implemented to limit hop delays that are regarded as a demerit in power aware routing. As a method of the implementation, RREQ (i.e., Route Request) is announced by adding allowable delay to the minimum number of hops between the source node and each node on the path. This mechanism is to prevent excessive hop delays by limiting the delays within a certain range when the RREQs are announced without the hop limitation control in power aware method.

In MANET, the QoS which deals with transmission quality during the starting node to the goal node transmission; power consumption that deals with survival time problem of network system due to the use of batteries as a main power supply; and inherent security problems in wireless communication are the important details which must be attended. The research concerning in this mechanism for MANET can also be applied to study of WSN.

3.1. Proposition of Lifetime Comparison Method

First calculate the lifetimes for all the nodes and update minimum lifetime value and average lifetime value on the path based on the calculations made. Next, add the average lifetime value to minimum life time value and then divide the result into 2, setting the resulting value as a Lifetime evaluation value of the relevant path. With such evaluation values obtained for each path, compare various paths to find the one with the longest lifetime. Equations to obtain the lifetime evaluation value for each node and to evaluate each path are as follows:

$$\text{Node lifetime evaluation value} = \frac{\text{Remaining power of the node}}{\text{Transmitting power consumption of the link}} \quad (1)$$

$$\text{Average value of path lifetime evaluation} = \frac{\text{Total lifetime of the path}}{\text{Nmber of hops on the path}} \quad (2)$$

$$\text{Path lifetime evaluation value} = \frac{\text{Lifetime value of the path} + \text{Average value of path lifetime evaluation}}{2} \quad (3)$$

In setting up the path, there could be many evaluation functions but the fact that most of them consider the power factors reflects the necessity of extending the lifetimes of relevant path and whole network. Minimum lifetime of the relevant path can be determined with the value of the minimum lifetime node and the average path lifetime represent average lifetime of the nodes on the relevant path. The average lifetime of the nodes and average value of minimum lifetimes become as a standard indices for setting up the lifetime comparison paths. Even if the average path lifetime becomes longer, the lifetime of the path can be shorter if the minimum lifetime of the node is short and no matter how large the minimum lifetime of the node is, whole system's lifetime will be short if the path has a low average lifetime. Therefore, in order to take both system lifetime and the lifetime of the relevant path into account, the lifetimes should be determined directly by reflecting the average lifetime of the paths and the minimum lifetime node value of the path. This determination method using calculated lifetime of each node is direct and reliable so that it reflects path's lifetime better than other methods.

3.2. Comparison of the paths established with the power-aware method in accordance with changes in the number of hops

To perform comparative analysis with the proposed protocol, following 3 routing models have been considered. The protocols to be compared are the Minimum Hops Routing Protocol Considering QoS (QAODV), the Delay-Power Aware Routing Protocol (proposal Method-1) proposed in the advance research [1], and the Power Aware Routing Protocol Considering the Lifetimes of Nodes(proposal Method-2) proposed in this paper. The classification is made as such Table 1.

In order to compare how each Power-aware method selects adequate path reflecting the conditions of the paths, the number of hops have been changed and compared each path with one another every time the number of hops on the paths increased by 1. Figure 2 shows paths indicator.

Table 1. The perform comparative analysis

QAODV	AODV routing method which has considered the delay first
Proposal Method-1 [1]	The Delay-Power aware routing method
Proposal Method-2	The power aware routing method considering node's hop lifetime (minimum hop + 2 hops)

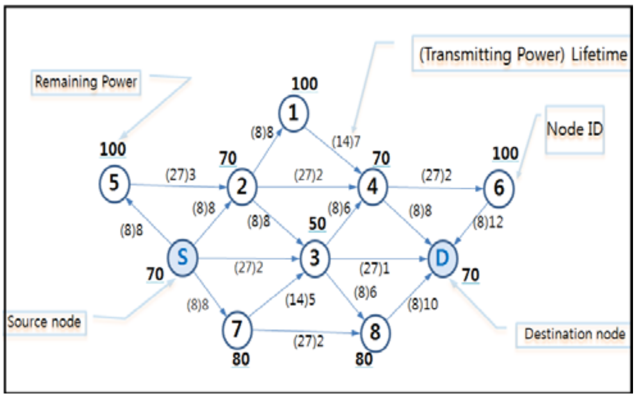

Fig. 2. Paths indicator.

Figure 3 shows the possible paths selected with 2 hops. In Proposal Method-1, the path has the highest estimated value for [S, 3, D], as in the 2-hop path case. Estimation equation for the remaining power is [(Min. Remaining Power + Ave. Remaining Power)/the number of hops] and the weights have been ignored. The weight for the remaining power or the number of hops could be changed in accordance with the purposes of the users so that they've been ignored to estimate the remaining power on average. The remaining powers of this path excluding the goal's (or destination: D) node are 70 and 50 respectively, averaging to 60. When substituting this value to the above equation, it becomes as (50 +60)/S = 55 and this is the highest estimated value of the remaining power of the path. Calculating the estimated value for the remaining power of the path [S. 7, 8, D] to compare with above mentioned path, the remaining powers of the nodes on the path[S, 7, 8], which excluded the goal node, are 70, 80 and 80 respectively and amounting to 230 and averaging to 77. Substituting them to the equation, the calculation is (70 +77)/3=49, which is lower than that of the path[s, 3, d). Therefore, the path[S, 3, D] has a larger power consumption rate and a link with minimum lifetime of 1, its lifetime is the shortest one.

In Proposal Method-2, the path[S, 7, 8, D], which is the min. power consuming path, has been setup. For the lifetime evaluation value, evaluated value which is estimated by dividing the remaining power value marked on the node by transmitted power value(within the parenthesis) is indicated following the parenthesis.

Therefore, since the lifetimes of nodes[S, 7, 8] are 8, 2 and 10 respectively, the average lifetime is 6.7(20/3). In this case, goal node is disregarded.

When Proposal Method-2 is applied, the calculation is made as (min. lifetime value of the path + average lifetime value)/2, and substituting each values as (2 + 6.7)/2, we obtain the value of 4.4, which is the highest lifetime evaluation value among the paths that have ≦3 hops.

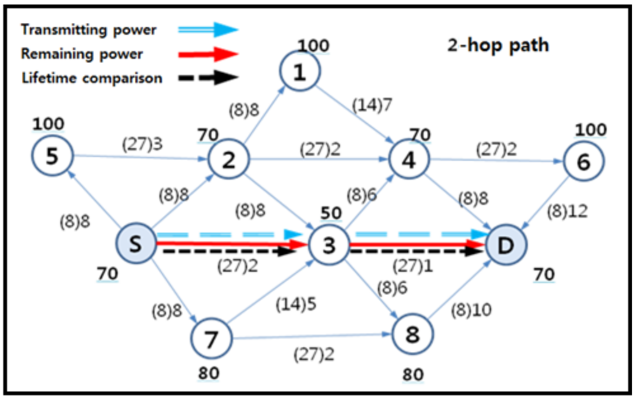

Fig. 3. Possible paths selected with 2 hops.

Figure 4 shows the possible paths selected with 3 hops. There are many paths set by Proposal Method-1 for the 3-hop situation but only 2 paths do not pass through No. 3 node where the traffic is converged and the remaining power is at minimum. They are path[S, 2, 4, D] and path [S, 7, 8, D], and assuming that their transmitting power consumption rates are the same, path[S, 7, 8, D] has more remaining power on the nodes, making it as the path with the longest lifetime. Thus, the lifetime comparison method that chooses the path by comparing the lifetimes and considering the remaining power can select the path with a longer lifetime better than the method that considers transmitting power. Meanwhile, the path[S, 3, D], which was set by considering the remaining power has the lifetime of 1 - the shortest min. lifetime. As a result, the path with the longest lifetime and more remaining power was selected in Proposal Method-2.

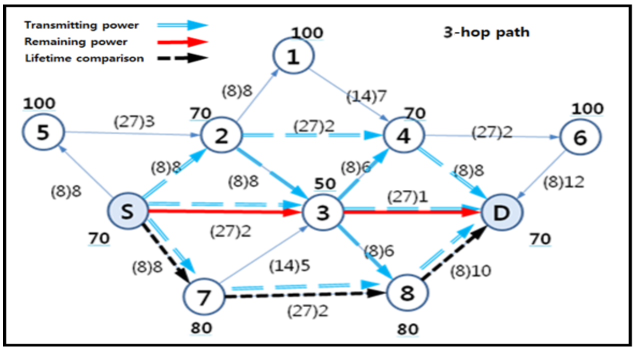

Fig. 4. Possible paths selected with 3 hops.

In Figure 5, the paths with 4 hops that have been selected by considering each power condition are shown. First, there are 2 paths ([S, 2, 3, 4, D] and [S, 2, 3, 8, D]) selected by considering the transmitting power. Here, the value of the transmitting power is lesser value of 32 compared to the 3-hop path whose value is 43. Proposal Method-1 still selects the path[S, 3, D], keeping the same selected path in 2-hop's case.

In case of Proposal Method-1, the evaluation value becomes lower it is reversely proportional to the number of hops and since this method follows the same method as the minimum-hop routing method in the topology shown in the figure, the highest evaluation value has been deduced from the path has the smallest number of hops and has not changed afterwards.

Different from the 3-hop situation, the path [S, 2, 1, 4] is selected with Proposal Method-2 and the evaluation value for this path is calculated as (7 + 7.8) / 2 = 7.4, which is the higher value than the one calculate in 3-hop path, which is 4.4. Such result has been deduced because the path's min. lifetime node has the value of 7 compared to the value of 2 calculated in 3-hop situation. This also resulted from the immediate reflection of each node's lifetime. The paths selected with the lifetime comparison method experience a little more power consumption but the remaining powers of their nodes are higher so that their lifetimes becomes longer.

The min. lifetime of the paths selected with Proposal Method-2 was 7 while it was ≦6 with Proposal Method-1. Thus, proposal Method-2 not only selects the path with the longest lifetime but also distributes power consumption by avoiding the nodes on which traffics are converged and have lower remaining powers and by passing through number 1 node which has much remaining power. As a result, we can see that Proposal Method-2 sets up the path with the longest lifetime and distributes power consumption evenly.

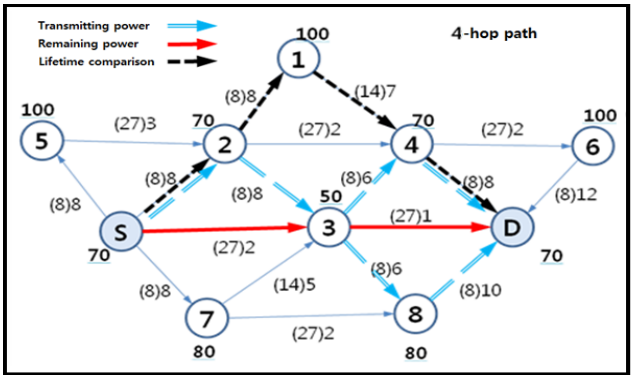

Fig. 5. Possible paths selected with 4 hops.

In Figure 6, 5-hop paths selected with Proposal Method-1 are shown. They are identical to the ones selected for 4-hop situation. Even if more number of hops is considered, there will not be any path changes.

In other words, Proposal Method-1 setup the 2-hop path as the one with the highest evaluation value, and in the method which had considered transmitting power and lifetime evaluation factors, 4-hop path was selected as the path that had the highest evaluation value. These paths statuses remain the same in the cases of ≧5-hop paths.

In each situation where the numbers of hops are different, Proposal Method-2 always selected the paths which had the same or longest lifetime but others had chosen the paths with the same or shorter lifetimes and could not avoid the paths where the traffics converged on the nodes. Accordingly, it is possible to can conclude that among the 3 types of hop-comparison methods in Power-Aware Routing, the method which considers lifetime or other factors such as the remaining power and transmitting power always selects the best and adequate paths.

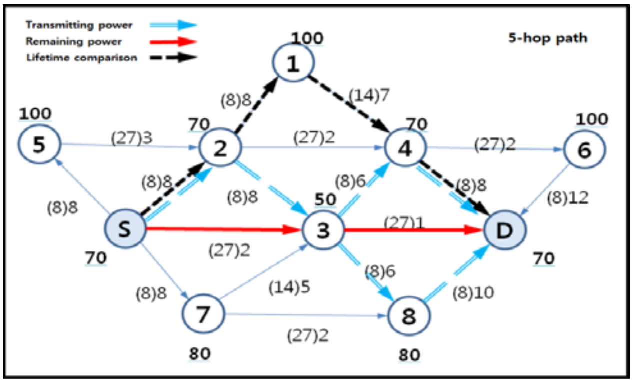

Fig. 6. Possible paths selected with 5 hops.

3.3. The number of link searches following hop-delay

Allowing the hop delay means not allowing the end-to-end delay and redundant searches in path searching process, both of which cause electric power consumption. Figure 7 to Figure 9 are the ones that shows the number of link searches at the time of path setting according to the D-value in routing process.

Figure 7 shows the way that the RREQ broadcasting disseminates when D=0 and in this process, only 12 links allows RREQs to pass through without the path-setting overheads since just the RREQs with minimum number of hops can go through each intermediate and goal node. For the path-setting, only one path that leads to the goal node first (i.e., [S, 3, D]) successfully arrives at the goal node and the rest of paths will be discarded as soon as their arrival because they have more than 2 hops in the paths. The only link that had been repetitively searched was the link (4, 6) and there was relatively no overhead. Total number of links searched is 12.

Although the path to be set is the one that has the minimum number of hops and absolutely no hope delay value, such minimum-hop path requires quite a large amount of electric power due to its longer transmission distance between the nodes. As one can see in the figure,

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since most of such shortest paths execute transmissions via central nodes with the shortest distance, the power consumption will be quite rapid and it's considered to be a demerit. In this figure, the highly inefficient path - for the reason of path restoration or resetting due to the path failure involving the node 3 - is shown.

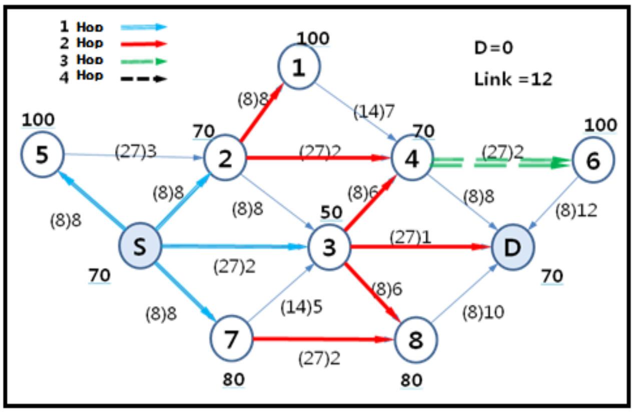

Fig. 7. The number of link searches when D=0.

Figure 8 shows the way that the RREQ broadcasting disseminates when D=1. Here, the only those RREQs in which 1 hop is added to the minimum-hop pass through and only the paths which involves 3 hops (1 hop added to the minimum 2 hops) or lesser number of hopes are allowed to arrive at the goal node so that such paths can be included as the path setting targets. The links after 1 hop are mostly redundantly searched and the total number of path search links at the times of RREQs is 29, more than a double when D=0.

The set paths have 3 hops and since the number of the relevant paths have increased by 6, it could be considered that the number of the paths which can reach the destination have also increased 6 times. In other words, while the path search links increased by 2 folds, the paths possible to set also increased 7 times, and because the power-reducing paths were included in these paths, the benefits of the power consumption reduction during the transmissions would be much greater than the loss by the hop delays.

Figure 9 shows the way that the RREQ broadcasting disseminates when D=2. In this case, the only those RREQs in which 2 hops are added to the minimum-hop pass through and only the paths which involves 4 hops (2 hop added to the minimum 2 hops) or lesser number of hopes are allowed to arrive at the goal node so that such paths can be included as the path setting targets. In this picture, the links that have been redundantly searched for 2 or 4 times after passing through 1 hop (even 6 times after minimum-hop of 2) are being indicated. Total number of links to be is 45, more than 3.7 times of the number of links that could be searched with minimum-hops, which are 12.

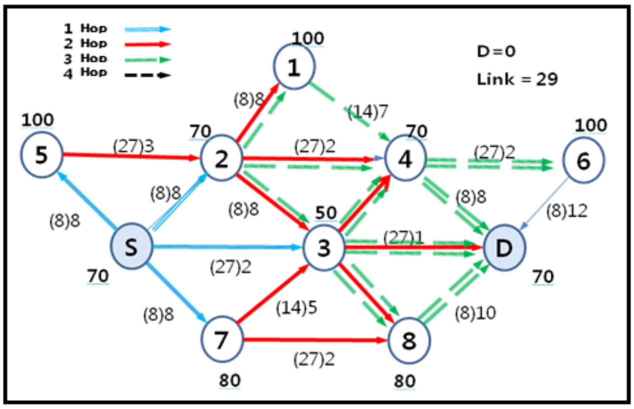

Fig. 8. The number of link searches when D=1.

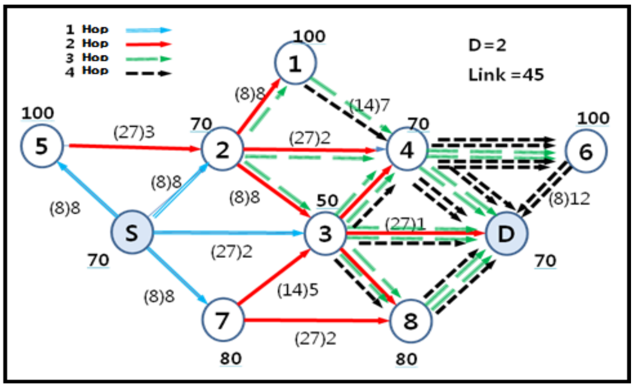

Fig. 9. The number of link searches when D=2.

Setting the hop delay value D larger, overlaps in RREQ link searching at the time of paths settings will be increased continuously. However, increase in hop delays would not bring about increased number of power-efficient paths. In the above picture, power consumption rate has increased more for the paths with 4 or more hops(i.e., delay value of D=3). In carrying out redundant search of the links by setting the value D as 3, the effectiveness like reduction in power consumption cannot be expected and some overheads are anticipated during the search.

IV. PERFORMANCE EVALUATION

In this paper, performance evaluation was conducted by randomly deploying 100 nodes on the 2-dimensional plane of 500m X 500m. The communication radius has been set at 50m and this means that, in terms of density, there are approximately 3.5 nodes within a single node communication radius and 2 to 3 neighbor nodes that can be communicated with.

We assume that the nature of each node is non-mobile (for all nodes) and energy-limited for there are no means to replenish the energy after initially allocated energy has been used up. Additionally, assume that all the nodes have their own IDs and can calculate transmission distance with response time themselves so that the transmitting power can be controlled in accordance with the distance.

The operational performance was verified with NS-2 in Linux system and the packet transmission success rates were measured. However, the power status of each node was checked by programming the indices related to the energy consumption with C-language under the same condition. Power required to transmit unit packet from Node i to Node j is determined as

$$E_T(i,j) = E_{TX} \cdot k + E_{AMP} \cdot K \cdot d_{ij}^{n}, \; (4 \geq n \geq 2) \quad (4)$$

And here, n=3. Initial power was set at 100 and the constant k was adjusted to make the transmitting energy of the unit packet between each node neighboring at the distance of 10m would become as value of 1.

For the test, path was set by deploying the source node and the goal node more than 100m apart and transmitting the unit packet so that the energy could be consumed. Repetitive path setting procedures were performed to conduct performance evaluation. Packet transmission success rate, remaining power status, power consumption for the transmission and the delay caused by the number of transmitting hops were measured every 10 attempts while performing 60 times of path settings and unit packet transmissions.

Figure 10 shows the packet transmission success rate in accordance with the number of path settings for each routing method. The success rates for the Proposal Method-1 [1] and the Proposal Method-2 are similar but both methods have shown 15% higher success rate than that of QAODV, indicating that the performance has been enhanced.

If the path setting and cancellation process are repeated, the nodes with depleted power appear and such depleted nodes withdraw from the path resulting path discontinuity and hop delays which make packet transmission more difficult. In case of QAODV, it considers hop delay condition as top priority and sets the paths where there are lesser hops. It seems that on these paths, the power of the node depletes fast because of large transmission power consumption due to the long transmission distance. Since the power consumption rate is proportional to 3 times of the transmission distance, the path with the longest distance per hop has the greatest power consumption rate and power-depleted nodes appear earlier than other methods.

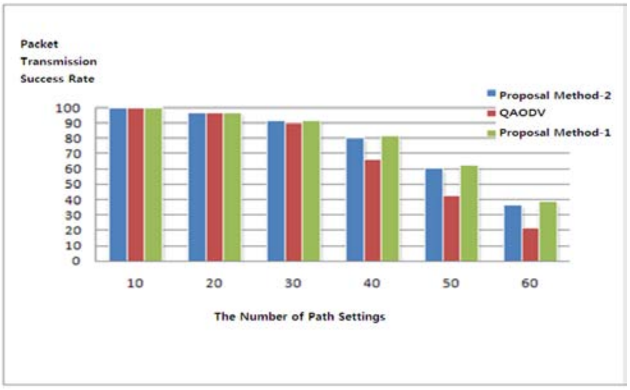

Fig. 10. Packet transmission success rate in accordance path settings.

Figure 11 makes this result much more definitive. The remaining power level in the whole system is an index related to system's lifetime and as for the QAODV, it was possible to observe that the power had been consumed more rapidly compared to the other protocols when the path settings had been repeated. Especially, in the case of Proposal method-1, despite of the fact that this method did consider the delays, it showed the power consumption rate similar to Proposal method-2 which hadn't considered the delays. Such observation is the result of selecting the path with a long lifetime by controlling the hop delay appropriately.

In Figure 12, relative delays resulted from each method in the path setting process have been compared. Each index represents relative value against the Proposal Method-2. Considering that the value of Proposal Method-2 is 100, QAODV has initially shown 70% less delay value but from 30 attempts, the value becomes almost the same, showing more delays than the Proposal Method-2 afterwards. This may account the fact that the QAODV method first selected the paths with lesser number of hops but due to the increased number of the power-depleted nodes shorter paths had disappeared forcing it to make detours to the paths where many hops existed. The Proposal Method-1 delays 120~130%. This result has been obtained because the method in discussion does not consider the delays at all so that it chooses the path with many available hops and the Proposal Method-2 limits the number of hops under steady level from the start when setting up the path and thereby avoiding excessive detouring paths.

In Figure 13, the relative power requirements in accordance with the path settings are shown. Considering the value of the Proposal Method-2 as 100, the Proposal Method-1 consumes about 91~95% power and QAODV method consumes around 120~130% power. This result shows that the proposed methods consume much less power than that of QAODV and such result could be seen as the result of the difference between considering or not considering the power consumptions in the methods used.

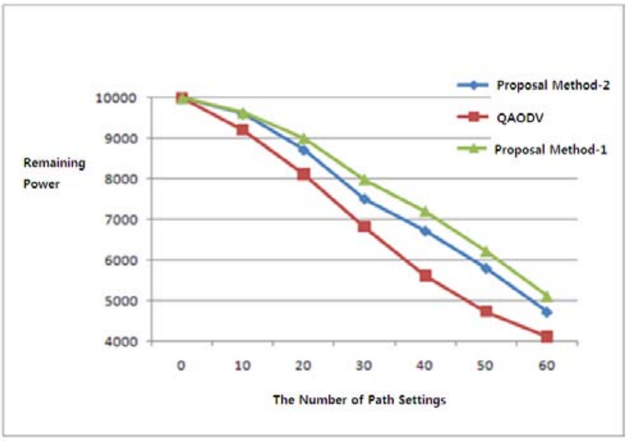

Fig. 11. System's remaining power in accordance path settings.

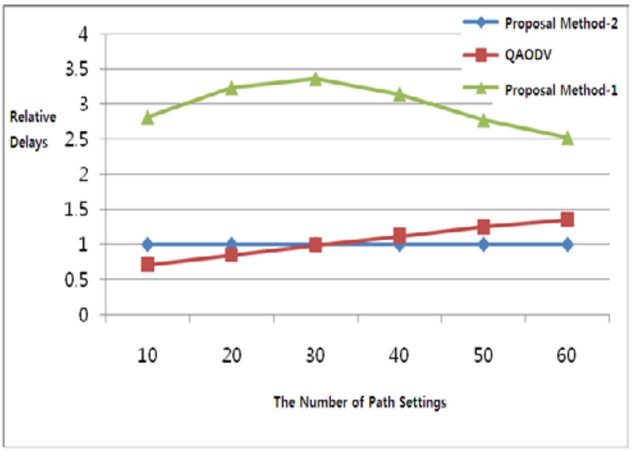

Fig. 12. Relative delays in accordance path settings.

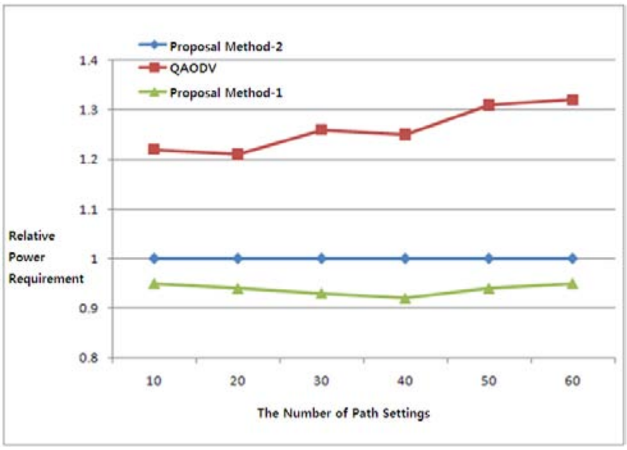

Fig. 13. Relative power requirements in accordance path settings.

As a result, the Proposal Method-1 [1], which considers the power first compared QAODV method which does not consider power status at all, has achieved the result of saving 25~35% power consumption on the paths where the delays have been increased by 20~30% but the Proposal Method-2 has saved 20~30% power within the range of 10% delay increase. That is to say, it had set up the paths that had a long lifetime considering the power factors without harming the QoS much.

V. CONCLUSION

The power aware routing method proposed in the advanced research causes some degree of delays due to the shortening of the transmission distance in order to consider power-relate factors. In the case of delays, their own drawbacks are classified as the complex problems that belong to the NP-complete. The transmission power consumption and hop delay are the conflicting factors and needed some kind of controlling mechanism that adequately adjust these factors.

Thus, in this paper, the Power Aware Routing Protocol considering the hop lifetimes of the nodes, which includes such control mechanism, has been introduced so that the problems underlying between QoS support and transmission power problems could be cleared. For the consideration given to the QoS, it was easy to consider bandwidth related factors, but since the delays and power consumption are in conflicting relation, the problem was not easy to handle. However, we've solved this problem by introducing the controlling mechanism. In the Delay-Power Aware Routing Protocol, we've also made it possible to search the paths that are close to minimum number of hops allowing as many additional hops as the value obtainable from the equation [minimum hops + D], choosing the hops as the measurement indices. Our method made it possible to route with the minimum hop method or with the routing method in which power was considered first - in accordance with the set D values. Normally, by setting up the negotiating paths, the system can be operated safely from two fatal factors mentioned above. From the heuristic analysis results, the adequate compromising hop delay value was to be the twofold of minimum hop number but it could change depending upon the transmitting distance or node densities. Compared to the power aware routing method which does not consider hop delays, the negotiating path was able to reduce overheads caused by the excessive RREQ announcements and to control hop delays adequately.

From the simulation test results, we were not only able to use the delay-power aware routing as the minimum hop routing and power aware routing by adjusting the D-value adequately but also able to select negotiating paths for these two methods adaptively. In terms of the negotiating paths, we've established the paths which have shown around 30% enhanced performance on the lifetime index of the network system enduring approximately 10% more delay compared to the QAODV which considers the delays only. This means extending the time of QoS provision on the network by largely increasing the survival time of whole network enduring a little delay.

Commercialization of smart devices and arrival of the ubiquitous age will bring about the world in which all the people and things are connected with networks. Since the proposed power aware method and the hop delay control mechanism can be used to find the communication paths in MANET or WSN (Ad-hoc communications) which mainly uses batteries , they can largely contribute to the lifetime extension of the system by reducing power consumptions when utilized in communications between soldiers during military operation, in disaster areas, at temporary events or exhibitions, mobile phone shadow areas, home networks, in-between vehicle communication, and sense networks.

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