A New AODV Route Discovery Protocol to Achieve Fair Routing for Mobile Ad Hoc Networks

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***Abstract*— We propose a new routing protocol for MANET (Mobile Ad hoc NETwork). This protocol achieves the fairness of the amount of communication among nodes. The amount of communication generation in MANET differs among nodes. Thus, there might be nodes that have much self-benefit communication and nodes with much other-benefit communication. The ratio of self-benefit communication to other-benefit communication differs among nodes in MANET. MANET is a network made up of equal ability nodes. Therefore this ratio is expected to be equal among the nodes. A protocol has been proposed to achieve the fairness using the ratio of self-benefit communication to other-benefit communication. However, the protocol has two problems. The definition of the ratio of self-benefit communication and other-benefit communication do not fully reflect the cost and benefit for the node. AODV routing protocol cannot obtain routes to achieve fairness. We propose a new routing protocol that improves the fairness definition and route discovery to achieve fairness.**

Keywords- MANET; fairness; communication amount ratio; AODV; routing protocol

I. INTRODUCTION

There are wireless devices everywhere in our daily life. Most wireless networks are based on an infrastructure that uses access points as wireless communication base stations. MANET (Mobile Ad Hoc NETwork) [1] does not require such wireless communication base stations. It is expected as a new type of wireless network. MANET is an independent network in which devices communicate only by their equipped wireless communication modules. MANET is expected to be used as a temporary network for mobile phones when the cellular network infrastructure is not available in the case of a disaster. Devices within the scope of their radio waves can directly communicate with each other. In addition, each device has a function as a router. Thus a device can communicate to a device outside the scope of its radio wave, because the devices can relay the other devices' packets. Wireless devices often move in MANET. Thus, the route to a destination device changes frequently because of the movement of the devices. Thus the routing protocols for MANET need to reconstruct the routing paths soon when the network topology changes. Many protocols have been proposed for MANET to achieve high throughput [2] [3], power consumption [4], and connection stability [5]. There is a load balancing protocol [6] that uses multiple paths to avoid concentration of relay packets. However very few works [7] [8] have been done for the following fair communication amount problem. Fairness of battery consumption is considered in [8] to achieve high availability of network nodes.

The amount of communication generation differs among nodes in MANET. Thus, there might be nodes that have much self-benefit communication and nodes with much other-benefit communication. The situation that the ratio of self-benefit communication to other-benefit communication differs among nodes is not fair because the self-benefit communication is the profit for the node and other-benefit communication has no profit for the node. Many routing protocols select relay nodes that are suitable for relaying data, for example, the number of hops is the minimum. Such suitable nodes tend to be located in the center of the network. The nodes feel unfair because they must execute much other-benefit communication. Therefore the ratio of self-benefit communication to other-benefit communication is expected to be equal among the nodes. If the ratio differs among nodes, the users feel unfair. A protocol [7] has been proposed to achieve the fairness using the ratio of self-benefit communication to other-benefit communication. However, this protocol has the problems of definition of the fairness and the obtained routes by AODV routing protocol are not suitable to achieve fairness. We propose a new routing protocol that adjusts the definition of fairness and obtains routes appropriate to achieve fairness.

II. CURRENT ROUTING PROTOCOLS FOR MANET

A. AODV (Ad hoc On-Demand Distance Vector)[9]

1) The characteristic of AODV

AODV(Ad hoc On-Demand Distance Vecotor) is a reactive type protocol that constructs communication paths on-demand. Each node has a routing table for packet delivery by the AODV.

2) Route Discovery of AODV

We show the detail of the route discovery algorithm by AODV.

1. The route to the destination node is requested at the time when the communication is necessary. The source node generates a RREQ packet with a new ID and the packet is broadcasted to the neighboring nodes in its effective radio wave range.

2. A node that receives the RREQ packet adds the routing information to the routing table and checks whether its destination node is itself. If it is not the destination and it has not yet received a RREQ packet with the same RREQ ID, it writes its node ID to the RREQ packet and broadcasts the RREQ packet. If it has already received a RREQ packet with the same RREQ ID, the node silently discards the newly received RREQ packet.
3. If a node that receives the RREQ packet is the destination node, it generates a RREP packet and sends the RREP packet to the source node. A node that receives the RREP packet adds the routing information to the routing table and sends the packet to the source node by the nodes' routing table. A RREP packet is sent from the destination node to the source node by each node's routing table untill reaching the source node.
4. The source node selects the route from which the first RREP packet arrived to the source node.

3) Data Delivery of AODV

Each node has a routing table for packet delivery. In AODV, each packet has no information of the full communication path for the packet. The entry of the AODV routing table has information of the tuples of a destination node and the next hop node to the destination. Each node determines the next node to be transferred from the routing table in order to deliver the packet to the destination node.

B. ISK Protocol[7]

ISK protocol aims the fairness of communication using the ratio of self-benefit communication to other-benefit communication. ISK protocol is a modification of path selection algorithm in AODV. The path selection is executed so that fair communication is achieved.

1) The characteristic of ISK Protocol

The path selection algorithm in ISK protocol has two problems. As shown in the next section, the definition of the ratio of self-benefit communication to other-benefit communication dose not fully reflect the cost and benefit for the node.

In the original AODV, the route of the first arrived RREP to the source node is used as the route from the source node to the destination node. ISK protocol selects the best route from the received RREPs. This protocol uses FV(Fair Value) that is the criteria of the fairness of amount of communication in each node.

$$FairValue(FV) = \frac{OtherData}{OwnData} \qquad (1)$$

OwnData = number of packets whose source or destination is the node

OtherData = number of packets of relay for the other nodes

OwnData indicates the amount self-benefit communication, that is, the number of data packets whose source node or destination node is the node itself. OtherData indicates the amount other-benefit communication, that is, the number of data packets whose source or destination node is not the node.

2) Route Discovery of ISK Protocol

We show the detail of the path selection algorithm by ISK protocol.

1. This process is the same as AODV.
2. This process is the same as AODV.
3. This process is the same as AODV with the exception of adding the value of FV in the packet header. If a node that receives the RREQ packet is the destination node, it generates a RREP packet and sends the RREP packet to the source node. The RREP packet has FV in the packet header. The node that receives the RREP packet adds its FV to the FV in the RREP packet and sends the RREP to the next node. Therefore, the FV in the RREP packet is the sum of FVs of the nodes in the path. A RREP packet is sent from the destination node to the source node by each node's routing table untill reaching the source node.
4. The source node selects the route with the minimum FV in the RREP packet.

III. Problems in Current Protocols

A. Problems in AODV Route Discovery for Fairness

In the route discovery process, MANET routing protocols broadcast RREQ packets in order to search the destination node. However broadcasting the RREQ packet becomes a heavy load on the network. AODV discards the received RREQ packets with the same RREQ ID in order to reduce the overhead of broadcast in the route discovery. In AODV, the route of the first arrived RREQ packet is used as the path from the source node to the destination node, thus the number of hops tends to be the minimum. Later arriving RREQ packets are discarded by AODV and the route of these packets are not constructed by AODV and ISK protocol. Therefore, the optimal route for fairness, whose number of hops is not the minimum, cannot be selected by ISK protocol. In order to achieve fairness, improvement of route discovery is necessary.

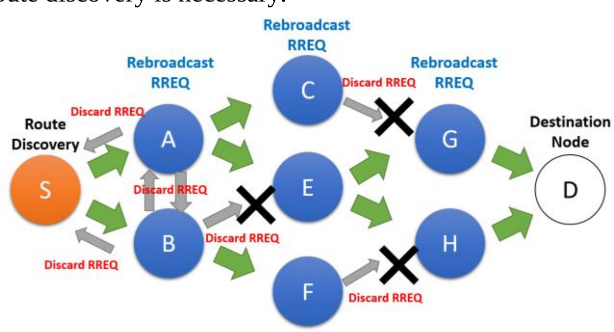

Figure 1. Route discovery process of AODV

We indicate the route discovery process of AODV. The source node S broadcasts the RREQ packet to the intermediate nodes to discover the destination node. Then the intermediate nodes receive the RREQ packet. If this RREQ packet is the first received RREQ packet of a RREQ ID, the node broadcasts the RREQ with appending its node information. If this RREQ packet is a packet whose RREQ ID is the same as the one in an already received RREQ packet, the node silently discards the newly received RREQ packet. In Fig.1, the packets come via C→G, B→E and F→H are discarded by the received node. Non-discarded RREQ packets continue to be broadcast until it reaches the destination node. An example of RREQ broadcast is shown in Fig. 1. RREQ packet arrives to the destination D via two paths, A → E → G → D and A → E → H → D. Thus these two paths are the candidates in the path selection of ISK protocol. These two paths have many common nodes. Completely independent paths are not likely to be constructed. In order to be able to use a path suitable for achieving fairness, it is necessary to adjust the route discovery process of AODV to obtain more independent paths.

B. *Problems of Fair Value*

We think that ISK protocol has a problem of the fairness evaluation among the nodes. ISK protocol categorizes the communication whose source node or destination node is the node itself or not. The protocol calculates a fair value (FV) as the ratio of these communication amount and evaluates the communication path based on the fair value (FV) of the nodes. In ISK protocol, the packets of self-benefit communication is defined as the one whose source node or destination node is the node itself. However, there are several cases when the source node is the node itself but the communication has no profit for the node. For example, if a node responds to communication requests from the other nodes and the node sends the data to the request nodes, the node might obtain no profit by the communication. A node that has important data in the MANET receives communication requests from many nodes. Requesting nodes obtain profit by the communication, but the reply node might not obtain profit by the communication. Thus such a communication should be considered as communication for the receiver (destination) nodes. However, ISK protocol considers such a communication is self-benefit communication. Such a server nature node receives communication requests from many nodes. These communication increases the ratio of self-benefit communication, thus the possibility for the server nature nodes to be selected as a relay node increases. This is unfair for the nodes that have important information.

In order to indicate this characteristic of ISK protocol, we executed a simulation to obtain FV (Fair Value) and the amount of relay data by self-made simulator using C-language. The simulator locates 100 nodes in 500m x 500m space. 25 nodes among the 100 nodes are server nodes and the other nodes (75 nodes) are client nodes. The simulator generates random communication requests from a client node to a server node or the opposite. The moving speed of nodes is 4km/h in average.

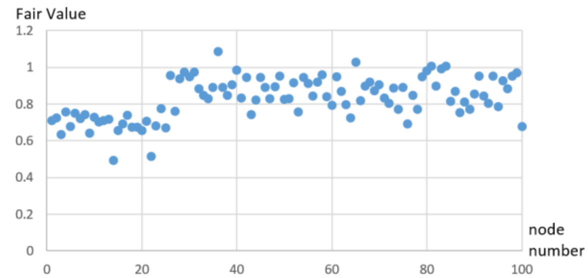

Figure 2. Fair Value by ISK protocol

Fig. 2 indicates each node's FV by ISK protocol. In the evaluation equation of ISK protocol, FV is small when the ratio of self-benefit communication is large. In Fig.2, the FVs of server nodes (number 1-25) are smaller compared to the FVs of the client nodes (number 26-100). Therefore, these nodes are likely to be selected as relay nodes because ISK protocol tries to equalize the FVs of all nodes.

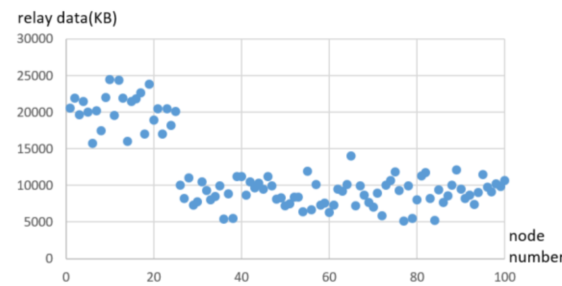

Figure 3. The amount of relay data in each node by ISK protocol

Fig. 3 indicates the amount of relay data in each node by ISK protocol. Fig. 3 shows that the amount of relay data of the server nature node is higher than the other nodes. The reason is that the server nature nodes relay many data because these are elected by the path selection. If the server nodes reply to requests, they are treated as the self-benefit communication and relay many data, thus the total amount of relay data increases. As shown by the simulation, this path selection has a fairness problem.

IV. The Proposed Protocol

We propose FRAODV (Fair Routing based on AODV) protocol that is a new AODV protocol to achieve fairness of communication amount in MANET. In MANET, in order to achieve fairness it is necessary to adjust the path construction process and to select the most appropriate path. We propose two modifications to AODV to achieve fairness. The first proposal is the change of AODV route discovery process. It obtains effective routes for the candidates in the path selection to achieve fairness. The second proposal is change to the definition of the ratio of self-benefit communication to other-benefit communication, in order to improve the bias of the relay of server nature node. Finally, we compare FRAODV and ISK protocol by network simulations.

A. Adjustment of AODV Route Discovery Process for Fairness

We improve the AODV route discovery process to achieve the fairness. The problem of AODV route discovery is the rule of discarding already received RREQ packets via another route. The aim of our change is to construct paths that are appropriate to achieve fairness. FRAODV evaluates each path of RREQ packets in the route discovery process, and broadcasts the RREQ packets based on the evaluation. FRAODV does not discard paths that might be suitable for adjusting the FV, and such a route is constructed as an available path. We show the detail of FRAODV route discovery process. The change from ISK protocol is that RREQ forwarding is decided by FV of the path to prevent discarding useful paths to achieve fairness.

1) Route discovery algorithm of FRAODV

1. This process is the same as AODV.
2. This process is the same as AODV with the exception of calculating FV in the packet header. A node that receives the RREQ packet adds the routing information to the routing table, compares FV and checks whether its destination node is itself. If it is not the destination and it has not yet received a RREQ packet with the same RREQ ID, it records the FV of the RREQ in the node, writes its node ID and adds its FV to the FV in the RREQ packet, and broadcasts the RREQ packet. If it has already received a RREQ packet with the same ID, it compares the FV in the newly received RREQ and already recorded FV in the node. If the FV of newly received RREQ is smaller than the recorded FV in the node, it replaces the recorded FV in the node and broadcasts the RREQ packet, otherwise, the node silently discards the newly received RREQ.
3. This process is the same as AODV with the exception of replying the RREQ and adding the value of FV in the RREP packet header. A RREP has the value of FV that is the summation of FVs of the nodes in the path. If a node that receives the RREQ packet is the destination node, it checks the FV and recorded FV. If the FV of newly received RREQ is smaller than the current path's FV in the node, the node generates the RREP packet and send to the source node.
4. The source node selects the route of the first received RREP. If the node receives a RREP packet whose FV is smaller than the currently selecting path's FV, the node selects the path of the newly received RREP packet.

2) Simulation for adjustment of AODV route discovery

We compare the original ISK and the modified ISK to verify the effect of the change in the route discovery process by the network simulator. The modified ISK uses the route discovery process of FRAODV. This simulation aims to compare the differences in the route discovery process. Thus, the path selection algorithm is unchanged, that is, the one in ISK algorithm is used in FRAODV. The simulation parameters are the same as the previous one.

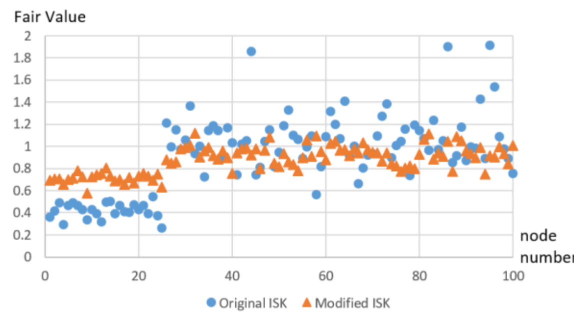

Figure 4. Comparison of the original ISK and the modified ISK with the FV.

Fig. 4 shows the comparison of FVs by the original ISK protocol and ISK protocol with the change the route discovery process in RREQ forwarding rule. Fig.4 shows that by the modified ISK dispersion of the nodes are smaller than the one by the original ISK. The reason is the modified ISK gives various paths as the candidates of the communication path compared to the ISK protocol. The FRAODV route discovery process of the modified ISK was shown to be effective to achieve fairness.

3) Overhead of proposed protocol in the route discovery

FRAODV might not discard the RREQ packets with the same RREQ ID and rebroadcasts some RREQs according to the value of the FV in the packet. Thus, since the number of times of broadcasting of RREQ increases, the overhead is expected to increase at the time of route discovery process.

The criteria of rebroadcasting the same RREQ is that FV of the newly arrived RREQ is smaller than the already received RREQ with the same ID. Since unnecessary RREQ packet to achieve the fairness is discarded in FRAODV, this protocol has a mechanism to reduce the overhead. We predict that the total amount of RREQ packets is expected to increase about 10 times compared with the AODV route discovery process. We consider that the overhead is allowable when considering the merit of achieving fairness.

B. Improvement of the Data Traffic Definition

We propose a new criteria of fairness of nodes. ISK protocol used FV for the criteria, which is the ratio of self-benefit communication to other-benefit communication. For a node, self-benefit communication is defined as the communication whose source node or the destination node is the node. The other communication is defined as the other-benefit communication. This definition has a problem that the server nodes are judged to have many self-benefit communication, thus the load of relay concentrate to the server nodes. This, we modify the definition of FV in the ISK protocol. We focus the upload and download communication. In generally, the characteristic of the server (data response) and client (data request) nodes are assumed to be following.

Server nature node: Upload Data ＞ Download Data

Client nature node: Download Data ＞ Upload Data

Using this property, we categorize the communication for itself or others. This change reduces the load on the server nature node. We define the fair value calculation equation as follows.

$$FV(Node) = \frac{Relay + UploadData}{DownloadData} \qquad (2)$$

$$SelectPath = \arg\min\{FV(Path) \mid Path \in A\} \qquad (3)$$

Equation (2) indicates the Fair Value (FV) of a node used in the route discovery process of FRAODV. FV of a path is defined as the sum of FVs of the nodes on the path. Equation (3) indicates the path selection at the source node, A is the set of paths obtained by RREPs. The difference of the new definition of self-benefit communication is that only download communication is treated as the self-benefit communication. Upload and relay communication are considered to contribute the other nodes. In order to confirm the effect of the change of the path selection evaluation and the change of route discovery process, we compare FRAODV and ISK protocol by the network simulation.

C. Simulation for comparison of the two protocols

We compare FRAODV and ISK protocol by the network simulation. The route discovery process is different between the two protocols. The evaluation equation of FV is different among two protocols. The simulation parameters are same as the previous one.

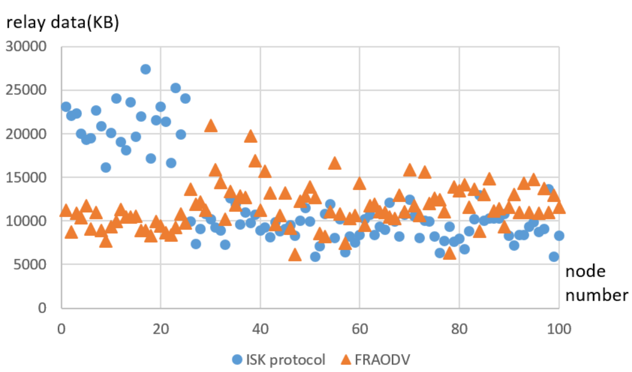

Figure 5. Comparison of FRAODV and ISK protocol with the amount of relay data

Fig. 5 indicates the comparison of FRAODV and ISK protocol with the amount of relay data. This comparison shows the effect of the difference of the route discovery and the path selection in these protocols. The difference in the amount of relay data between the server nature nodes and client nodes is small by FRAODV. It means that the load concentration on the server nature nodes is reduced by changing the categorization of communication. In contrast, ISK protocol has the load concentration in the server nature nodes. Since FRAODV categorizes upload data to other-benefit communication, the load concentration problem of ISK protocol was reduced. The simulation result shows that the load concentration problem is improved. The high adjustment by FRAODV is the effect of the new fairness definition and relay node allocation rule. By our proposed method, the unfairness for the user who has important information and delivers the information to many nodes is reduced.

V. CONCLUSION

We proposed FRAODV based on AODV to achieve fairness. FRAODV improves the load concentration problem to the server nature node in ISK protocol. In addition it adjusts the route discovery process to obtain better candidates in the path selection algorithm. This improvement has high fairness among the nodes in the MANET than the presented method. Our protocol has an additional overhead of broadcast RREQ packets. The further study includes reducing the RREQ packets.

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