Researches on an Ad-hoc Routing Protocol considering Traffic Conditions

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***Abstract*—With the spread of mobile nodes, studies on MANET (Mobile Ad-hoc Network) that can build networks solely with mobile nodes are drawing much attention. However, most of the ad-hoc routing protocols have not considered the traffic conditions in the network. Thus, we propose an ad-hoc routing protocol that takes account of traffic conditions, by way of extending OLSR (Optimized Link State Routing).**

Keywords-MANET; route; routing; Ad-hoc; OLSR; traffic

I. INTRODUCTION

Mobile nodes equipped with wireless LAN have been spreading rapidly. Along with this trend, studies on MANET that can build networks autonomously solely with mobile nodes are drawing much attention.

For the routing of MANET, routing protocols specialized in wireless communication are used. Such protocols are generally called "ad-hoc routing protocols". Many types of ad-hoc routing protocols have been proposed to date, and most of them choose the route whose number of the hop counts is the smallest (hereafter called the "shortest route") when creating a route. However, in the case of MANET, there is a high possibility that communications are relayed through certain specific nodes intensively. Thus, on the shortest route which includes such heavily loaded nodes, occurrence of delays of communications could increase, and batteries may be consumed quickly to cause the cutting-off of links. When a link is cut off, it becomes necessary to rebuild the route again, and the throughput decreases substantially. Therefore, the simply shortest route is not necessarily the best choice.

The following are some representative studies on ad-hoc routing protocols with the objective of improving the throughput. ABR (Associativity-Based Long-lived Routing) [8] selects a stable route through which links will not be cut off for a long time. Each node transmits beacon signals to other nodes existing in the vicinity with certain fixed intervals. The link established by the node that receives the highest number of beacon signals is expected to have a good durability and thus, communication can be done in a stable manner. However, since there may be little difference in the number of receipts of beacons in the environment where there is little move of nodes, it is possible that a route through which no improvement of the throughput is expected may be chosen.

ETR (Estimated-TCP-Throughput Maximization based Routing) [9] predicts the throughputs of several candidate routes to the destination, by expanding the DSR (Dynamic Source Routing) and chooses the route with the highest throughput. The throughput is calculated with the model formula proposed by Floyd and others. For this calculation formula, such information as the round-trip time and the packet loss ratio is required and a new control message is needed with certain intervals to collect such information. However, there is a problem that the overhead of the network increases by the new control message.

In this paper, we propose an ad-hoc routing protocol that calculates the load of each route and chooses the route with the smallest traffic, by expanding OLSR (Optimized Link State Routing). Hereafter, we show the classification of ad-hoc routing protocols of MANET in Chapter II, explain the outline of OLSR in Chapter III, our proposed method of expanding OLSR in Chapter IV and finally our conclusion in Chapter V.

II. CLASSIFICATION OF AD-HOC ROUTING PROTOCOLS

In the case of MANET, it is necessary for each node to have a relaying function to communicate with other nodes beyond the reachable range of the radio waves and to swiftly cope with the change in the link conditions caused by the moves of nodes. There are various uses kinds of usage of MANET and different types of routing protocols are proposed depending on the usage. Although many ad-hoc routing protocols have been studied till now, no protocol that can be applied to any environment has been developed yet. The ad-hoc routing protocols developed thus far can be categorized in three types as shown in Table I. They are individually used in different environments where the features of each protocol are most suitable.

Table I. Classification of Ad-Hoc routing Protocols

Types	Protocols
Proactive	OLSR, DSDV, TBRPF
Reactive	AODV, DSR, TORA, ABR
Hybrid	ZRP

A. Proactive-type

In the case of proactive-type routing protocols, routing tables are already in place before the demand for communication occurs, and it can start communication immediately when a demand for communication has come. Each node has one or more tables to store routing information and delivers renewed information on the route to the entire network, reflecting the change in the network topology. There are several types of proactive protocols based on the differences in the number of tables required for routing and also in the broadcasting methods to convey the network structure. The proactive-type routing protocols have the features that they are suitable for networks that have a high communication frequency because control packets are flowing even at the time of no communication and consequently no delays occur when they start communication although they consume more electricity.

B. Reactive-type

Reactive-type routing protocols are, in other words, an on-demand-type protocol. At the time when a route to the destination has become necessary in a node, it starts a process to search for the route within the network. This process continues until the route is found or all possible route patterns have been tried. When the route was found and established, that is maintained until it becomes no more necessary or it is no more possible to get access to the destination. The Reactive-type routing protocols have the features that they are suitable for networks in which moves of nodes are frequent because routes are built on demand, although it takes time to decide upon the route.

C. Hybrid-type

Hybrid-type routing protocols are a type of compound protocols that has the features of both Proactive-type and Reactive-type protocols. A network is divided into plural zones and a Proactive-type protocol is used in each zone, and periodical renewal of routing information is done to the node in the same zone only. In the case where the destination node is outside the zone of the source, a route is built using a Reactive-type protocol. Although Hybrid-type protocols can take advantage of the features of both Proactive-type and Reactive-type protocols in such a way, they encounter a problem when nodes are crowded as the management of topology gets quite difficult.

In this paper, we propose a method by which the least congested traffic route is chosen out of the shortest routes so that the degradation of the throughput is avoided.

The traffic volume on the route is constantly changing even while routing protocols are active. When we expand the routing protocol of MANET, we think it important to deal with the change in the traffic conditions. In the case of Reactive-type protocols, once a route is established, the route is never recalculated until the route becomes unnecessary or access to the destination becomes unavailable. On the other hand, in the case of Proactive-type protocols, it is possible to periodically update routing tables. Accordingly, we chose the Proactive-type routing protocol as our study target and focused on

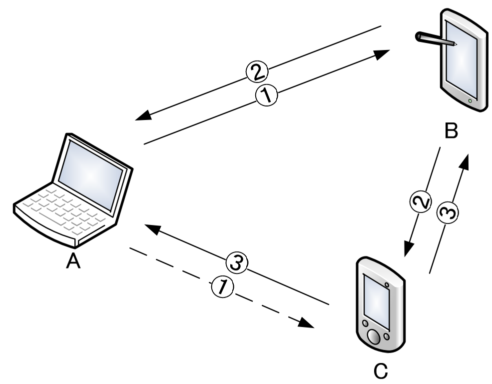


Fig. 1. Sending and receiving HELLO messages

"OLSR" (Optimized Link State Routing), which is the representative and most widely used one among various Proactive-type routing protocols.

III. OLSR

OLSR is a Proactive type routing protocol adopted in MANET proposed in the Project Hipercom [10] of INRIA. The following is the outline of OLSR.

A. Identification of neighbors

Each node broadcasts HELLO message periodically. The default value of the transmission interval of the HELLO message is two seconds. HELLO message contains such information as the address of the originator, a sequence number and the addresses of neighbors. Therefore the node that receives the HELLO message can get the addresses of the neighbors as well as the addresses of neighbor's neighbors, namely the addresses of nodes which are 2 hops away (hereafter called "2-hop neighbor"). In addition, if the receiver's own address is included in the received HELLO message, it is confirmed that the neighbor received the HELLO message which the receiver had originally sent. This means that it is possible to send and receive HELLO messages in both directions between the two, and such link is called a symmetric link. On the other hand, if the address of the receiver is not included in the received HELLO message, the link is recognized as an asymmetric link. Such states of links are also included in HELLO message to be sent.

Fig. 1 shows the situation where Node B receives the HELLO message of Node A, while Node C fails to receive the message. Thereafter, the HELLO message of Node B is received by Node A and Node C, and Node A recognizes that the link between Node A and Node B is symmetric, by finding that the address of Node A is included in the HELLO message from Node B. Meanwhile, Node C recognizes that Node A is a 2-hop neighbor. Then, further thereafter, if the HELLO message sent by Node C is received by Node A, Node A recognizes that the link between Node A and Node C is asymmetric because the address of Node A is not included in the message.

B. OLSR's Flooding method

The most important feature of OLRS is its efficient flooding manner. The flooding is the method for each node to deliver information about the node itself to all other nodes in the network. In normal flooding, source node broadcasts a message to neighbors, and neighbors that received the message relay the message to all other nodes by repeating it. If a node receives the same message repeatedly, it discards the redundant messages. Nevertheless, in the normal flooding method, the total number of broadcasted messages as well as the total number of redundant receipts of the same messages gets quite big.

In the case of OLSR, the minimum required relaying nodes (i.e., MPR:Multipoint Relay) is defined. Each node, after selecting its own MPR, notifies neighbors of the information by HELLO message. Each node that has received the message can identify the nodes that have been selected as MPR. Such nodes are called MPR selectors. Each node relays the messages from its MPR selectors only. In this way, the number of broadcasted messages and the number of redundant receipts of the same message can be reduced.

C. Delivery of topology information

OLSR periodically executes the flooding of topology information by a TC (Topology Control) message. It is only MPRs that create the TC message. The default value of the transmission interval of TC messages is five seconds. The TC message includes such information as the address of the originator, a sequence number and the addresses of its MPR selectors. The topology information delivered by a TC message is not the topology of all links, but the topology of MPR selectors only.

D. Other control messages

Besides HELLO message and TC message, OLSR has other control messages such as MID (Multiple Interface Declaration) message and HNA (Host and Network Association) message. The MID message is used only in the case where nodes have plural interfaces. The HNA message is a supplemental message used when the node functions as a gateway. As we do not make any modification to MID and HNA messages in our proposed method described in this paper, we omit explanation of these control messages.

E. Information possessed by each node

Each node has a repository composed of the seven tables shown in Fig. 2. These tables are created based on the HELLO messages which reach neighbors only and the TC messages flooded to the entire network.

The link set consists of the address of the local node itself, addresses of neighbors, the length of time for a link considered to be symmetric, and the length of time for a record to be kept alive. The neighbor set consists of the address of the neighbor, information about the state of link (whether symmetric or asymmetric), and the indicator to be chosen as MPR. The 2-hop neighbor set consists of the address of the neighbor and address of the symmetric 2-hop neighbor, and the time length for a record to be kept alive. The MPR set consists of the address of the node chosen as MPR and the time length for a record to be kept alive. The MPR selector set consists of the address of the node chosen as MPR selector and the time length for a record to be kept alive. The topology information base consists of the addresses of destinations, the addresses of nodes reachable by one hop, and the time length for a record to be kept alive. The duplicate set is a table which is established to avoid redundant processing of received messages.

We explain the behavior of nodes on Fig. 2. The node which received a HELLO message updates Information repository such as the link set, 2-hop neighbor set, MPR selector set, and duplicate set. In addition, in line with the

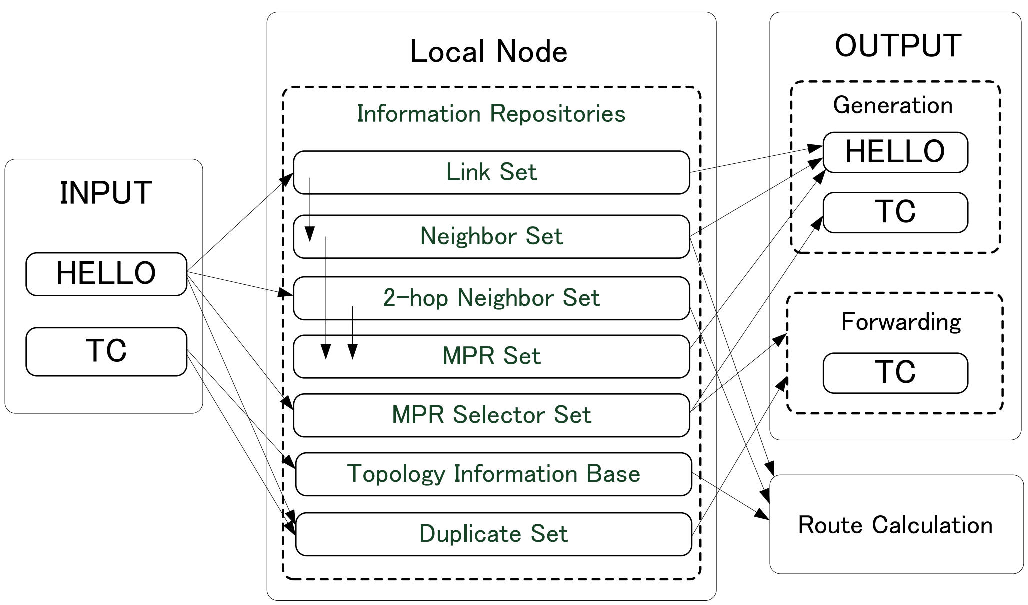


Fig. 2. Information repository

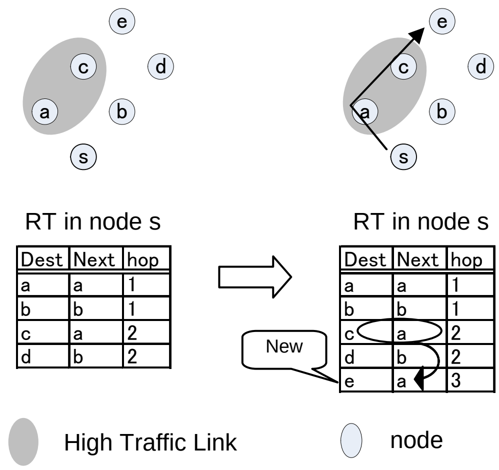


Fig. 3. RT generation method by OLSR

updating of the link set and the 2-hop neighbor set, the neighbor set and the MPR set are also updated. Meanwhile, the node that receives the TC message, updates the topology set and the duplicate set. Based on these updated tables, new HELLO messages and TC messages are created. TC messages are relayed based on the MPR selector set and the duplicate set. In addition, routing tables (RT) are created based on the neighbor set, the 2-hop neighbor set, and the topology information base.

F. Route Calculation

RT of OLSR consists of the destination node (Dest), the next hop node (Next) on the route to Dest, and the number of hop counts (hop) to Dest, and maintains one route for each Dest. Fig. 3 shows the process of creating a new route to Node "e" in RT of node "s" from the state where routes for Nodes "a"~"d" have already been established. The route to "e" must pass "c" or "d" because they are the neighbors of "e". As the route to "c" must pass "d", and the route to "d" must pass "b", as indicated in RT, the route to "e" must pass "a" or "b". In this case "a" is chosen for Next of the route to "e", because the route "a" is found first as shown in Fig. 3. In RT of Nodes "a"~"d" as well, the route to Node "e" is determined in the same manner, and one shortest route s → a → c → e is completed.

However, in this method, the first discovered shortest route is simply chosen. If the route so chosen is a route in a bad state of high load link because of heavy traffic, the throughput gets low because of the overhead of node processing or packet loss.

IV. EXPANDED OLSR

In our proposed system, route selection is made in consideration of the state of traffic volume, in contract with the existing OLSR. Thus, one item about the traffic volume needs to be added to the related information tables in the repository (link set, neighbor set, 2-hop neighbor set, topology information base). Also, RCT (Route Calculation Table), which indicates the calculation results of the total traffic volume of several shortest routes to the destination node (Route) is added to the repository. RCT consists of Dest, Route, hops, and total traffic (Traffic) of the routes to the destination nodes. Furthermore, each node adds traffic information to HELLO and TC messages to be sent. The nodes that receive these messages update tables in the repository together with the traffic information. The final RT is created based on the contents of RCT.

Fig. 4 shows the operation of the expanded OLSR, based on the flow of the processing of control messages in OLSR. In balloon 1) ~ 5), the following operation is performed.

1) Dispatch of control message

The originator of HELLO and TC messages adds its own traffic volume to these messages before sending them.

2) Updating of link set

Recording the traffic volume of the originator's node in the

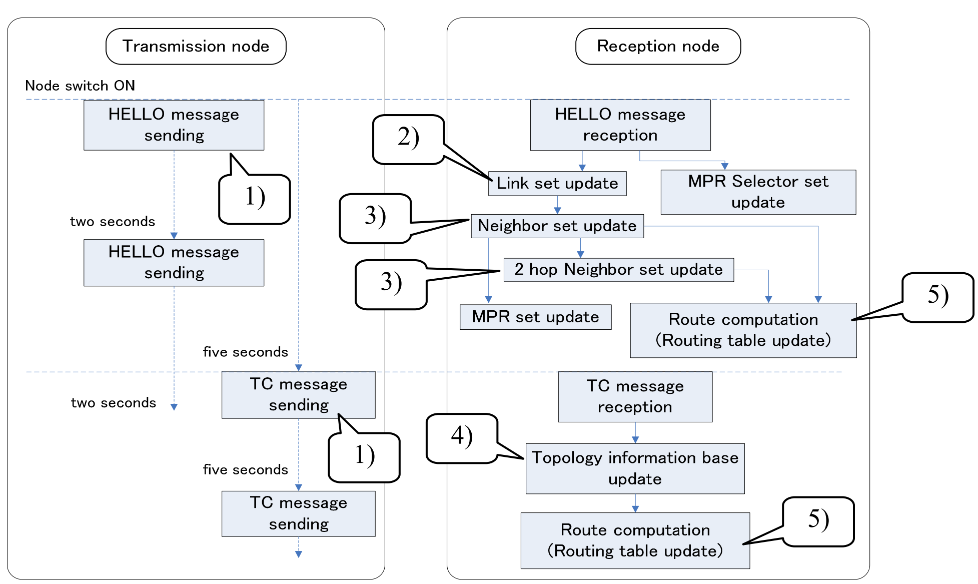
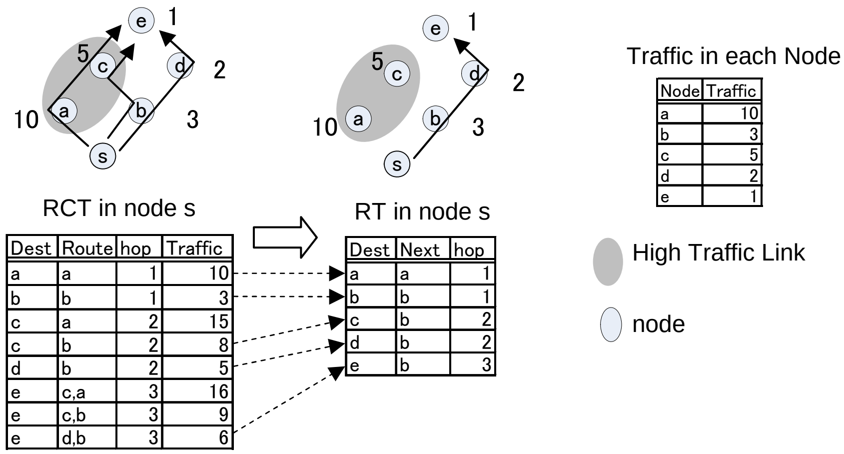


Fig. 4. Movement of expansion OLSR



RCT in node s

Dest	Route	hop	Traffic
a	a	1	10
b	b	1	3
c	a	2	15
c	b	2	8
d	b	2	5
e	c,a	3	16
e	c,b	3	9
e	d,b	3	6

RT in node s

Dest	Next	hop
a	a	1
b	b	1
c	b	2
d	b	2
e	b	3

Traffic in each Node

Node	Traffic
a	10
b	3
c	5
d	2
e	1

Fig. 5. RT generation method by expansion OLSR

record of neighboring node, which corresponds to the node of the originator of HELLO message. If there is no corresponding record, a new record which regards the originator's node as the neighboring node is newly created.

3) Updating of neighbor set and 2-hop neighbor set

Registering the traffic volume on the record of the neighbor set and the 2-hop neighbor set that corresponds to the updating of 2).

4) The update of the topology set

Registering the traffic volume of the originator's node in the record of the destination node that corresponds to the originator's node of TC message. If there are no corresponding record, a new record which regards the originator's node as the neighboring node is newly created.

5) Route calculation

In advance of the route calculation (RT renewal), RCT is created. RCT is created in the same m as the route calculation as explained in Chapter 3, Section F, but in order to maintain plural routes to the destination node, the entire routes are recorded to make a comparison among them.

Upon completion of the creation of RCT, the route with the least traffic is chosen and RT is created.

Fig. 5 shows the method to create the most suitable route in the expanded OLSR. Fig. 5 indicates a route creation method in the same way as Fig. 3, taking account of node "s". The numbers described by each node indicate the volume of traffic of the node.

The total traffic volume for each route is calculated in RCT, by creating plural shortest-route candidates from HELLO and TC messages. In Route, the entire nodes passed to the destination node are described. The routes with one hop or 2 hops to Dest are calculated by referring to the neighbor set and the 2-hop neighbor set. The routes with more than 3 hops are calculated in the following way. Because the neighbors of "e" are "c" and "d" from the topology information base, Route of "e" is determined as [c, a], [c, b], and [d, b], by referring the record where Dest is "c" and "d" in RCT, and adding "c" and "d" to the value of Route. Upon determination of RCT, the least traffic route is chosen from among the routes to the same destination. Finally, from Route of the selected record in RCT, the first route is chosen for Next in RT, that is "b" in the case of [c, b]. In the case of nodes "a"~"d", routes which avoid heavy traffic links like s→b→d→e as shown in Fig. 5 are completed, by creating RT in the same way.

V. CONCLUSION

In the case of MANET, communications may be relayed through certain specific nodes intensively and the load of such nodes gets quite heavy. Since many of the existing ad-hoc routing protocols simply choose the shortest route, there is a possibility that the load of the route gets heavy and as a result, the throughput tends to be lowered. In this paper, we showed a method to realize an ad-hoc routing protocol that chooses a route of the low load as much as possible by using the traffic volume as an indicator to choose a route. Hereafter, we will carry a simulation and verify the operability of our proposed method. We will also study other factors than the traffic volume, including the degree of battery consumption.

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Researches on an Ad-hoc Routing Protocol considering Traffic Conditions

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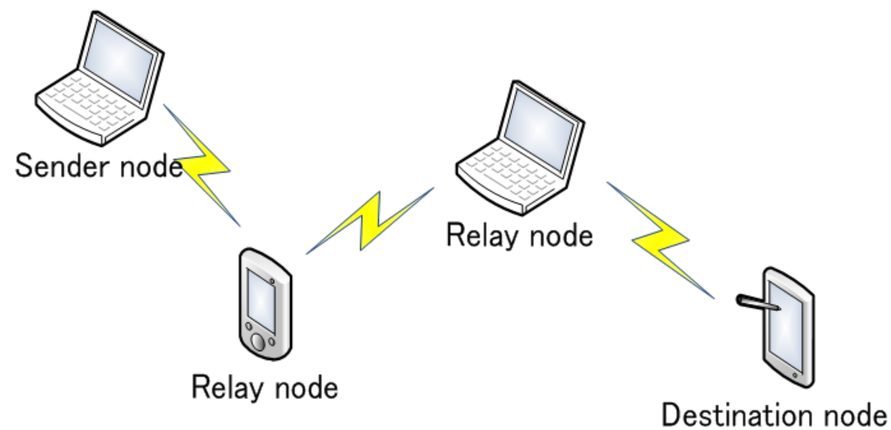
Background

With the spread of wireless mobile nodes, studies on MANET are drawing much attention.

- MANET (Mobile Ad-hoc Network)
  - Access points are not needed in the system.
  - A network is composed of only mobile nodes which have wireless LANs.
  - All nodes have relay functions.
  - Multi-hop communications are possible with remote nodes.
  - A particular routing protocol is used in the nodes.



- Scenes of use
  - Communications at the time of a disaster, where network infrastructures are broken.
  - Temporal communications at a conference or an event site.

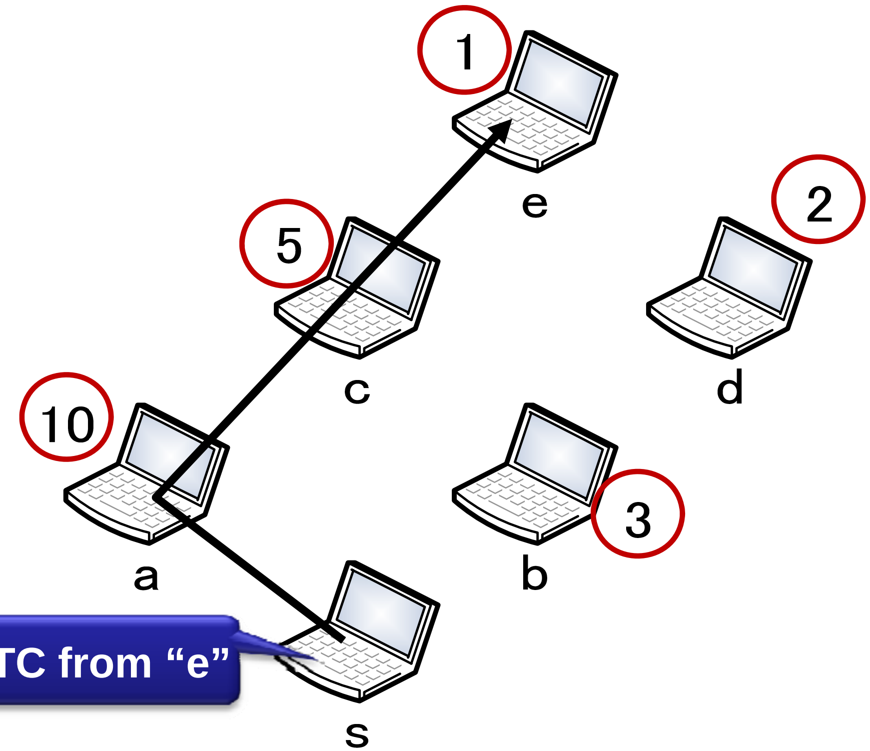
How to select route in OLSR

Route generation from “s” to “e”

RT(Routing Table) of “s”

Dest	Next	hops
a	a	1
b	b	1
c	a	2
d	b	2
e	a	3

New



- When “s” newly receives TC from “e”, the route to “e” is added in routing table.
- The massage in TC shows that “e”’s neighbors are “c” and “d”. The Next column for “e” is set to “a”, that is the same with “c”, because “c” is found at first .
- In the same way the route to “e” is made in every nodes, and the route generation is completed.

This route includes “a” that has high traffic, and is not the best route.

Operation of Extended OLSR ①

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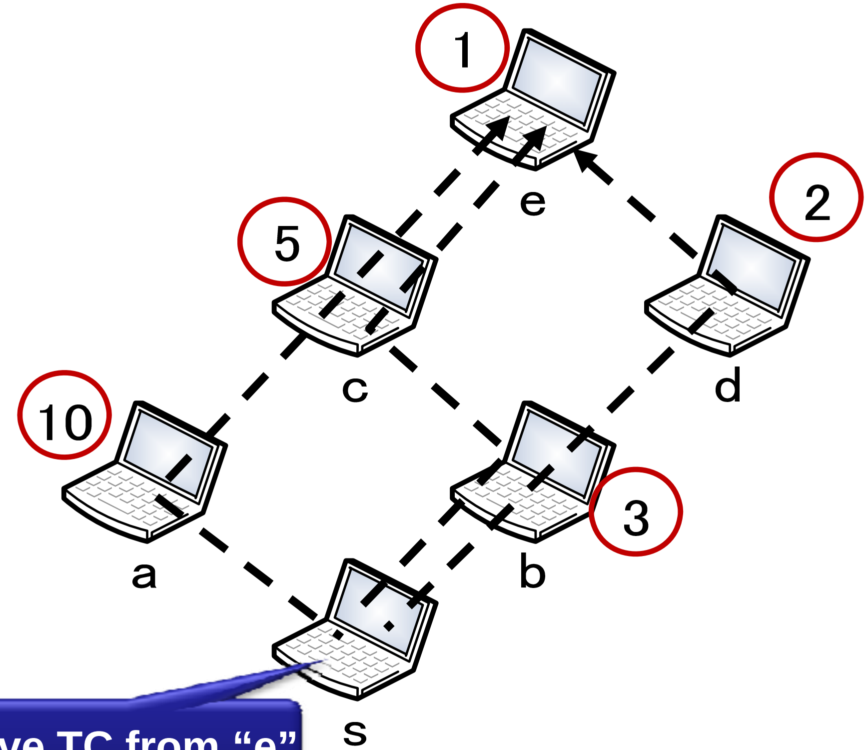
Route generation from "s" to "e"

RCT(Route Calculation Table) of "s"

Dest	Relay	hops	Traffic
a	a	1	10
b	b	1	3
c	a	2	15
c	b	2	8
d	b	2	5
e	c, a	3	16
e	c, b	3	9
e	d, b	3	6

New



- When "s" newly receives TC from "e", plural shortest routes are added in RCT.
- All intermediate nodes like "c", "a" are set in the Relay column.
- The total traffic of the route is set in the Traffic column.
- In the same way, RCT is generated in every nodes.

Plural shortest routes are completed.

Operation of Extended OLSR ②

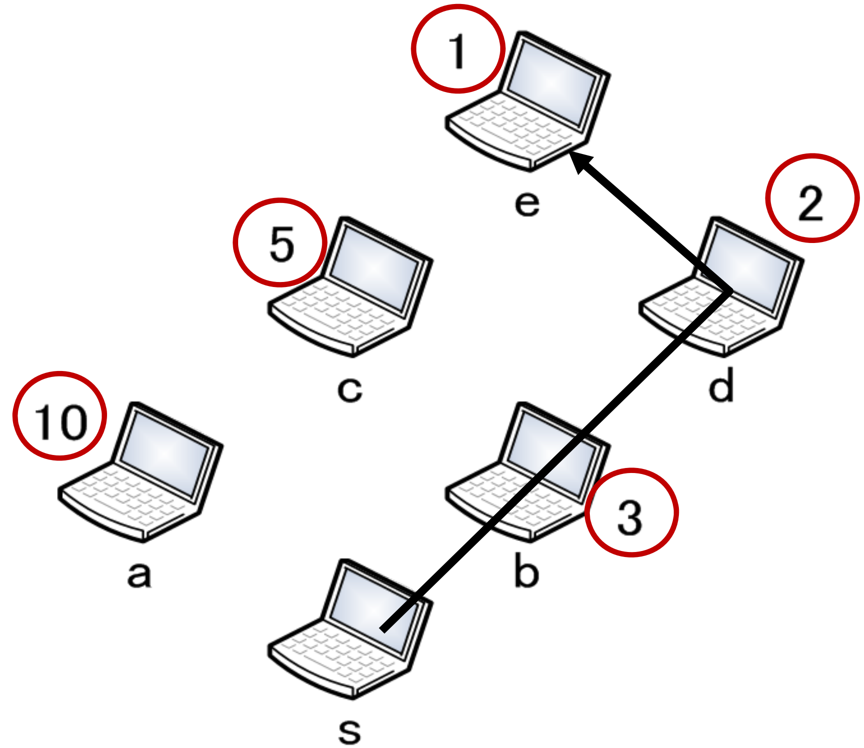
Route generation from "s" to "e"

RCT(Route Calculation Table) of "s"

Dest	Relay	hops	Traffic
a	a	1	10
b	b	1	3
c	a	2	15
c	b	2	8
d	b	2	5
e	c, a	3	16
e	c, b	3	9
e	d, b	3	6

RT(Routing Table) of "s"

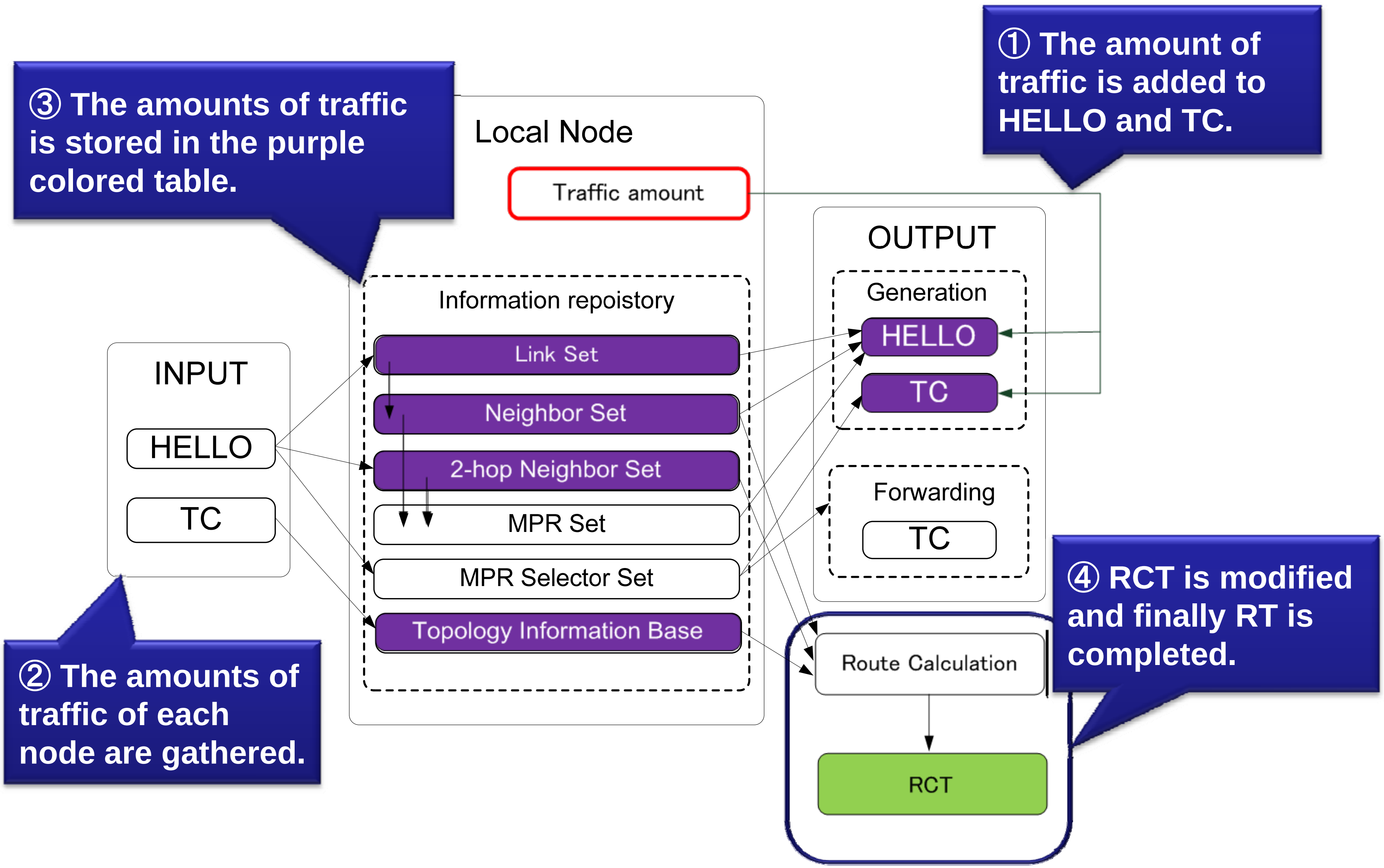
Dest	Next	hops
a	a	1
b	b	1
c	b	2
d	b	2
e	b	3



- The route which the traffic is minimum is selected from RCT, and finally RT is generated.

RT is generated in every nodes, and the best route which the total traffic is minimum is completed.

A realization method of Extended OLSR



Ad-hoc routing protocol

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- Nodes can keep the communication even if a network topology changes.

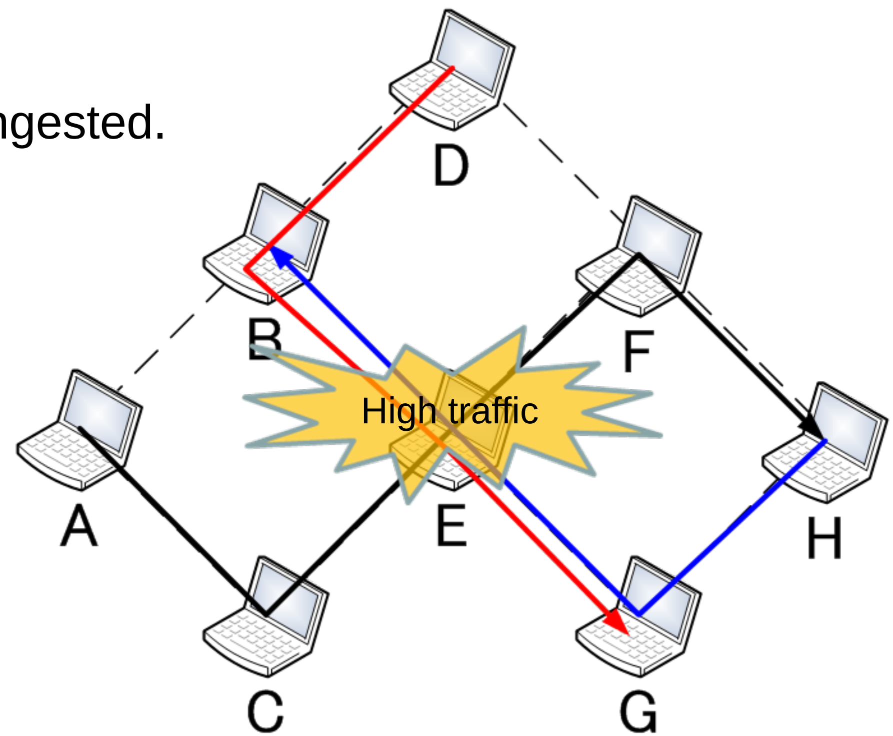
Types	Characteristic
Proactive	➢Routing tables are maintained periodically, so communication begins immediately. ➢It is effective for the network where the changes of network configurations are very little and the traffic of communication is rather high.
	ex.) OLSR (Optimized Link State Routing)
Reactive	➢Routing tables are generated when the communication begins, and the same route is kept while the route is stable. ➢It is effective for the network where traffic of communication is low and the network configuration changes frequently.
	ex.) AODV (Ad hoc On-Demand Distance Vector)

Assignment of Ad-hoc routing protocol

- In most Ad-hoc routing protocols, the shortest route, that is to say, hop counts are minimum, is selected as the best route.
- However, the selected route may not be the best route.
  - The traffic of "E" will be highly congested.

Packet loss occurs frequently.

Throughput decreases significantly.



How to send and receive Control messages

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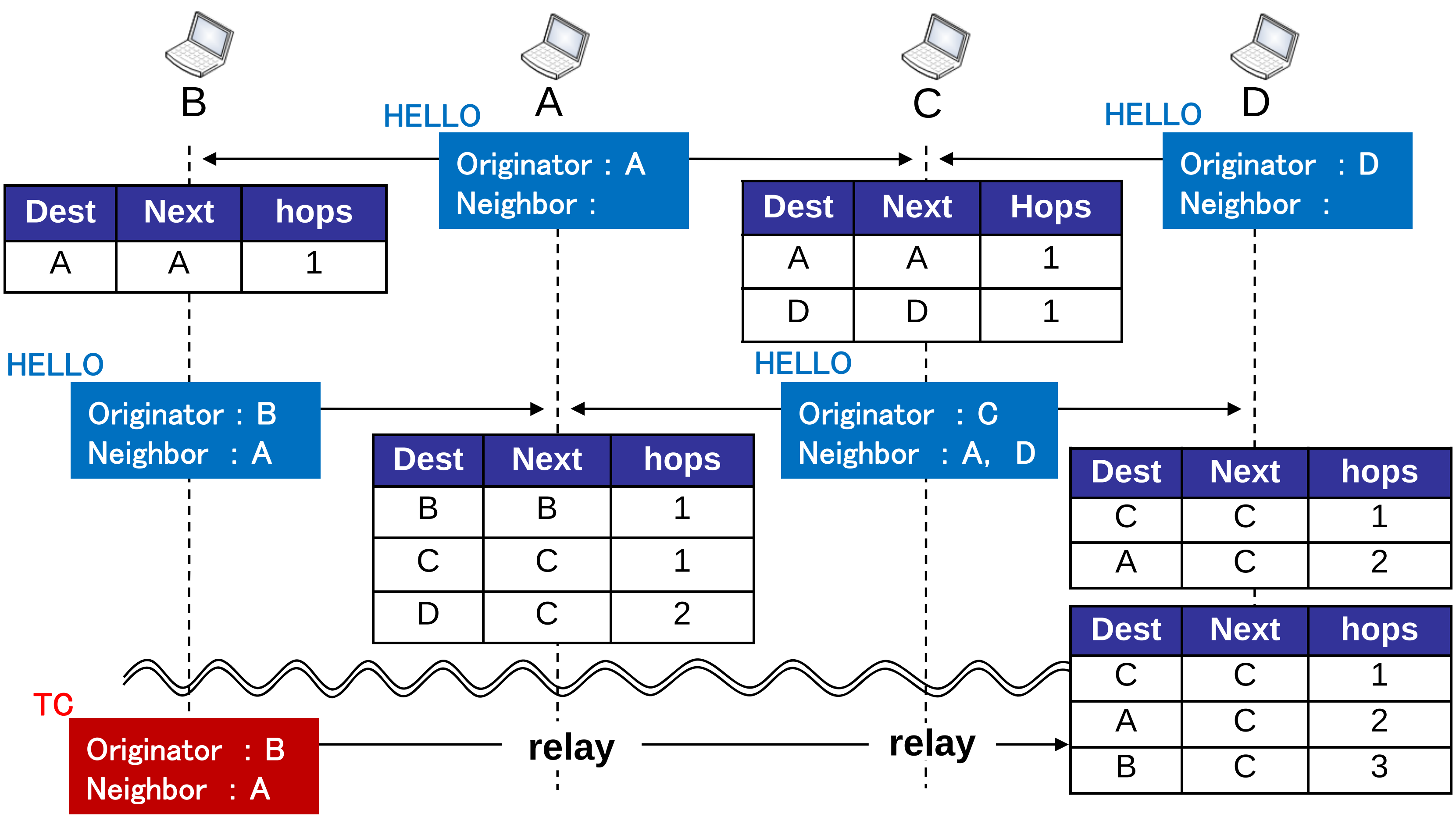
- Sending and receiving HELLO and TC.
  - HELLO and TC carries an originator address and neighbor addresses.



Appendixes

Proposal method

The Base protocol

- The proactive type grasps the topology of a whole network with control messages delivered from nodes regularly.
- We think that the traffic of nodes can be collected with the control messages.

We choose OLSR that is the most popular proactive type protocol to realize the proposed method.

Summary of OLSR

- In OLSR, routing tables are made with the message of HELLO and TC.
- **HELLO**
  - Broadcasted to neighbor nodes every 2 seconds.
- **TC (Topology control)**
  - Flooded to the whole network every 5 seconds.

Extended OLSR

- Traffic values measured in the nodes are added to the messages in HELLO and TC. So all nodes can grasp the traffic in the system.
- Here, **RCT (Route Calculation Table)** is newly defined. From RCT, the total traffic to the destination node can be calculated.
- There are plural shortest routes to the destination node. RCT has all the information of the routes.
- The route with the smallest traffic is selected for the best route.
- Then RT is made from the above result.

Information repository in OLSR

Information repository

- It is built from massage in HELLO and TC.
- It has various kinds of information.
- Link Set
  - It is the set of nodes within the range of wireless signals.
- Neighbor Set
  - It is the set of neighbor addresses and their willingness.
- 2-hop Neighbor Set
  - It is the set of two hop neighbor.
- MPR Set
  - It is the set of neighbors chosen as MPR.
- MPR Selector Set
  - It is the set of nodes which choose oneself as MPR.
- Topology Information Base
  - It is the set of network topology including nodes more than three hops and their neighbors.

Existing Method

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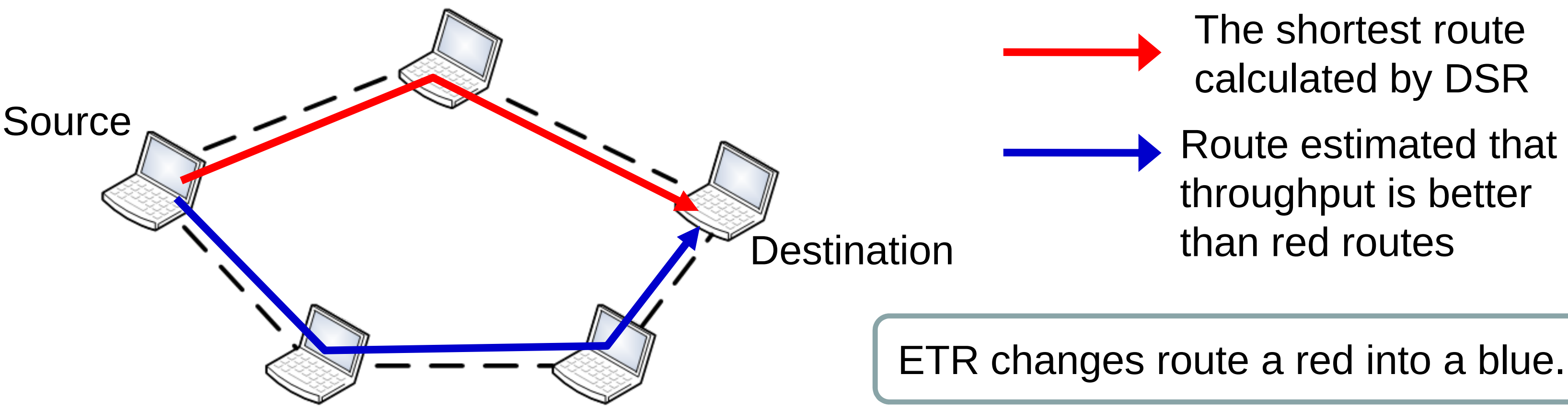
- ETR (Estimated-TCP-Throughput Maximization based Routing)
  - This method expanded DSR (Dynamic Source Routing) that is a reactive type.
  - It can switch the route calculated by DSR to the route which is expected to be better.
  - It is necessary in ETR, throughput is calculated by round trip times and packet loss rates. They are collected by RTPLM(Round-Trip Packet Loss ratio Measurement) requests and responses those are transmitted at a certain interval from the beginning of communication.



ETR changes route a red into a blue.

Summary

- Assignment of ad hoc routing protocol
  - If the route is simply selected, it may not the best route.
- This presentation
  - We have proposed Extended OLSR that can select the best route considering traffic state in the system. And shown the realization method.
- Schedule for the future
  - We will evaluate the proposed system with the network simulator ns-2.