A Robust Routing Protocol by a Substitute Local Path in Ad Hoc Networks

Mary Wu[1], SangJoon Jung[2], Seunghwan Lee[3], and Chonggun Kim[1,*]

[1] Dept of Computer Eng., Yeungnam Univ.,
214-1, Deadong, Kyungsan, Kyungbuk, 712-749 Korea
mrwu@yumail.ac.kr, cgkim@yu.ac.kr
[2] Dept. of General Education, Kyungil Univ.,
33, Buho-ri, Hayang-up, Kyongsan, Kyungbuk, 712-701 Korea
sjjung@kiu.ac.kr
[3] SoC R&D Center, System LSI division, Samsung Electronics Co.
seung1972@hotmail.com

Abstracts. Ad hoc wireless networks consist of mobile nodes in an area without any centralized access point or existing infrastructure. The network topology changes frequently due to nodes' migrations, signal interferences and power outages. One of the ad hoc network routing protocols is the on-demand routing protocol that establishes a route to a destination node only when it is required by a source node. The overhead of maintenance is low, but it is necessary to reestablish a new route when the routing path breaks down. Several recent papers have studied about ad hoc network routing protocols avoiding the disconnection of the existing route. Each active node on the routing path detects the danger of a link breakage to a downstream node and try to reestablish a new route. The node detects a link problem, try to find a substitute local path before the route breaks down. If the local reestablishment process fails, the route breaks down. In this paper, a robust routing protocol is proposed to increase the success rate of the local route reestablishment and enhance the communication delay performance. The results of computer simulation show that the proposed routing protocol increases system performance.

1 Introduction

Ad hoc network is the cooperative engagement of a collection of mobile nodes without the required intervention of any centralized access point or existing infrastructure, where all nodes are capable of moving and can be connected dynamically in an arbitrary manner. Nodes in a network function as routers, which discover and maintain routes to other nodes in the network. One important challenge in the design of ad hoc networks is the development of dynamic routing protocols that

* Correspondence author.

M. Gavrilova et al. (Eds.): ICCSA 2006, LNCS 3982, pp. 93 – 103, 2006.

can efficiently find routesbetween two communicating nodes. The on-demand routing protocols establish a routing path to a destination node only when the source node has data to transmit[1-6]. AODV(ad hoc on-demand distance vector routing)[4], DSR(dynamic source routing)[5], TORA(temporary-ordered routing algorithm)[6], ABR(associativity based routing)[7], SSA(signal stability-based adaptive routing)[8] are categorized in this type. When a node requires a route to a destination, it initiates a route discovery procedure. This procedure is completed once a route is found or a possible route has been examined.

In order to obtain a stable routing path, ABR uses a cumulated number of beacon signals to measure the stability of neighboring nodes. The stability measurement factor is appended to search packets so that the destination node can construct a stable route according to the result of stability measurement. SSA uses the information of the signal strength at the link to choose a stable route. If there is a route failure due to host mobility, signal interference or power outage, it requires additional time and heavy traffic of reconfiguring the route from the source to the destination. ARMP(active route maintenance protocol)[9] tries to prevent disconnecting of the current route by monitoring the status of the signal strength and stability of the individual links. Two nodes of a weak link perform a local route reestablishment process to find a substitute local path before the routing path is broken. But, if the local route reestablishment process fails, the route may be broken. The success rate is important. In this paper, RRAODV(robust routing protocol of AODV) is proposed to increase the success rate of the local route reestablishment and enhance the route efficiency. RRAODV is on-demand routing protocol based on AODV. Simulation results demonstrate that the proposed RRAODV reduces the probability of local route breakage compared to that of the previous studies.

2 Overview of Local Recovery Methods of Route

2.1 ARMP

ARMP establishes a substitute partial route before the occurrence of route disconnection. When the state of a link is changed to an unstable state, the end nodes detect whether a route disconnection will be caused in the near future by the link status. One of the end nodes of this link is selected as an active node to establish a substitute local path.

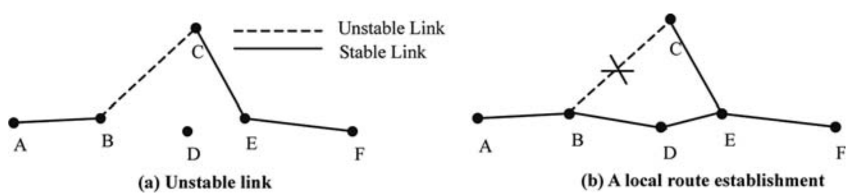


Fig. 1. A local recovery in ARMP

In fig.1, a neighbor node of node D will be selected as stepping node to connect node B with node E. Thus, a new local route can be established before the original route is disconnected. If the local route reestablishment process fails, the route is going to break.

2.2 Concepts of the Proposed Robust Routing Protocol

The proposed RRAODV is proposed to increase the success rate of the local route reestablishment. Active nodes which are nodes on the routing path monitor the signal strengths to the next node and check the stability of the link state. When the signal strength of a link is less than SS_{thr}(signal strength threshold of stable link state), the link is considered unstable. The node of an unstable link starts the reconstructing of a local routing path. The signal strengths of links on the ad hoc network are maintained in each node[9]. The reestablishment process has two steps. First, the node selects one of the downstream nodes in its transmission range as a new next node. In fig.2(a), the routing path has node S, A, B, C, E, F, G, D as active nodes at T_i. In fig.2(b), node E moves and node C has a weak link connection with the next node E at T_{i+1}. Node C starts to select a new next node. The downstream nodes of node C are nodes E, F, G, D. There is node F in the transmission range of node C at T_{i+1}. In fig.2(c), node C selects the downstream node F as the new next node.

If there isn't any downstream node in the transmission range of node C, the reestablishment process migrates to the second step. In fig.3(a), the routing path is S, A, B, C, E, F, G, D at T_i. Node E moves and node C has a weak connection to the

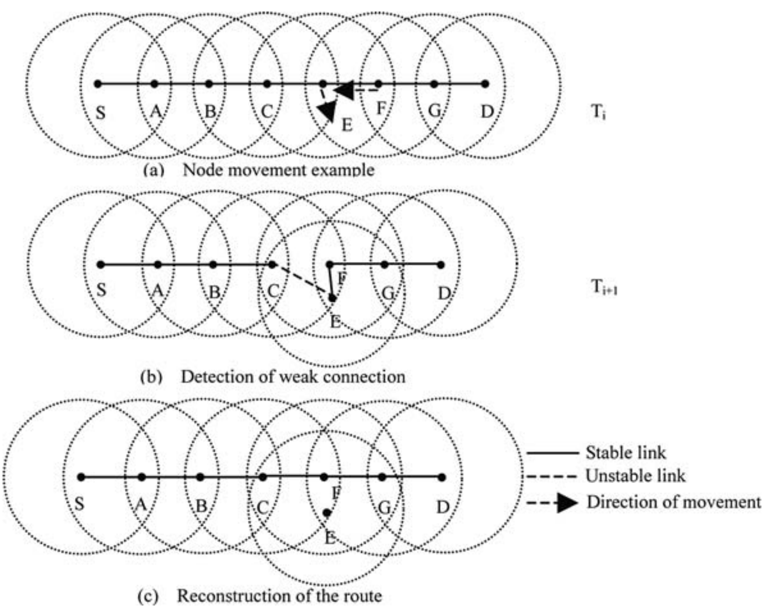


Fig. 2. Selection of one of the downstream nodes as a next hop node

next node E at T_{i+1}. In fig.3(b), there isn't any downstream node in the transmission range of node C at T_{i+1}. In this case, the first selection process is failed. In the second step, the node C selects one of the non-active neighbors which have connection to one of the downstream nodes which will become the new next node. The non-active node H is selected as the stepping node from node C, to connect to the downstream node F. As the result, node H is selected as the new next node of node C.

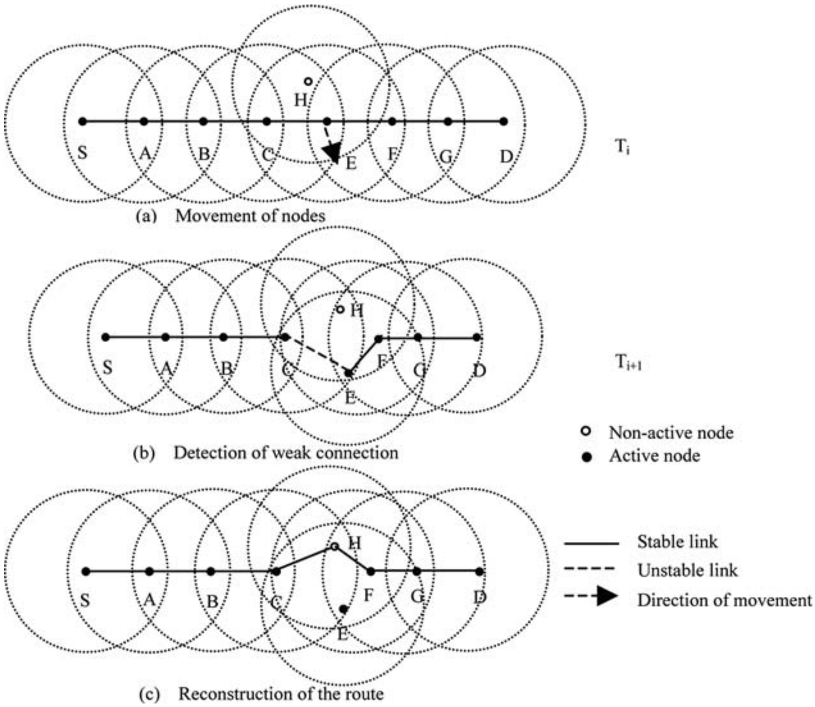


Fig. 3. Selection of one of the non-route neighbors which have connection to the downstream node

3 Operation of the Robust Routing Protocol

RRAODV mainly consists of three phases, the first phase is the ordinary route searching process. In the second phase, each node on the routing path monitors the link state to the next node. In the third phase, when a node has an unstable link to the next node, it requires a route reestablishment process.

3.1 Routing Table and Packet Format

The route discovery is started by broadcasting a RREQ(route request) packet to its neighbors. If a node which receives RREQ is an active node on the routing path to the destination or itself is the destination, the node transmits a RREP(route reply) back to its previous neighbor which sent the RREQ. A node that received the RREP propagates the RREP toward the source. When each node receives the RREP, the node prepares routing informations and store it in the routing table. The routing table entry contains the following information[4]:

Destination, Next Hop, Number of hops, Sequence number for the destination, Active neighbors for this route, Expiration time for the route table entry.

In the proposed method, the information about downstream nodes is added to the routing table. In fig.4, node E receives a RREP from node F and records the information of downstream nodes G, D. In this case, node G is the first downstream node, and node D is the second downstream node. Table.1 is an example of the routing table on node E.

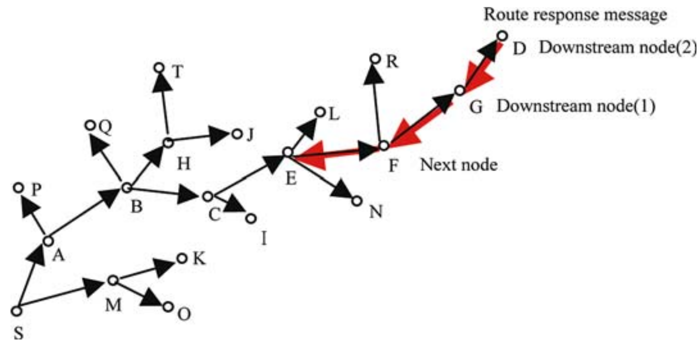


Fig. 4. RREP message transmission

Table 1. The routing table of the node E

Destination	Next hop	Hop count	Number of downstream	Downstream
D	F	2	1	G
			2	D

	Type=2	R	A	Reserved	PS	Hop Count=2
	Destination IP address (Node D IP address)					
	Destination Sequence Number					
	Originator IP address (Node S IP address)					
	Lifetime					
Extended fields	Down stream node (Node D IP address)					
	Down stream node (Node G IP address)					
	Down stream node (Node F IP address)					

Fig. 5. The extended RREP message sent by node F to node E

When an intermediate node receives a RREP, it propagates the RREP toward to the source including its own IP address in a downstream node field of the RREP massage. The extended RREP massage format is shown in fig.5. Node F writes its own IP address to the downstream node field and propagates the message to node E.

3.2 Estimation of the Link Fault Using Link States

Local connectivity is confirmed by hello messages. If hello messages are not received from the next active node on the routing path during a certain interval, the node will send the notification of a link failure on AODV[4]. In the proposed method, each active node records the signal strength of hello messages received from neighbors. In fig.6, node E receives hello messages which have information about node F and the downstream nodes G, D.

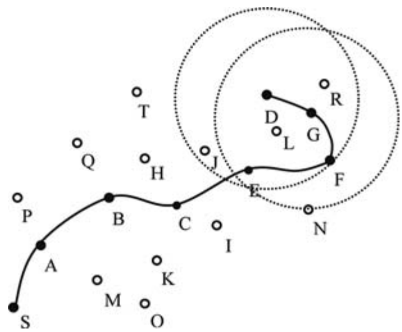


Fig. 6. An example of a routing path

Table 2. The table of the signal strength from the next node F(node E)

Time	Next node	Signal strength	Link state
HT_i	F	SS_{FE}	S(stable) or U(unstable)

Table 3. The table of signal strength from the downstream node G, D(node E)

Time	The number of downstream	Downstream	Signal strength
HT_i	1	G	SS_{GE}
HT_i	2	D	SS_{DE}

Nodes maintain the signal strength from the next node and the downstream nodes like table 2 and table 3. SS_{FE} is the signal strength which node E receives from node F.

Whenever each active node detects an unstable link state, a candidate node must be chosen to establish a substitute stable routing path. A link which the signal strength is less than SS_{thr} is considered unstable.

3.3 Selection of a New Next Node

All nodes have to manage a list of one-hop neighbors. By receiving a hello message from a new neighbor, or failing to receive consecutive hello messages from previous neighbors, a node can detect that the local connectivity has changed[4].

The selection of a new next node has two steps. First, the node has an unstable link to the next node selects one of the downstream nodes in its transmission range as a new next node. If there isn't any downstream node in the transmission range, as the second step, the current node selects one of non-active neighbors which can connect to one of the downstream nodes as the new next node. If the second step also fail, the current node transmits the RERR(route error) message to the source node and it restarts the route discovery process as AODV. In the first local recovery process, when downstream nodes are available as next node candidate, then the nearest node to the destination node have to be selected as the next node.

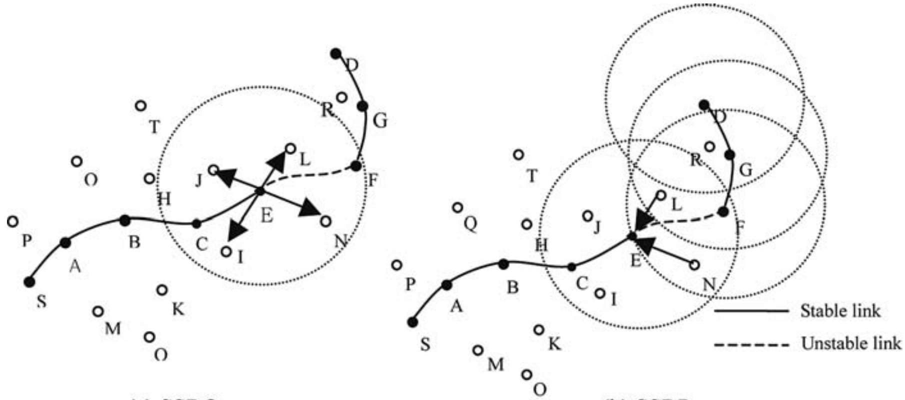
In table.3, if SS_{DE} is stronger than SS_{thr}, node D is chosen as a new next node. If not, node E checks SS_{GE}. If SS_{GE} is stronger than SS_{thr}, node G is chosen as a new next node. If there isn't any node has that the signal strength is stronger than SS_{thr} in the table, node E initiates the second selection process.

In the second selection process, the node broadcasts a SSRQ(signal strength request) message to select a stable non-active node which will work as a stepping node to connect to one of the downstream nodes. In fig.7(a), node E broadcasts a SSRQ packet, then one-hop-neighbor nodes I, J, L, N receive it. The SSRQ includes the information of the downstream nodes and the signal strength in fig.8(a). The non-active nodes I, J, L, N check the information of the downstream nodes. If they have some information from the downstream nodes, they reply SSRP(signal strength reply) packets including the signal strength information to node E. There is node L in the transmission range of the downstream node G and the next node F in fig.7(b). Therefore, node L has managed the signal strength of node G and node F. When node L receives the SSRQ, it replies the SSRP to node E including the signal strength of nodes G and node F.

The signal strength message format is shown in fig.8. It contains a type value of 5. The code of SSRQ message value is 1, and SSRP is 2. Node E receives SSRP packets from nodes L, N and selects node L as a new next. Node G is also selected as the next of the next node on the routing path.

Node E selects one of non-active neighbors with a stable links to the downstream nodes on the routing path. The selected node must have the sufficient signal strength both the previous node and the downstream node.

In the table 4, the one-hop neighbors of node E are nodes I, J, L, N. There isn't any neighbor within the transmission range of the 2^{nd} downstream node D. Therefore, the values of SS from the 2^{nd} downstream field are all 0s. There are nodes L, N in the transmission range of the 1^{st} downstream node G. The signal strength of node L from the 1^{st} downstream node G is SS_{GL}, and that of node N is SS_{GN}. If SS_{GL} is stronger than SS_{thr}, the node is selected. If SS_{GL} is weaker than SS_{thr}, and SS_{FL} is stronger than SS_{thr}, node L is selected. Both SS_{GL} and SS_{FL} are weaker than SS_{thr}, then node E transmits a RERR message to the source node.



(a) SSRQ (b) SSRP

Fig. 7. Gathering of the signal strength message

Type =5	Code =1	Reserved
Request node address = E		
Signal strength		
Next node address = F		
Signal strength		
1st downstream node address = G		
Signal strength		
2nd downstream node address = D		
Signal strength		

Type =5	Code =2	Reserved
Request node address = E		
Signal strength = SS_{EL}		
Next node address = F		
Signal strength =SS_{GL}		
1st downstream node address = G		
Signal strength = SS_{GL}		
2nd downstream node address = D		
Signal strength		

(a) SSRQ (b) SSRP

(a) SSRQ (b) SSRP

(a) SSRQ (b) SSRP

Fig. 8. The format of the signal strength message

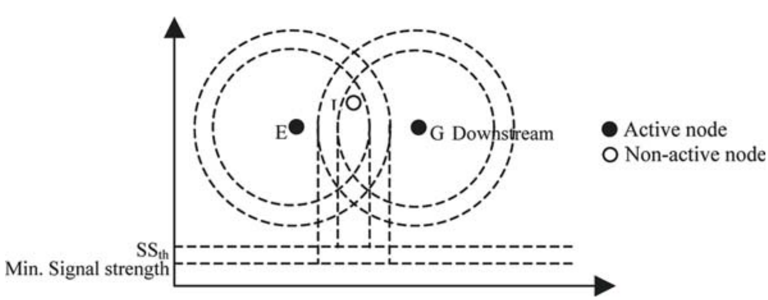


Fig. 9. Selection of one of the neighbors which can connect to the downstream node

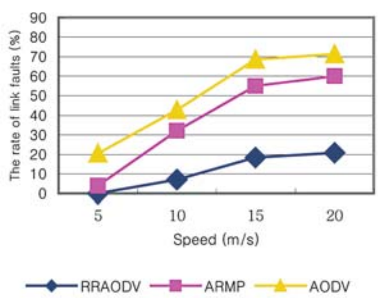
Table 4. The table of the signal strength

One-hop neighbor	SS from node E	SS from next node F	SS from 1st downstream G	SS from 2nd downstream D
I	SS_{EI}	0	0	0
J	SS_{EJ}	0	0	0
L	SS_{EL}	SS_{FL}	SS_{GL}	0
N	SS_{EN}	SS_{FN}	SS_{GN}	0

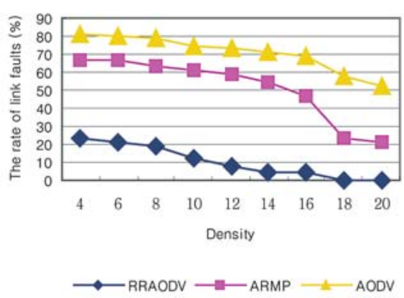
4 Experiments and the Results

A computer simulation is derived to evaluate performance, the rate of link faults, the success rate of the selection process, the delay of RRAODV, ARMP, and AODV. The MANET size is 1000 x 1000 units. Nodes move at speeds 5, 10, 15, 20, 25 or 30 units per second. The transmission range is 250 units. The SS_{thr} of a stable link is set to 10 units. The fig.10(a) shows the rate of link faults, as the node speed is varied and the node density is set to 16. The results show that the rate of link faults increases, as the speed increases and the rate of link faults of RRAODV is less than those of ARMP or AODV. The fig.10(b) shows the rate of link faults, as the node density is varied and the node speed is set to 15(m/s). The rate of link faults of RRAODV is less than that of ARMP or AODV. The results also show that the rate of link fault decreases as the density increases.

The fig.11(a) shows the delay as the node speed is varied. The node density is set to 16 and SS_{thr} is set to 10. The delay increases as the node speed increases. The delay of RRAODV is less than that of ARMP or AODV. The fig.11(b) shows the delay as the node density is varied. The node speed is set to 15(m/s) and SS_{thr} is set to 10. The delay decreases as the node density increases. The delay of RRAODV is also less than that of ARMP or AODV.

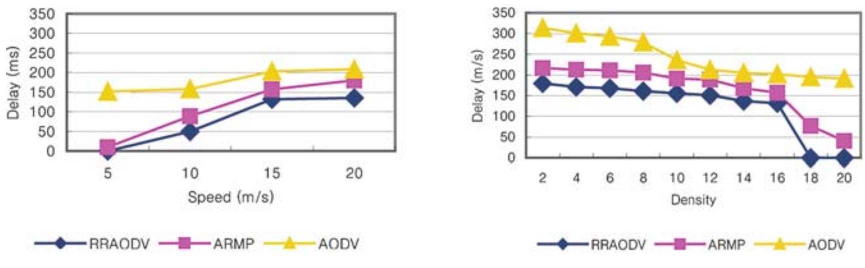


(a) The rate of link faults depending on speed



(b) The rate of link faults depending on density

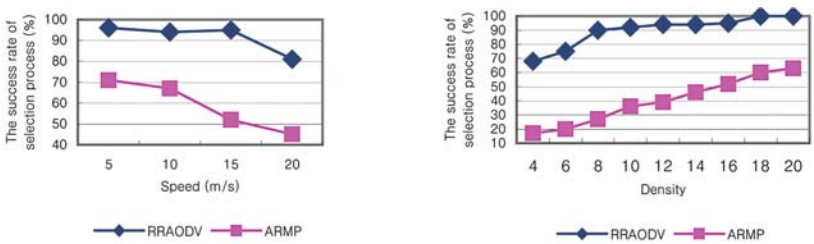
Fig. 10. Comparison of the rate of link faults in the RRAODV, the ARMP, and the AODV



(a) The delay depending on speed

(b) The delay depending on density

Fig. 11. Comparison of the delay in the RRAODV, the ARMP, and the AODV



(a) The success rate of the selecting process depending on speed

(b) The success rate of the selecting process depending on density

Fig. 12. The success rate of the substitute local routing path selecting process in the RRAODV and the ARMP

The fig.12(a) shows the success rate of the local substitute routing path selecting process of RRAODV and ARMP as the node speed is varied. The node density is set to 16 and SS_{thr} is set to 10. The fig.12(b) shows the success rate of the local substitute routing path selecting process of RRAODV and ARMP as node density is varied and the node speed is set to 15(m/s). The results show that the success rate of RRAODV is larger than that of ARMP.

5 Conclusions

We proposed RRAODV routing protocol for preventing the current route from disconnection. In RRAODV, by extending the range of node selection, the success rate of the substitute local routing path selection process is raised. It also reduces the probability of route breakage than that of ARMP and AODV. By the computer simulation, the local recovery delay RRAODV is apparently lower than that of AODV and the success rate to keep the route to the destination increases. A practical implementation of the protocol is also an essential future work.

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