이동 Ad Hoc 네트워크에서 사전 활성화 라우팅 선택과 관리유지 알고리즘의 구축

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요 약

기존의 이동 Ad Hoc On-demand 라우팅 알고리즘은 단지 경로의 손실이 발생할 경우에만 경로 발견을 시작하며, 단절된 경로를 발견하고 새로운 경로 확립하는데 막대한 경비와 시간이 소요된다. 본 논문에서는 기존 라우팅 알고리즘에서 사전 활성화 경로 선택과 관리유지 방식을 추가하는 것을 제안한다. 본 연구의 핵심 아이디어는 수신되는 패킷의 신호파워 세기가 손실되기 전의 최적 임계치 신호파워 세기까지 근접하게 되면 경로는 손실될 경향이 높다고 간주하는 것과 수신되는 패킷의 신호파워 세기가 최적 임계치 이하로 떨어졌을 경우, 사전경고 패킷을 발생하는 것이다. 사전경고 패킷을 발생 후에, 송신 노드는 계속적으로 패킷이 전송하는 동안 사전에 경로 발견을 시작하기 때문에, 모든 경로의 단절에 대한 잠재적인 가능성을 피할 수 있다. 성능평가 연구를 위하여 네트워크 시뮬레이토(NS2)가 사용된다. 결과에 의하면 본 알고리즘은 기존의 DSR과 AODV 프로토콜보다 패킷 전달율과 평균 지연시간 그리고 오버헤드 측면에서 성능이 우수한 경향을 나타낸다.

키워드 : 이동 애드 혹 네트워크, 경로 알고리즘, DSR, AODV

The establishment of Proactive Routing Selection and Maintenance Algorithms for Mobile Ad Hoc Networks

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ABSTRACT

In conventional on-demand mobile ad hoc routing algorithms, an alternate path is sought only after an active path is broken. It incurs a significant cost in terms of money and time in detecting the disconnection and establishing a new route. In this thesis, we propose proactive route selection and maintenance to conventional mobile ad hoc on-demand routing algorithms. The key idea for this research is to only consider a path break to be likely when the signal power of a received packet drops below an optimal threshold value and to generate a forewarning packet. In other words, if a path is lost with high probability, the neighboring node that may easily be cut off notifies the source node by sending a forewarning packet. Then the source node can initiate route discovery early and switched to a reliable path potentially avoiding the disconnection altogether. For the simulational study, network simulator(NS2) is used. The result of simulation shows that the algorithm significantly improves the performance of networks comparing to conventional on-demand routing protocols based on DSR and AODV in terms of packet delivery ratio, packet latency and routing overhead.

Key Words : Mobile ad hoc network, Routing Protocol, DSR, AODV

1. Introduction

Unlike conventional communication infrastructure based on base stations connected to wired networks, a mobile ad hoc network [1,2,3] is a new type of network which operates in an environment in which all devices are mobile, multiple hop wireless links are used to obtain smooth data transmission between nodes that are not located within the direct wireless transmission scope from each other and depends on data forwarding/routing by many intermediate nodes.

Research and standardization activities on mobile ad hoc networks are actively being carried out by the MANET Working Group (Mobile Ad hoc Networks Working Group)[4] in IETF (Internet Engineering Task Force). Their current focus is on establishing standards for routing protocols.

Conventional on-demand mobile ad hoc routing algorithms [5-9] initiate route discovery only after a path is

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broken, incurring a significant cost in terms of money and time in detecting the disconnection and establishing a new route.

In this paper, we investigate the effect of adding the proposed robust on-demand proactive route selection and maintenance to conventional mobile ad hoc on-demand routing algorithms. Two key ideas for this research are to only consider a path break to be likely when signal power strength for a received packet approaches an optimal threshold value prior to a path break and to generate a forewarning packet when the signal power of a received packet drops below an optimal threshold value. In other words, if a path is lost with high probability, neighboring node that may easily be cut off notifies the source node by sending a forewarning packet. Because the source node can initiate route discovery in advance while continuously transmitting packets, the inherent possibility that all paths may break can be avoided. The results of an simulation in which the proposed robust on-demand advance-active route selection and maintenance algorithm was added to conventional mobile ad hoc on-demand routing protocols based on DSR (Dynamic Source Routing)[10] and AODV (Ad Hoc On-Demand Distance Vector Routing)[11] show that the proposed algorithm provides highly reliable and robust routes and that the number of paths in which loss occurred decreased significantly comparing to DSR and AODV. In most cases, packet latency also decreased continuously. The results of performance evaluation show that the algorithm outperforms the conventional on-demand routing protocol based on DSR and AODV in terms of packet delivery ratio, packet latency and routing overhead.

This paper is organized as follows. In Section 2, the robust on-demand proactive route selection and maintenance algorithm is presented. The results of performance evaluation is illustrated in Section 3. Conclusion for this work is given in Section 4.

2. Design of Robust On-Demand Proactive Route Selection and Maintenance Algorithm

In this section, the robust on-demand proactive route selection and maintenance algorithm is proposed. First, we analyze conventional mobile ad hoc on-demand routing algorithms. Then we write about generation of forewarning packet due to node failure and link damage for the proposed algorithm. Discovery procedure of proactive route is also discussed.

2.1 Problems with Conventional Mobile Ad Hoc On-demand Routing Algorithms

For conventional mobile ad hoc on-demand routing algorithms, node failure and link damage may cause damage to the route currently being used. For mobile ad hoc networks, there is a greater tendency for network damage to occur due to node mobility. If such damage occurs, nodes in the forward direction of the damaged link (next node in the direction of the source node) voids all information for receiving nodes that cannot be reached due to the damaged link from the routing table. Then RERR containing information about the damaged node is generated and transmitted to nodes in the direction of the source node. If previous nodes that used the damaged link are a majority, RERR is broadcasted. When the source node receives the RERR, it initiates route discovery again only if it needs a route to the corresponding receiving node [16]. In other words, conventional algorithms temporarily halt data transmission, send RERR (Route Error) message to the source node and then initiates route discovery and establishes a new route when a path loss occurs due to node failure and link damage. They are not suitable as an efficient and low-cost routing algorithm because data transmission is halted temporarily and a considerable recovery time and cost is needed until a new route is secured. As number of nodes increase, this problem will become worse.

2.2 Proposed Robust On-Demand Proactive Route Selection and Maintenance Algorithm

In this paper, we studied the effect of adding the proposed robust on-demand proactive route selection and maintenance to the conventional mobile ad hoc on-demand routing algorithms. Two key ideas for this research are to only consider a path break to be likely when signal power strength for a received packet approaches an optimal threshold value prior to a path break and to generate a forewarning packet when the signal power of a received packet drops below an optimal threshold value. In other words, if likelihood for a path break is high, a neighboring node that may easily be cut off notifies the source node by sending a forewarning packet. Because the source node can initiate route discovery in advance while continuously transmitting packets, the inherent possibility that all paths may break can be avoided. Because the proposed algorithm starts route discovery before the current route is lost, it can reduce the cost required to find an alternative route.

Reduction in latency may also be expected.

2.2.1 Signal power strength measurement and threshold establishment

The main point of the proposed algorithm design is to use route quality to determine whether a route cannot be used. Typically, quality of a route is determined by signal power strength, route age, number of hops and occu-rrence of collisions. In this paper, we assume that route quality is determined by signal power strength of the received packet. In addition, since most routes are lost because of node failure and link damage on mobile ad hoc networks, the key to this paper is regarding signal power strength as the most direct method to measure the capability for reaching each node.

For the proposed algorithm, since packet transmission power strength depends on node speed and position, determining the optimal threshold for signal power strength of a packet received by a node before a route is lost is the most important aspect from an efficiency point of view. If signal power strength optimal threshold is set too low, time for discovering alternate route before route loss occurs will be insufficient. If it is set too high, on the other hand, latency may be increased due to unnecessary overhead for discovering routes even though existing route has not been lost. In this paper, we carried out many simulations in order to obtain an appropriate signal power strength optimal threshold.

From ISM band of IEEE 802.11 compatible WaveLAN-II[12] by Lucent, we carried out the simulation by adding a module that measures signal power strength to the following packets: hello packet which is used by all nodes in a network using the mobile ad hoc network on-demand protocol to broadcast their existence to their neighboring nodes, in regular interval T, in order to obtain information from them, RREQ packet which searches a route up to the receiving node, RREP packet which notifies whether a route has been found, RERR packet which assumes a maintenance role if a route failure occurs and Ack packet which is used to notify reception of data.

Typically, in the mobile ad hoc network scenario, maximum node speed is assumed to be 20 *m/sec* and recovery time is assumed to be 0.1 *sec*. In this environ-ment, we selected an arbitrary node and measured the signal power strength of the packets received by this node. If signal strength values for packets before and after a node failure and link damage is analyzed, after collecting signal strength values for each packet. Signal power strength for the receiving node decreases as shown by the relation below.

$$P_r = P_o / r^m \tag{1}$$

P_o is power strength of signal a node takes, P_r is power strength of signal received by the node, r is the distance between source and receiving nodes and m is the number of nodes connected to the receiving node within the ranges of mobiles.

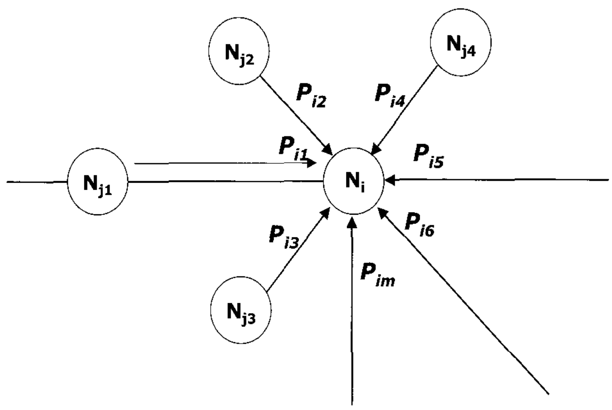
Therefore, in this research, sufficient time consideration for advance route exploration was taken into account. If simulation is carried out with mean value of signal power for packet received before node failure and link damage as the optimal threshold for signal power strength, optimal value for the data can be obtained. This value becomes the optimal time for discovering a route for each node. Optimal threshold (δ) for signal power strength is assumed to be as follows:

$$\delta = \frac{P_{r1} + P_{r2} + P_{r3} + \dots + P_{r(m-1)} + P_{rm}}{m} = \frac{\sum_{k=1}^{m} P_k}{m} \tag{2}$$

2.2.2 Forewarning packet occurrence

Forewarning packets are generated only when the signal power strength dips below the optimal threshold. For the conventional mobile ad hoc on-demand routing algorithms,

when node failure or link damage occurs, data trans-mission is temporarily halted and all receiving nodes that cannot be reached due to the link loss are eliminated from the routing table of the next node in the direction of the source node. Then RERR including information concerning the lost receiving node is generated and broadcast to nodes in the direction of the source node.



(Fig. 1) Signal power strength at node N_i

Type	Length	Reserved
Error Source Address		
Error Destination Address		
Unreachable Node Address		

(a) The format of forewarning packet on DSR protocol

Type	|N|	Reserved	Dest Count
Unreachable Destination IP Address			
Unreachable Destination Sequence Number			

(b) The format of forewarning packet on AODV protocol

(Fig. 2) The formats of forewarning packet for the proposed on-demand proactive route selection and maintenance algorithm

When the source node receives the RERR, it initiates route discovery again only if it needs a route to the corresponding receiving node.

However, in the proposed algorithm, when signal power strength of the received packet approaches the signal power strength optimal threshold, the route loss is regarded as a possibility and a forewarning packet is generated. It notifies the neighboring nodes and the source node that possibility of a route loss is high, before signal power strength dips below the optimal threshold by generating a forewarning packet.

[Figure 2] shows the format of the forewarning packet that is sent to the source node by on-demand mobile ad hoc routing algorithms when a path is broken.

2.2.3 Route discovery and maintenance

When the source node receives a forewarning packet, route discovery and maintenance involving existing RERR packet is similar to conventional on-demand routing algorithm. If a route does not exist, source node sends the RREQ packet to neighboring nodes by flooding. A neighboring nodes that receives this RREQ searches it's route cache or table and if a route to the receiving node exists, adds the route up to the receiving node and sends the RREP packet to the source node. If a route does not exist, it adds it's address to the RREQ packet and passes it along to the next node. This procedure is repeated until the receiving node gets the RREQ packet. Then the accumulated route is added and RREP packet is sent to the source node using the acquired route. When the source node gets the RREP packet, it transfers to the new route before node failure or link loss occurs and transmits the data. Because the source node starts the search for a route in advance while packets are continuously transmitted, the inherent possibility that all paths may be severed can be avoided. Because the proposed algorithm initiates route discovery before the current route is lost, it can reduce the latency and cost required to find an alternative route.

Algorithm :

P_o is power strength of signal a node takes.
P_r is power strength of signal received by the node.
r is the distance between source and receiving nodes.
m is the number of nodes traversed within the range of mobiles.
F_p is forewarning packet.
δ is a threshold value of signal strength.
R_o is an existing route.
R_n is a new route.

1. If mean maximum value for power received before node failure or link damage occurs in a packet is assumed to be the optimal threshold, the optimal threshold is given as follows:

$$\delta = \frac{P_{r1} + P_{r2} + P_{r3} + \dots + P_{r(m-1)} + P_{rm}}{m} = \frac{\sum_{k=1}^{m} P_k}{m}$$

2. When $p_r \le \delta$, forewarning packet F_p is generated in the direction of the source node.
3. When the source node receives a forewarning packet F_p, it initiates route discovery again and after finding a new route R_n, resets the path from the existing route to the new route.
4. Transmit data along the new route R_n through the selected path.

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3. Performance Evaluation

In this section, network simulation was used to evaluate and compare the implementation of the proposed proactive route selection and maintenance algorithm with DSR and AODV protocols.

3.1 Simulation Environment

In this research, discrete event simulator ns-2 (network simulator 2)[13,14] was used to measure performance. The version used was ns-2.26 and the proposed protocol implementation was based on DSR and AODV included in ns-2 CMU expansion version [15]. The proposed protocol was implemented using DSR and AODV routing protocol on the simulation platform.

This simulation was carried out with respect to mobile nodes in a square area of 1000×1000m^2. Wireless transmission scope of 250*m* and a free space propagation channel was assumed. Data transmission rate was set to 2 Mbps and each simulation was carried out for 300 seconds. CBR source sends 4 packets per second and data payload is 512 bytes. Mobile nodes are assumed to move arbitrarily and irregularly following the *random waypoint model*. Two parameters (maximum node speed and pause time) determine movement pattern of a mobile node. Each node moves to an arbitrary destination within the simulation area at a speed selected arbitrarily. Node speed is uniformly distributed between 0 and the maximum value of 20 *m/sec*. When a node reaches a destination, it will stay for a fixed stop time of 1 second and then move on in the same manner [16].

3.2 Simulation Result and Analysis

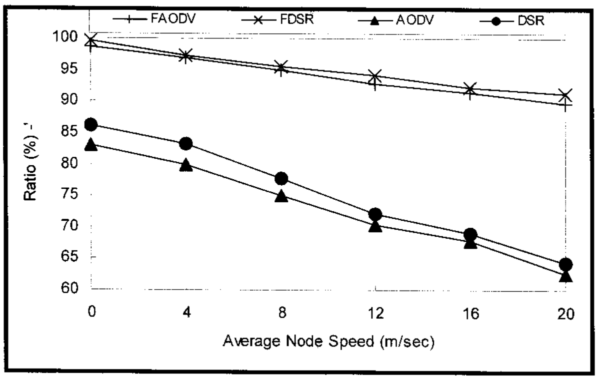
In this section, the simulation results for the proposed proactive route selection and maintenance algorithm are compared and analyzed with that of AODV and DSR. Three performance measures (packet delivery ratio, packet latency and routing overhead) are evaluated and compared with respect to two simulation factors (mean node speed and the number of nodes). The proposed proactive route selection and maintenance algorithms are labeled FDSR (Forewarning DSR) and FAODV (Forewarning AODV).

Packet Delivery Ratio

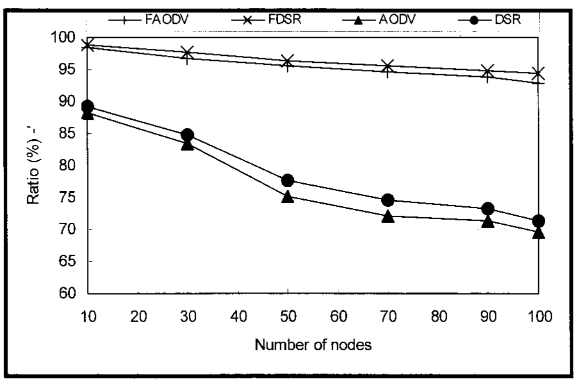
[Figure 3] shows packet delivery ratio as a function of change in average node speed and the number of nodes for DSR, AODV, FDSR and FAODV. For all 3 simulation cases, packet delivery ratio of FDSR was 3% better than DSR and FAODV was 27% better compard to AODV. Especially, since source node swaps path to a discovered route in advance before node failure or link damage occurs, FDSR and FAODV do not have data or link loss and have a higher packet delivery ratio compared to DSR and AODV. In other words, because the source node can initiate route discovery in advance while continuously transmitting packets, the inherent possibility that all paths may break can be avoided. If any one of mean node speed and number of nodes increased, there was a tendency for routing overhead to increase for all four protocols. This is because high node mobility causes more frequent link damage and cause loss of more packets. If the number of nodes is increasing, traffic interference due to signal strength will increase, and then raise the possibility for link damage.

Average Packet Latency

[Figure 4] shows packet latency as a function of change in average node speed and the number of nodes for DSR, AODV, FDSR and FAODV. Mean latency for FDSR was 13% shorter than DSR and FAODV was 49% shorter compared to AODV. This difference was true for all three simulation cases and widened as mean node speed, number of connections and number of nodes were increased. Therefore, compared to DSR and AODV, FDSR and FAODV can be considered to be more robust even in poor operating environments with high node mobility, a large number of sessions (connections) and high node density. If any one of average node speed and the number of nodes increased, there was a tendency for routing overhead to increase for all four protocols.

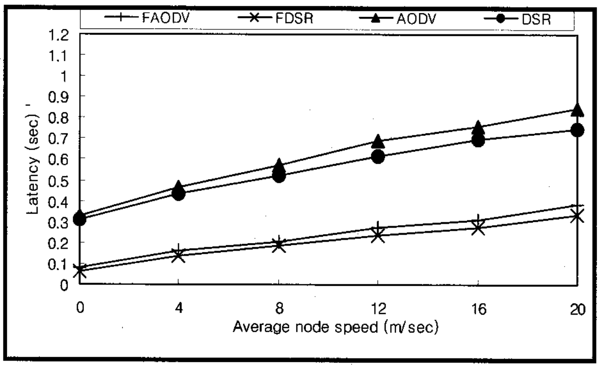


(a) Average Node Speed

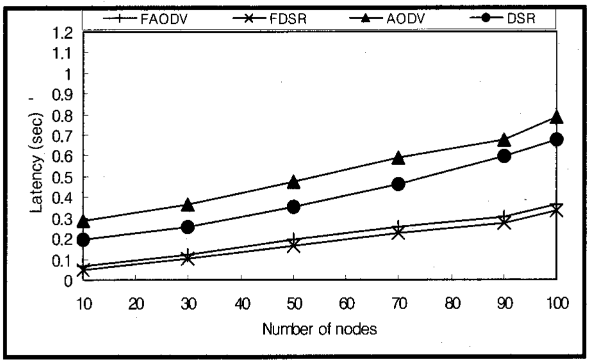


(b) Number of Nodes

(Fig. 3) Packet Delivery Ratio

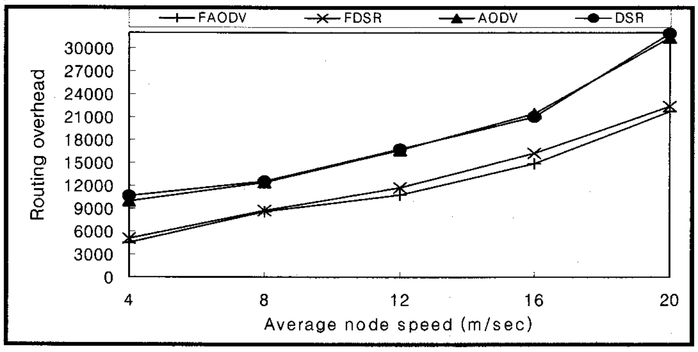


(a) Average Node Speed



(b) Number of Nodes

(Fig. 4) Average packet latency



(Fig. 5) Routing overhead

Routing Overhead

[Figure 5] shows routing overhead as a function of change in mean node speed for DSR, AODV, FDSR and FAODV. In this paper, each hop transmission was counted as one transmission for calculating the total number of routing packets transmitted per second (number of hello, RREQ, RREP and RERR). For change in mean node speed, the routing overhead for FDSR was 43% lower than DSR and FAODV was 75% lower compared to AODV. Furthermore, this difference became more pronounced as the number of nodes increased. Compared to DSR and AODV, FDSR and FAODV had lower routing overhead even in poor operating environments with high node mobility, a large number of sessions (connections) and high node density. If any one of mean node speed and the number of nodes increased, there was a tendency for routing overhead to increase for all four protocols.

4. Conclusion

We studied the effect of adding the proposed robust on-demand advance-active route selection and maintenance algorithm to the conventional mobile ad hoc on-demand routing protocol. Two key ideas for this research are to only consider a path break to be likely when signal power strength for a received packet approaches an optimal threshold value prior to a path break and to generate a forewarning packet when the signal power of a received packet drops below an optimal threshold value. In other words, if likelihood for a path break is high, a neighboring node that may easily be cut off notifies the source node by sending a forewarning packet. Because the source node can initiate route discovery in advance while continuously transmitting packets, the inherent possibility that all paths may break can be avoided. The results of an simulation in which the proposed robust on-demand advance-active route selection and maintenance algorithm was added to conventional mobile ad hoc on-demand routing protocols based on DSR and AODV show that the proposed algorithm provides highly reliable and robust routes and that the number of paths in which loss occurred decreased significantly compared to DSR and AODV protocols. In most cases, packet latency also decreased continuously.

Performance evaluation results show that the proposed robust on-demand proactive route selection and maintenance algorithm outperforms the conventional on-demand routing protocol based on DSR and AODV in terms of packet delivery ratio, packet latency and overhead. In other words, in poor operating environments with high node mobility, a large number of sessions and high node density, the proposed algorithm can provide more robust routes compared to conventional methods.

For future research, we would like to apply the proposed on-demand proactive route selection and maintenance routing algorithm technique to other protocols besides on-demand protocols to obtain routes with improved robustness and scalability. We would also like to extend the proposed design ideas to DSR and AODV based on hierarchical routing protocols.

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