Ad Hoc Network에서 라우팅 성능 향상을 위한 이웃 노드 정보를 이용한 적응성 경로 구성 전송 방식

(Adaptive Query Flooding using Neighbor Information for Routing Performance Enhancement in Ad Hoc Networks)

이 학 후 † 강 상 욱 † 안 순 신 ††
(Hakhu Lee) (Sangwook Kang) (Sunshin An)

요 약 무선 이동통신이 실생활에 널리 보편화되면서, 무선 이동 기술은 휴대 무선 통신 장비에 대한 폭발적인 수요와 함께 통신 영역에서 중요한 역할을 담당할 것으로 보인다. 무선 이동통신 기술 중 특히 기존의 통신 인프라의 도움없이 임시적으로 무선 이동 노드들끼리 네트워크를 구성하는 mobile ad hoc network (MANET)이 최근에 주목을 받고 있다. 더욱이, ad hoc network의 특성을 고려할 때 효율적인 라우팅 프로토콜의 설계가 중요하다고 할 수 있다. 최근에는, 라우팅 프로토콜 중에서 on-demand 프로토콜이 낮은 라우팅 부하로 주목을 받고 있다. 그러나, on-demand 프로토콜은 경로 구성을 위해 경로 구성 패킷(query packet)을 broadcasting 하는 방식, 즉 flooding 방식, 을 사용하여 많은 수의 경로 구성 패킷을 발생시키는 문제점이 있다. 이러한 flooding 방식은 매우 비 효율적이며 또한 broadcast storm문제를 발생시킨다. 본 논문에서는 broadcast storm 문제를 해결하기 위해 Dynamic Adaptation Query flooding Using Neighbor Topology(NT-DAQ) 방식을 제안한다. 경로 구성 과정에서, 각 이동 노드들은 이웃 노드들의 정보를 기초로 하여 경로 구성에 참여 여부를 결정하게 된다. 이러한 제안 방식은 경로 구성 패킷의 수를 최소화 하여 네트워크 성능을 향상 시킬 수 있으며, 또한 시험을 통해 제안한 방식의 효율성을 입증하였다.

키워드 : mobile ad hoc network, flooding, 적응성 경로 구성

Abstract As the wireless mobile communication is being widespread, mobile technologies will have important roles in the communication with the explosive growth of demanding for wireless portable devices. Among the mobile technologies, a great deal of interest has been taken in mobile ad hoc network (MANET), which is a collection of wireless mobile nodes forming a temporary network without the aid of stationary infrastructure in recent. Furthermore, considering characteristic of ad hoc networks, the design of efficient routing protocols is an important issue. In recent years, on-demand protocols among routing protocols have noticed because of the low routing overhead. However, on-demand protocols suffer from production of the enormous query packets by broadcasting in order to setup routes, that is, a flooding scheme. The flooding scheme is very costly and results in serious problem, which we refer as the broadcast storm problem. In this paper, we propose a Dynamic Adaptation Query flooding Using Neighbor Topology (NT-DAQ) scheme, in order to resolve the broadcast storm problem. When a route discovery is in progress, each mobile node decides on the basis of neighbor topology information whether discovery process participates or not. Therefore, our proposed scheme enables to improve network performance in which minimize the number of query packets. We evaluate the efficiency of our proposed scheme through simulation.

Key words : mobile ad hoc network, flooding, dynamic adaptation query flooding

† 비 회 원 : 고려대학교 전자공학과
hhlee@dsys.korea.ac.kr
klogic@dsys.korea.ac.kr
†† 종신회원 : 고려대학교 전자공학과 교수
sunshin@dsys.korea.ac.kr

논문접수 : 2004년 6월 4일
심사완료 : 2004년 8월 12일

1. Introduction

With the explosive growth of the demanding for the mobile computing, wireless networks have become increasingly popular in the mobile computing industry. In particular, a mobile ad hoc network [1,2,3] has recently attracted a lot of attentions, which is a collection of wireless mobile nodes forming a temporary network without the aid of any established infrastructure. In ad hoc networks, adjacent nodes directly communicate between one another over wireless channels. However, since the transmission range of nodes is limited, the nodes that are not neighboring must communicate with the support of one or more intermediate nodes acting as routers. Due to the mobility of nodes, the topology of connections between communicating nodes may be quite adaptive. Thus, routing protocols must be adaptive and enable to maintain routes in spite of the changing network connectivity and design of efficient routing is a central challenging issue in such mobile ad hoc networks. Routing protocols of ad hoc networks can generally be categorized as table-driven and on-demand.

Table-driven protocols [3,4] attempt to maintain consistency, up-to-date routing information from each node to every other node in the network. Hence, these protocols require periodic routing messages regardless of whether it is needed or not and this feature is wasted both bandwidth and battery power in mobile nodes. On the other hand, on-demand protocols [3,4] set up and maintain routes from a source to a destination on a demand basis. To discover routes, it uses flooding technique, where the source floods the entire network with a query packet in search of a route to the destination. After receiving the query, each node checks whether it has destination information or not and propagates to neighbors via a wireless broadcast. This technique guarantees that the query reaches all nodes in network. In this paper, we call such flooding as network-wide flooding. Some of these protocols are TORA [4], SSR [4], DSR [6], AODV [7], and ABR [8]. According to recent performance papers, on-demand protocols have shown low routing overhead in comparison with table-driven protocols.

However, flooding scheme [5,9,10] incurs a numerous number of query packets and results in increasing of network overhead consequently. So, we focused on a solution of the flooding problem that incurs considerable network overhead, which increases end-to-end delay and decreases routing performance. To resolve flooding problem, we propose a new scheme, Dynamic Adaptation Query flooding Using Neighbor Topology (NT-DAQ) employing topology information of neighbor nodes within a radio transmission range of a node. The design principle of NT-DAQ scheme establishes neighbor node table using periodic beacon hello messages for link breakage detection and its existence signification. Using metric information of its table, each of nodes composes query flooding threshold range. When a source node needs a route to some destination, it broadcasts a query message to its neighbors, including query flooding threshold range information. Each node that receives query message checks query flooding threshold range information in receiving message and determines whether its message rebroadcasts or not. In case of a rebroadcast, it exchanges a receiving threshold for a self-threshold and broadcasts to neighbor nodes. In this way, it can reduce forwarding of unnecessary query message and contribute to improve network performance in consequence.

The remainder of the paper is organized as follows. In Section 2, we introduce a brief background on the on-demand routing protocols, AODV and ABR, and review flooding mechanism using on-demand protocols. Section 3 describes our new scheme, Dynamic Adaptation Query flooding Using Neighbor Topology (NT-DAQ) architecture in detail. Section 4 shows simulation result with their explanation. Finally, Section 5 provides our conclusions.

2. Background

2.1 Ad hoc On-demand Distance Vector protocol (AODV)

AODV [7] is an on-demand variation of distance vector protocols. AODV uses the basic on-demand mechanism of Route Discovery and Route Maintenance, which include the use of hop-by-hop routing and sequence numbers and periodic beacons. Routes are discovered on an as-needed basis and are maintained only as long as they are necessary. When a source node desires to send a message to some destination and does not already have a valid route to that destination, it initiates a path discovery process. It broadcasts a route request packet to its neighbors via flooding, until either the destination or an intermediate node with a "fresh enough" route to the destination is located. Once the request packet reaches the destination or an intermediate node with a fresh route, the destination or intermediate node responds by unicasting a route reply packet back to the neighbor. In order to maintain routes, AODV normally requires that each node periodically transmit a beacon hello message. In this way, each node maintains routing table, including route information. According to each node dynamically moving, if the link breaks, a Route Error message is sent to the source node and each node over link updates their route table. However, as mentioned above, AODV like on-demand routing protocols has serious problem such as increasing of routing overhead, using flooding mechanism.

2.2 Flooding mechanism with Zone Routing Protocol (ZRP)

ZRP [11] is an example of such hybrid of reactive and proactive routing protocols. On the one hand, it limits the scope of the proactive procedure only to the node's local neighborhood. On the other hand, the search throughout the network, although global, can be performed efficiently by querying selected nodes in the networks, as opposed to querying all the network nodes. A node proactively maintains routes to destinations within a local neighborhood, which is referred to as a routing zone. A node's routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as zone radius. Each node maintains its zone radius, and routing zones of neighboring nodes overlap. ZRP has the potential to be more efficient in the generation of control traffic than traditional routing protocols. However, without query control schemes, the ZRP can actually produce more traffic than flooding mechanism. Hence, to resolve this problem, several query control schemes had been developed for ZRP. However, the performance of these schemes shows difficult to apply the optimal zone radius to reduce the redundant number of query packets according to network load and node mobility.

2.3 Flooding mechanism with on-demand protocols

Most of on-demand protocols use flooding as basic mechanism to propagate query messages. In flooding, a node transmits a query message to all of its neighbors and so on until a query has been propagated to the entire network. For this reason, flooding produces a lot of unnecessary query messages and incurs considerable routing overhead as mentioned before. Therefore, several optimized flooding mechanism have been proposed, called heuristic-based and topology-based [5]. However, problem of heuristic-based protocols is used a fixed threshold. For this reason, since the topology of ad hoc networks dynamically changes, it is desired to be a dynamic threshold. On the other hand, since topology-based protocols are used a periodic hello message, it desires the accuracy of neighbor information and requires a short hello interval. For this reason, it incur considerable network overhead. Above all, several problems of flooding mechanism motivate our paper and suggest a new approach, reducing the routing overhead by using neighbor topology information.

3. Dynamic Adaptation Query flooding Using Neighbor Topology

In this section, we introduce the basic design of the Dynamic Adaptation Query flooding Using Neighbor Topology (NT-DAQ) architecture to resolve the flooding problem in ad hoc networks.

3.1 Neighbor Topology Maintenance

The proposed NT-DAQ scheme is based on neighbor node table, including neighbor topology information. Hence, it is essential to collect neighbor environment information. The term of neighbor expresses nodes within radio transmission range of a node, that is, one hop limited. The neighbor topology of each node is achievable via periodic hello message, which detects link breakage and signifies its existence. Each node that receives hello message updates their neighbor table (e.g., increasing associativity ticks, sender speed information, receiving time, and distance between nodes) [12] to reflect sender topology information. Furthermore, the associativity tick of a neighbor table is incremented when receiving a hello message. An associativity ticks among neighbor table metrics can be explained by link stability measure between nodes. Hence, a high associativity ticks indicates a strong stable status of wireless link and it is expected to be long-lived link. A distance metric is estimated by the signal strength of a receiving hello message, or supported by positioning devices such as GPS (Global Positioning System). In the case of the signal strength, the distance metric can be estimated by a follow formula [13]. $P_r=P_tG_tG_r(\lambda/d)^n$, where P_r, P_t, n, λ, G_t, G_r, and d are the power level when a hello message is received and transmitted, constants related to physical environment, the carrier's wavelength, and sender/receiver antenna gains, distance between nodes, respectively.

Since P_r and P_t can be measured, the distance d can be determined by the above formula. In this paper, we use the GPS method for distance and speed information. Each node purges a time-out of neighbor table entries based a receiving time, periodically. Figure 1 illustrates how a hello message is broadcasted within wireless transmission range of N1 mobile node.

Each node periodically sends hello message including topology information (i.e., its speed and position) and receives hello message within radio transmission range (i.e., one hop limited). Node 1 receives hello message to neighbors N2, N3, N4, N5, N6, N7, N8, and N9, respectively. Since they are one-hop neighbor of N1, the N1 is able to receive periodic hello message. When the N1 receives a hello message, it updates their neighbor table, including increasing associativity ticks, speed of sender node, receiving time, and distance using position information. After a hello interval, Node 1 purges neighbor entries of non-receiving node. The Table 1 shows the structure of N1 neighbor table applied above Figure 1.

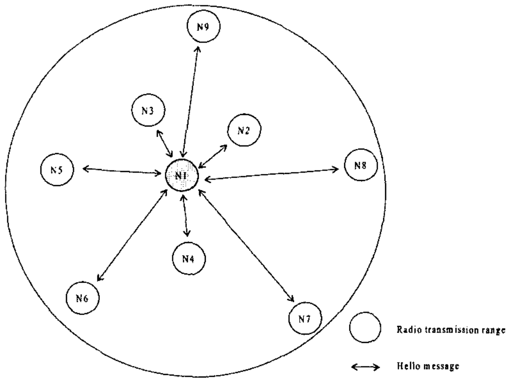


Figure 1 An example of neighbor topology maintenance

Hello message interval indicates a trade-off between routing overhead and validity of neighbor information. A shorter hello interval will make neighbor information more up-to-date. However, it will increase routing overhead by creating too many hello messages. Hence, we propose a scheme to use an average value of neighbor table metrics (i.e., an average value of distance and speed) for avoiding shorter hello interval. Although ad hoc networks is in a dynamic network that needs

Table 1 An example of N1 neighbor table

Neighbor	Associativity ticks	Distance (m)	Speed (m/s)	Receiving Time (sec)
N2	5	70	10	180:10.23
N3	11	100	13	179:30.40
N4	12	80	5	180:50.30
N5	7	180	15	181:01.10
N6	8	210	7	180:20.35
N7	15	220	16	183:05.10
N8	20	215	3	182:40.01
N9	6	240	8	181:40.05

shorter interval, an average value of distance and speed applied a longer hello interval may be quite similar to an average value applied a shorter hello interval. Hence, it can be to use a relatively longer hello interval in ad hoc networks. It will be discussed further in the following section.

3.2 Dynamic Adaptation Query flooding

A main idea of the NT-DAQ scheme is to minimize routing overhead according to reducing the number of unnecessary query packets. In ad hoc networks, mobile nodes randomly distribute and communicate with each other using multi-hop wireless links. Therefore, most of nodes may be overlapped in the radio transmission of neighbors and flooding that avoids the overlapped areas of neighbor nodes can be to produce less the number of query packets. The overlapped area range of query forwarding node can show a relative average distance between neighbors and its. If a neighbor node locates far from query forwarding node, it can forward query packet to possibly avoid the overlapped areas. On the contrary, if a neighbor node locates nearby query forwarding node, it can produces the redundant number of query packet because it locates the overlapped radio ranges. Hence, our proposed scheme presents an average distance parameter on the basis of decision whether or not neighbor locates nearby query forwarding node. Although the topology of neighbors dynamically changes considering a characteristic of ad hoc networks, a periodically average distance of each node is similar to previous result or slowly changes because a character of ad hoc network isn't high mobility that the position of mobile node changes on a sudden. Each node has a dynamic average distance between its and neighbors according as the topology of neighbors may dynamically change. To put it more concretely, an average distance indicates total distance of neighbors divided by the number of neighbors. To require the overlapped areas information, it uses a neighbor table of each node. According to a neighbor table, flooding threshold zone that uses its distance and speed metric may indicate the overlapped areas from the standpoint of node that have a query packet. Each node adaptively establishes flooding threshold zone according to neighbor table metrics, since the topology of neighbors may dynamically change. When nodes receive a query packet, nodes in the threshold zone range of query forwarding node are not needed to forward the query. In this way, our proposed scheme can reduce superfluous query packets.

Description of the NT-DAQ mechanism is as follows. As mentioned above section, each node maintains neighbor table using periodic hello message and purges a time-out of neighbor table entries periodically. Using its neighbor table information (i.e., distance and speed metric), each node determines an average distance value (D_a) and an average speed value (S_a) of neighbors in purging time periodically. As mentioned above, an average distance indicates total distance of neighbors divided by the number of neighbors. An average speed is required in the same way. Consequently, each node establishes a flooding threshold zone considering its speed (S), using the following formula.

$$R = D_a \pm \alpha(S_a - S) \quad (1)$$

R : A radius of flooding threshold zone

α : A constant of hello message interval

According to Equation (1), α and speed of mobile node (S) is the parameter to determine the variation rate of the flooding threshold zone radius (R). As mentioned above, hello interval indicates a trade-off between routing overhead and validity of neighbor information. If α is high, it can be to alleviate network overhead according to hello messages and the flooding threshold zone is relatively large. However, owing to invalidity of neighbor information, it may be to incur more routing overhead than pure routing protocols over specified wireless network environment. On the contrary, if α is low, it can be to increase network overhead because of hello messages. Hence, in this paper, we apply a relatively high scope of α, because a shorter interval is unnecessary as mentioned above section.

A mobility of mobile node considerably influences the routing overhead during flooding and route reliability. In case of a high mobility node, it may be that a route breakage frequently occurs

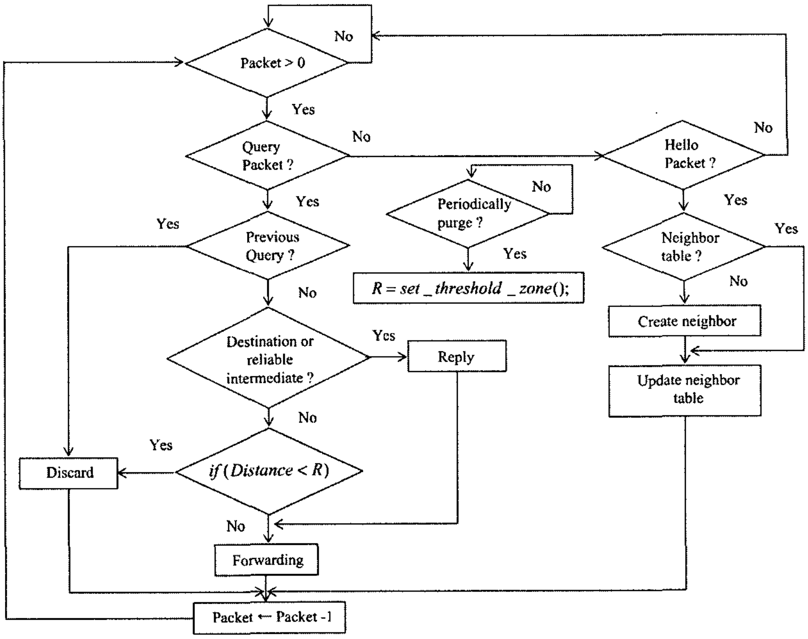


Figure 2 Comparison operation between the NT-DAQ and flooding scheme[1)]

according to a lack of route reliability and connection with nodes at the boundary of a node that has a query to send or forward lacks a more reliability. Hence, the size of flooding threshold zone is proportional to mobility of a mobile, which can establish a more reliable route. If a node is a high mobility than neighbors, it has a relatively reductive flooding threshold zone. Otherwise, it has a relatively extensive flooding threshold zone. The flooding threshold zone is the area in which received query packets discard and each node establishes a flooding threshold zone, using hello message. A node that has a query to send or forward appends its own radius information of threshold zone (R_n) in the query and floods a query packet. When a node receives the query packet, it compares a receiving radius information (R_o) with a distance between receiver and sender (D) and decides whether forwarding or not. If a receiving node is located in the flooding threshold zone of node that transmitted the query packet (i.e., $R_o > D$), it discards the query packet. On the other hand, a receiving node updates its own radius information (R_n) instead of a receiving radius information (R_o) in the query packet and forwards immediately.

Figure 2 describes the overall operation of the NT-DAQ scheme as mentioned above, compared with flooding scheme.

Figure 3 illustrates an example of the NT-DAQ scheme, which the shading in the circle indicates the flooding threshold zone of N1.

The mobile node, N1, floods a query packet,

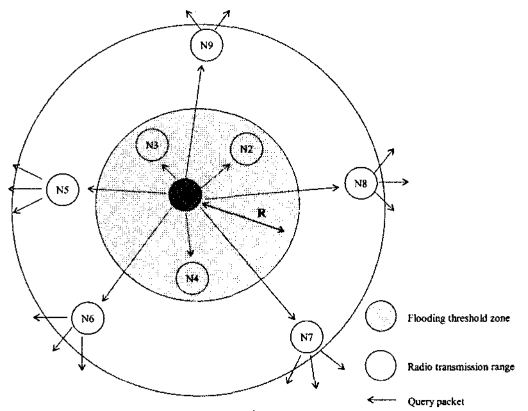


Figure 3 An example of dynamic adaptation query flooding

1) In this paper, each mobile node follows this flooding mechanism. Shaded portions indicate the novel algorithm added to network-wide flooding mechanism.

which includes its own threshold radius information. When each neighbor node is received the query from N1, it decides whether forwarding or not, considering a receiving radius information. The neighbor nodes, N2, N3, and N4, discard query packet, since they are in the flooding threshold zone of N1. On the contrary, N5, N6, N7, N8, and N9 flood it immediately, updating their own threshold radius information, since they are not in the flooding threshold zone of N1.

In consequence, our proposed scheme reduces the number of unnecessary query packets and inevitably alleviates routing overhead.

To investigate further, we compare NT-DAQ with flooding scheme in term of forwarding overhead complexity.[2] The forwarding overhead complexity of NT-DAQ and flooding scheme is $O(N-x)$ and $O(N)$ respectively, where N indicates the number of neighbor nodes of query forwarding node and x is the number of neighbor nodes included flooding threshold zone of query forwarding node. As mentioned above, the complexity comparison of NT-DAQ and flooding scheme shows that NT-DAQ is more efficient than flooding according to reducing the redundant number of query packets.

4. Performance Evaluation

We conduct a performance evaluation of the proposed scheme (NT-DAQ) through simulations using CMU's wireless extensions [14] for the Network Simulator 2 (ns-2) [15]. We compare pure-AODV protocol with AODV protocol including our proposed scheme, that is, NT-DAQ. We evaluate the performance of our proposed scheme using three metrics; end-to-end delay, packet delivery ratio, and control traffic overhead. Thus, using above metrics, we can observe the performance enhancement of our scheme such as low delay and low routing overhead, respectively.

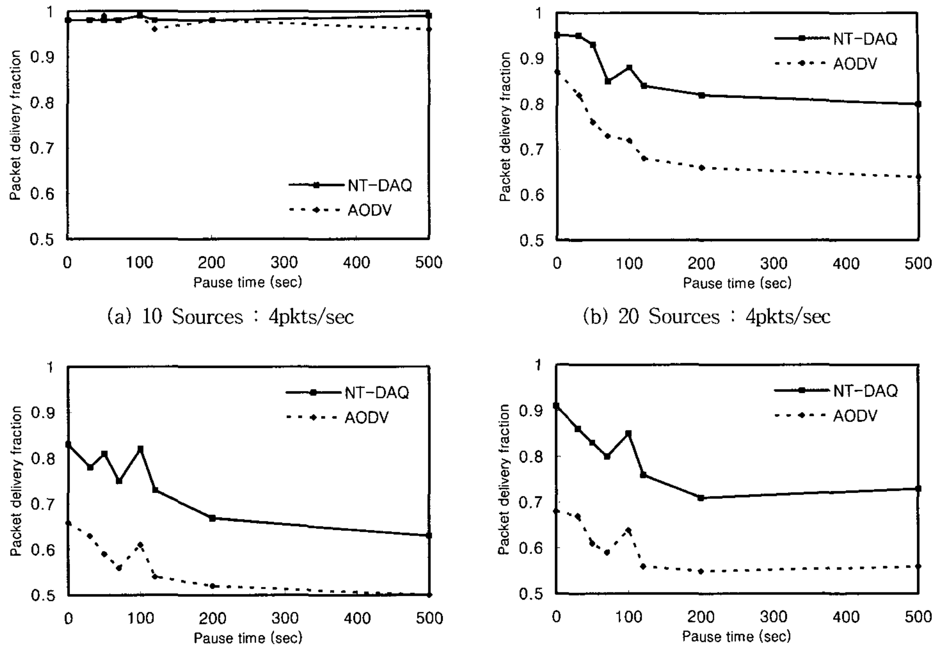
4.1 Simulation Model and Scenarios

The mobile nodes use the IEEE 802.11 [16] wireless channel model and MAC model provided by the CMU extensions. The radio model for mobile nodes uses characteristics similar to a commercial radio interface, which is Lucent's WaveLAN. It is a shared media radio with a nominal bit-rate of 2Mb/sec and radio propagation range is 250 meters. Each node has an interface queue which buffers the packets until the MAC layer can transmit. The interface queue is FIFO, with a maximum size of 50 packets. Routing packets have higher priority than data packets in the interface queue. In this scenario, every traffic sources apply CBR (Constant-Bit Rate) traffic model. Also in all transmitted packets, IP and UDP headers are included, because of complex TCP protocol mechanism. CBR sources generate traffic packets, the size of 512 bytes.

Source-destination pairs randomly spread over the ad hoc network. The mobility model uses the *random waypoint* model in a square field. Each node starts the simulation by remaining stationary for pause time seconds and moves to their destination at a speed distributed uniformly between 0 and 20 m/sec. The reason why the speed of mobile node limits is that an ad hoc network not corresponds to the extremely high speed environment. When a node reaches the destination, it pauses again for pause time, chooses another destination, and proceeds there as previously described, repeating this behavior until the simulation ends. Our evaluations are based on the simulation of 50 mobile nodes forming an ad hoc network, which are randomly distributed in the 600m X 600m square area for 500 seconds of simulated time. For our simulation, the following scenarios are used.

- Mobility patterns: A pause time indicates mobility of node. Hence, the longer pause time indicates low mobility and the shorter pause time indicates high mobility. Furthermore, a pause time of 0 seconds corresponds to continuous, and a pause time of 500 seconds corresponds to no motion. It is used 8 different pause times: 0, 30, 50, 70, 100, 120, 200, and 500 seconds.
- Traffic sources: It is indicates the number of source-destination couples. Hence, the high number of traffic sources indicates the higher network load. 10, 20, 30, and 40 traffic sources are used.

2) Forwarding overhead complexity is the number of query packets forwarded by neighbor nodes upon sending a query packet in the aspect of query forwarding node.



(a) 10 Sources : 4pkts/sec
(b) 20 Sources : 4pkts/sec
(c) 30 Sources : 3pkts/sec
(d) 40 Sources : 2pkts/sec

Figure 4 Packet delivery fraction of AODV and NT-DAQ

- Sending rate of packets: There is to indicate the number of data packets per second. For the 10 and 20 traffic sources, we use sending rate of 4 packets per second. For the 30 and 40 traffic sources, we use sending rate of 3 packets per second and 2 packets per second, respectively. The different sending rate is the reason why the high traffic loads have the relatively poor performance results because of high network congestion.

For the fairness of simulation results, our simulation results show the average of five operations with different mobility scenarios.

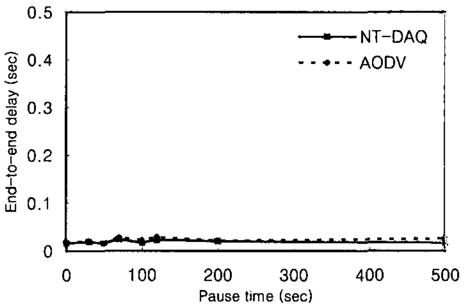
4.2 Simulation results

Our simulations compare the performance of routing protocol according to the following three metrics [17-19].

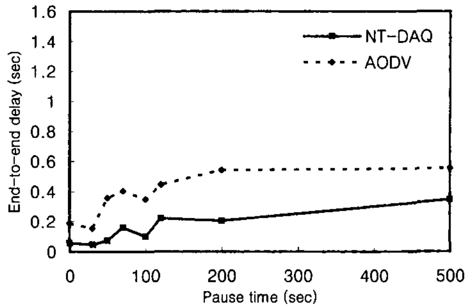
- Packet delivery fraction: The fraction between the number of data packets originated by source mobile node and the number of data packets reached by destination mobile node.
- Routing overhead: The fraction between the total number of routing packets (i.e., RREQ, RREP, ERROR, HELLO) and the number of data packets reached by destination node. Forwarding of routing packets by intermediate nodes is included. And another aspect, it is the total number of routing packets transmitted during simulation.
- Average end-to-end delay: Difference between the time which a data packet is generated by source node and the time which a data packet reaches destination node. This includes all possible delays, route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times.

4.2.1 Performance analysis about the packet delivery fraction

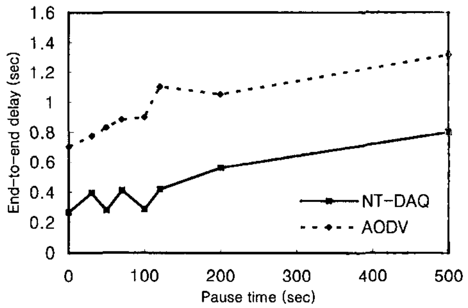
This subsection shows the results of the performance evaluation of our proposed scheme, NT-DAQ, and AODV protocol about the packet delivery fraction. As shown in Figure 4, NT-DAQ describes better performance in all cases. With a low network load, 10 sources, the two schemes show similar results, which are more than 95%. For 10 sources, packet delivery fraction is relatively unaffected with the number of query packets. These results indicate that AODV is efficient routing protocol under low network load. However, for 20,



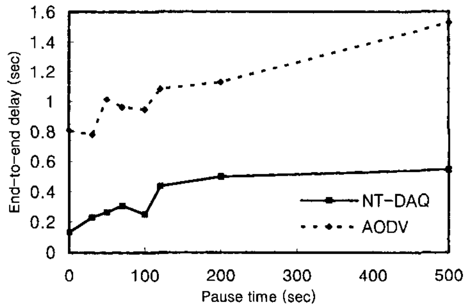
(a) 10 Sources : 4pkts/sec



(b) 20 Sources : 4pkts/sec



(c) 30 Sources : 3pkts/sec



(b) 40 Sources : 2pkts/sec

Figure 5 Average end-to-end delay of AODV and NT-DAQ

30, and 40 sources, packet delivery fraction with NT-DAQ improves about 10 ~ 20%, compared with a low network load (i.e., 10 sources). Hence, these improvements are due to the lower routing overhead with NT-DAQ which results in reduction of unnecessary query packets. As the results presented in, performance of AODV is highly affected with the number of query packets and network load environments (i.e., the number of source nodes and data packet rate) and it shows that NT-DAQ scheme can be to reduce the number of query packets.

4.2.2 Performance analysis about the average end-to-end delay

Figure 5 illustrates the end-to-end delay of data packets. NT-DAQ has shorter delay than AODV protocol and this difference becomes more obvious as longer pause time (i.e., low mobility). This is caused by low network congestion among neighbors and reduced multiple access interference and showed that the shorter delay is obtained by the NT-DAQ scheme operation. Even at high mobility, the difference of delay variation between AODV and NT-DAQ is conspicuously big. Most inclinations on this simulation results are very similar to the above results, which is described in the packet delivery fraction, Figure 4. This is reasonable because NT-DAQ scheme considerably reduces the number of query packets and results in lower network congestion as mentioned above. In lower network load, 10 sources, our proposed scheme does not affect on the overall delay variation. However, as network load increased, the difference of the delay variation obviously increases, especially 30 and 40 sources. This indicates which NT-DAQ scheme effectively reduces the number of unnecessary query packets and avoids multiple access interference. For example, with 40 sources and 100 seconds in pause time, the comparison of AODV and NT-DAQ delay variation, it shows that the delay performance improves about three times.

4.2.3 Performance analysis about the routing overhead

Figure 6 shows the routing overhead versus the fraction of each of traffic cases. Routing overhead

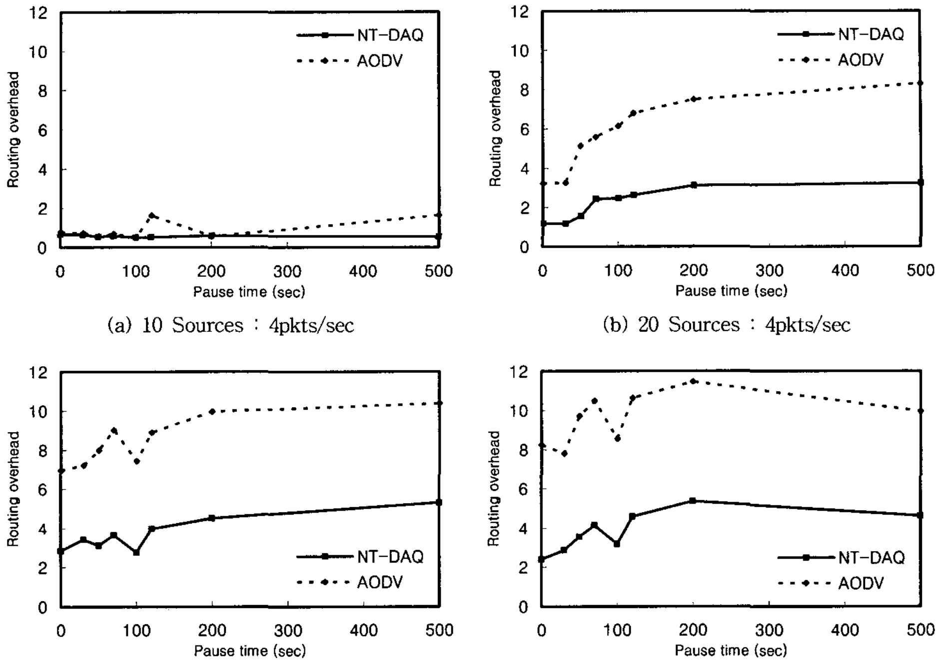
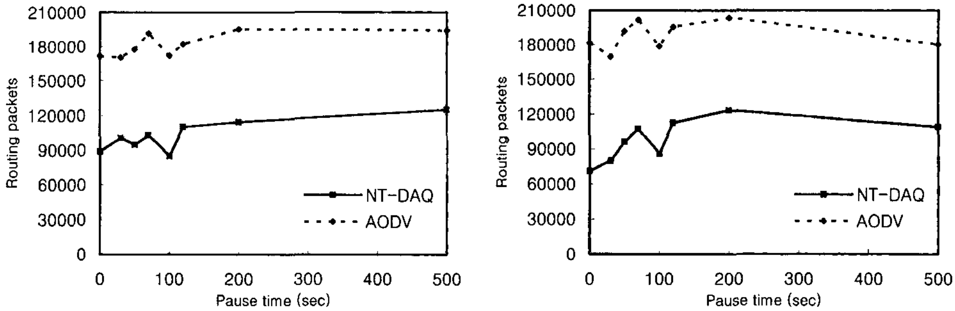


Figure 6 Routing overhead of AODV and NT-DAQ

exhibits how many control traffic is demanded to successfully deliver data traffic from source to destination. It is expressed that the protocol with low routing overhead represents better protocol efficiency. In on-demand routing protocols using flooding method, the proportion of query packet out of routing overhead traffic is very large. Hence, the reduction of the number of unnecessary query packets yield low routing overhead. In this result, the performance of NT-DAQ routing overhead does not change significantly until the network load is increased. This indicates that the low network load produces the small number of query packets and reduces multiple access interference. However, as the number of network load increases, NT-DAQ obviously shows better performance than AODV, which our proposed scheme results in significant reduction of query packets in all cases. Especially, for the 40 sources, NT-DAQ shows better performance than other traffic cases. Relatively low routing overhead with NT-DAQ scheme reduces the network congestion in case of high traffic sources, that is, with 30 and 40 sources, thus leading substantial improvements in packet delivery fraction and end-to-end delay. To investigate further, we evaluate the effect of routing overhead, aspect of the number of routing packets. Figure 7 shows the routing overhead with 30 and 40 sources, in case of relatively high network load. In comparison with AODV, Figure 7 shows that NT-DAQ considerably reduces the number of routing packets. This is reason why NT-DAQ scheme outperforms AODV protocol. Hence, the reduction of query packets considerably influences the efficiency of routing overhead.

5. Conclusions

On-demand protocols suffer from the production of enormous query packets via flooding. Hence, to resolve flooding problem which produces the great number of query packets, we present a novel routing scheme for on-demand protocols in ad hoc networks. The proposed scheme, Dynamic Adaptation Query flooding Using Neighbor Topology (NT-DAQ), is based on the pure on-demand protocols and designed as the goal of minimizing



(a) 30 Sources : 3pkts/sec (b) 40 Sources : 2pkts/sec

Figure 7 Routing packets of AODV and NT-DAQ

the routing overhead during flooding, according to the reduction of unnecessary query packets. Furthermore, our approach can decrease route setup time by avoiding multiple access interference. As a consequence, it enables to enhance the packet delivery fraction and the end-to-end delay performance. We evaluate whether our proposed scheme guarantee a special performance factors, like packet delivery fraction and end-to-end delay and routing overhead, versus pure AODV protocol. As mentioned above section, the performance comparison of AODV protocol and our proposed scheme shows that our proposed scheme provides better performance in proportion to increasing the network load. Especially, in case of low mobility of 40 sources, NT-DAQ shows better performance than other cases, which routing overhead is reduced about 60% and the number of query packets reduces about 45%. This indicates that network congestion seriously increases in case of low mobility environments and our proposed scheme effectively reduces network congestion. Furthermore, considering characteristic of ad hoc networks, the network congestion greatly increases in case the high density network, because of multiple access interference. Hence, in case of the high density networks, it may be that our proposed scheme operates more effective than the low density networks.

We conduct a performance evaluation of NT-DAQ scheme through a mobile node including GPS device, to obtain distance information among neighbors. Our future plan is to evaluate NT-DAQ scheme including signal strength method and more complexity routing scheme, using various neighbor table metrics. We also plan to evaluate the performance of our proposed scheme in case low density network, in additional to various simulation model and scenarios.

References

[1] C.K Toh, "Ad Hoc Mobile Wireless Networks: Protocols and Systems," *Prentice Hall PTR*, New Jersey, 2002.

[2] J. Macker and S. Corson, Mobile ad hoc networks (MANET), *IETF Working Group Charter* (2004), http://www.ietf.org/html.charters/manet-charter.html.

[3] Charles E. Perkins, "Ad Hoc Networking," pp. 173-219, *Addison Wesley*, 2001.

[4] E.M. Royer and C.-K. Toh, "A review of Current Routing Protocols for Ad-Hoc Wireless Networks," *IEEE personal Communications*, vol. 6, no.2, pp. 46-55, April 1999.

[5] Yunjung Yi and Mario Gerla, "Efficient Flooding in Ad hoc Networks: a Comparative Performance Study," *UCLS Report*.

[6] J. Broch, D.B. Johnson, and D.A. Maltz, "The Dynamic Source Routing Protocol for mobile Ad Hoc Networks," *Internet Draft*, draft-ietf-manet-dsr-09.txt, April 2003.

[7] C. Perkins, E. Belding-Royer, S. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing," *IETF RFC 3561*, http://www.ietf.org/rfc/rfc3561.txt, July 2003.

[8] C-K Toh, "Associativity-Based Routing for Ad-Hoc Mobile Networks," Wireless Personal Communications, vol. 4, no. 2, pp. 103-139, March 1997.

[9] Yu-Chee Tseng, Sze-Yao Ni, En-Yu Shih, "Adaptive Approaches to Relieving Broadcast Storms in a Wireless Multihop Ad Hoc Network," *Infocom*, 2001.

[10] Sze-Yao Ni, Yu-Chee Tseng, Yuh-Shyan C hen, Jang-Ping Sheu, "The broadcast Strom Problem

in a Mobile Ad Hoc Network," *MobiCom* '99.

[11] Z. Hass and M. Pearlman, "The Performance of Query Control Schemed for the Zone Routing Protocol," *Proceeding of ACM SIGCOMM' 98*, pp. 167-177, September 1998.

[12] Hakhu Lee and Sunshin An, "Redundancy Path Routing Considering Associativity in Ad Hoc Networks," *Proceedings of the 30th KISS autumn conference*, vol. 30, no. 2-3, pp. 199-201, October 2003.

[13] Simon Haykin, "Communication systems," 4th Ed., pp. 521 - 522, *John Wiley & Sons*, 2001.

[14] The CMU Monarch Project, The CMU Monarch Project's Wireless and Mobility Extensions to *ns*, CS Dept., Carnegie Mellon University, Aug. 1999, http://www.monarch.cs.cmu.edu/.

[15] The VINT Project, The UCB/LBNL/VINT Network Simulator-ns (Version2), http://www.isi.edu/nsnam/ns.

[16] IEEE Std. 802.11-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," *IEEE Std. 802.11-1999*, 1999.

[17] S. C and J. M, "Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations," *IETF RFC 2501*, http://www.ietf.org/rfc/rfc2501.txt, Jan. 1999.

[18] Josh Broch, D.A., David B. J, Y-C. H, and J. Jetcheva, "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols," *in Proc of MobiCom'98*, October 25-30.

[19] Samir R. Das, C.E. Perkins, and E.M. Royer, "Performance Comparison of Two On-demand Routing Protocols for Ad Hoc Networks," *IEEE INFOCOM 2000*, pp. 3-12, March 2000.

이 학 후

1996년 동아대학교 전기공학과 졸업 1996년~현재 삼성전자㈜ 네트웍 사업부 책임 연구원. 2003년~현재 고려대학교 대학원 전자·컴퓨터공학과 석사과정. 관심분야는 Mobile Network, W-CDMA CDMA2000, QoS Multicast Routing

강 상 욱

1980년 단국대학교 전자공학과 졸업 1982년 단국대학교 전자공학과 공학석사 2002년~현재 고려대학교 대학원 대학원 전자·컴퓨터공학과 박사과정. 관심분야는 Sensor Network, Mobile Network, Home Network

안 순 신

1973년 2월 서울대학교 전자공학과 학사 1975년 2월 한국과학원 전자공학과 석사 1979년 2월 ENSEEIHT 정보통신 박사 1982년 고려대학교 전자공학과 교수. 1991년~1992년 NIST 방문연구원. 1999년 정보과학회 부회장. 관심분야는 multimedia communication, network management, Intelligent network, distributed system, Ubiquitous computing, Ad-hoc network