A Modified AOMDV Routing Protocol for Maritime Inter-ship Communication

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ABSTRACT

In maritime communication, QoS problem caused by routing is very important. In this paper, we propose a method based on AOMDV protocol providing a route recovery mechanism when a link breaks in an active route to reduce lost packets. The results show that the proposed method can reduce packet loss ratio and delay time compared with the AOMDV.

Key Words : Ad-hoc network, AOMDV, Maritime communication, Route recovery, MANET

Ⅰ. Introduction

Nowadays, communication between ships is based on systems such as UHF and VHF radios near port waters and satellite communication for long-range communication such as INMASART. However, they are also low performance when compared to land-based wireless neetwork such as 3G. In addition, the cost of equipment and expense of ensuring QoS for such a network is expected to remain high.

Recently, some research has been conducted on using a mesh network to solve performance problems for ship-to-ship communication in the shore line area. However, there have been no studies on ship-to-ship communication with an Ad-hoc network over IEEE 802.16e. A mobile ad-hoc network, or MANET[1] is a collection of mobile nodes sharing a wireless channel without any centralized control or established communication backbone.They have no fixed routers with all nodes capable of movement and are arbitrarily dynamic. These nodes can act as both end systems and routers at the same time. As routers, they discover and maintain routes to other nodes in the network. The topology of the ad-hoc network depends on the transmission power of the nodes and the location of mobile nodes, which may change from time to time[2].

One of the main problems in ad-hoc networking is the efficient delivery of data packets to the mobile nodes where the topology is not pre-determined and the network has no centralized control. Hence, due to the frequently changing topology, routing in ad-hoc networks can be viewed as a challenge.

In table-driven or proactive routing protocols, consistent and up-to-date routing information of the network topology of all nodes is maintained at each node with respect to the time. Routes are built from each node to every other node before they are needed. Any changes occurring in topology is broadcast through the network, notifying all the nodes of the changes. Proactive protocols maintain routing information about the available paths in the

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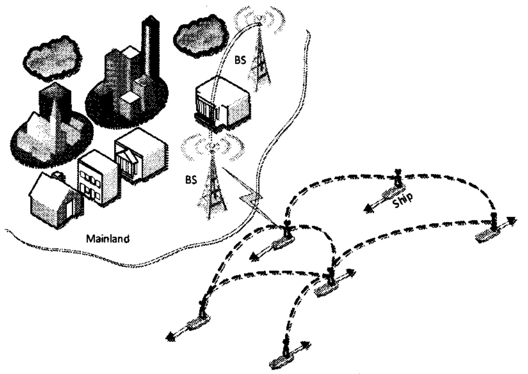

Fig. 1. The model of inter-ship communication

network even if these paths are not currently being used.The major drawback of these approaches is that the maintenance of unused paths may occupy a large part of the available bandwidth if the topology changes frequently[2].

In on-demand or reactive routing protocols, the routes are created based on need. To find a path from source to destination, it uses route discovery mechanisms. Only the routes that are currently in use are maintained, thereby maintaining low control overhead and reducing the network load since a small subset of all available routes is in use at any given time. Reactive routing protocols have some inherent limitations. First, since routes are only maintained while in use, it is usually to perform a route discovery before packets can be exchanged between communication peers. This leads to a delay for the first packet to be transmitted. Second, even though route maintenance for reactive algorithms is restricted to the routes currently in use, it may still generate an important amount of network traffic when the topology of the network changes frequently. Finally, packets to the destination are likely to be lost if the route changes[2].

The main challenge of MANETs is to route with low overheads even under dynamic conditions. Overhead here is defined in terms of routing protocol control messages which consume both channel bandwidth as well as the battery power of nodes for communication/processing. Several studies on performance comparisons[3] have shown that on-demand protocols achieve lower routing overheads in comparison to proactive protocols and position-based routing protocols are even lower than on-demand reactive routing.

Existing routing protocols in ad-hoc networks utilize the single route that is built for a source and destination node pair. Due to node mobility, node failures and the dynamic characteristics of the radio channel, links in a route may become temporarily unavailable, making the route invalid[2]. The overhead of finding alternate routes mounts along with additional packet delivery delay. This problem can be solved by using multiple paths between source and destination node pairs, where one route can be used as the primary route and the others as backups. Performance can be adversely affected by high route discovery latency and frequent route discovery in dynamic networks. This can be reduced by computing multiple paths in a single route discovery attempt. Multiple paths can be formed for both traffic sources and intermediate nodes with new routes being discovered only when needed, reducing route discovery latency and routing overheads. Multiple paths can also balance network load by forwarding data packets aling multiple paths at the same time.

In this paper, we propose a method based on the AOMDV routing protocol for inter-ship communication near port waters. But ad-hoc network modes can be problematic in some ways such as ensuring QoS. In the ad-hoc network, the end-to-end packet delivery ratio depends on the recovery path when one link breaks and also depends on the number of hops. A modified AOMDV protocol uses a single mechanism to recover the route for ship-to-ship communication. This method will solve the packet loss problem. In addition, data packets will be transferred to the destination node with an acceptable delay time.

The rest of the paper is organized as follows. Section II gives an overview of the AOMDV protocol, describes operation mechanisms, etc. New modifications for AOMDV and movement patterns are described in Section II and III. In order to show the effectiveness of the proposed modifications, we provide simulation results followed by a discussion of the simulation methodology used in the Section IV. Finally, Section V concludes the paper.

Ⅱ. AOMDV Routing Protocol

The Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV)[4] protocol is an extension to the AODV protocol for computing multiple loop-free and link-disjoint paths[2]. The routing entries for each destination contain a list of the next hops along with the corresponding hop counts. All the next hops have the same sequence number. This helps in keeping track of a route. For each destination, a node maintains the advertised hop count, defined as the maximum hop count for all the paths, which is used for sending route advertisements of the destination. Each duplicate route advertisement received by a node defines an alternate path to the destination. Loop freedom is assured for a node by accepting alternate paths to the destination if it has smaller hop count than the advertised hop count for that destination. Because the maximum hop count is used, the advertised hop count does not change for the same sequence number[2]. When a route advertisement is received for a destination with a larger sequence number, the next hop list and the advertised hop count are reinitialized.

AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQ arriving via a different neighbor of the source defines a node-disjoint path. This is because nodes cannot broadcast duplicate RREQs, so any two RREQs arriving at an intermediate node via a different neighbor could not have traversed the same node. In an attempt to get multiple link-disjoint routes, the destination replies to RREQs, the destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow reverse paths, which are node-disjoint and thus link-disjoint. The trajectories of each RREP may intersect at an intermediate node, but each takes a different reverse path to the source to ensure link-disjoint[2]. The advantage of using AOMDV is that it allows intermediate nodes to reply to RREQs, while still selecting disjoint paths. But AOMDV has more message overheads during route discovery due to increased flooding and since it is a multipath routing protocol, the destination replies to the multiple RREQs have longer overheads.

Ⅲ. M-AOMDV Solution

Figure 2 shows an ad-hoc network using the AOMDV routing protocol. Source node S is transmitting data to destination node D, with node F detecting that link F-J is broken. Node F will start a "local repair"[4] to discover a route to the destination node by generating an RREQ packet with that destination if there is no other route to D. If node F cannot receive any RREP packet, node F will transmit a RRER packet for this destination. Therefore, data packets are cached at node F and if source node S must restart route discovery this data will be deletes. But if S finds a new route it will increase data transfer time.

We propose a modified AOMDV local repair mechanism as follows:

1) Multipath routing: have multiple routes for one destination in the routing table at each node. Each route group for one destination is shown as table 1

2) In Figure 3, a link breaks in the active route i.e. the F-J link. If the routing table of the intermediate node F has other sub-routes to destination D, it will select the route with the lowest hop count and send data via this route. If there is no sub-route to D, node F does not send any RRER

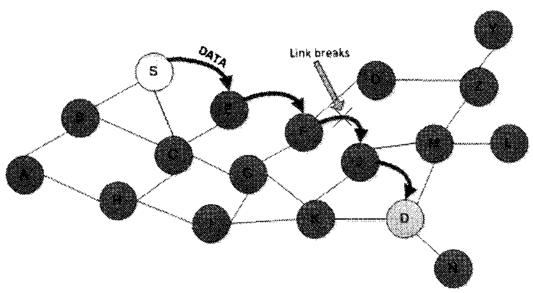

Fig. 2. Local repair process of the AOMDV routing protocol

Table 1. Routing table entry for destination D at node F

Destination	Destination Seq. No	Next hop	Hop count	Priority Notice
D	2	J	1	Main route
D	2	G	2	Sub route
D	2	O	3	Sub route

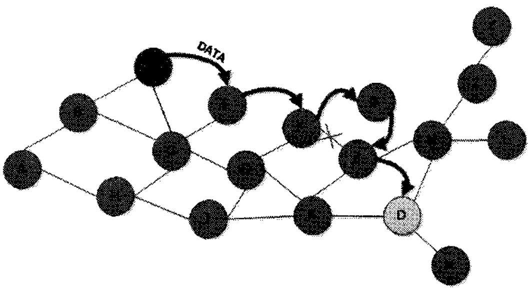

Fig. 3. Route recovery process at F

packet. Instead, it tries to reach node D via another hop[5]. It searches again for a node from its neighbors. It finds a new node X and starts sending packets via X to D as shown in Figure 4.

3) If, after step 2, node F cannot find a new route to D, it will transmit a RRER packet to the source node S via node E. If the routing table of node S has another sub route to D, S will select this sub route and start sending packets via the green route, as shown in Figure 4. If S has only one route to D, it will restart route discovery for this destination.

This mechanism is applied when the local repairing mechanism is considered. The mechanism can be described as the following mathematical algorithm:

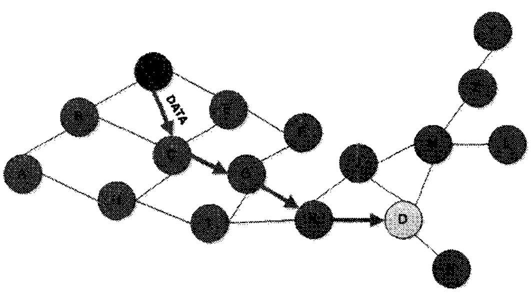

Fig. 4. Route recovery process at S

Begin

If (intermediatenodedetectlinkfailure)and (there is sub route for the destination)

Start sending the packet through that route.

Else

Intermediate node will start local route discovery for destination with single-hop distance considering the next node of the route.

If (intermediatenodereachs a new next node on the route)

Start sending the packet via this node.

Else

Intermediate node sends RRER packet to source node.

If(Sourcenodehasasub route to destination)

Start sending the packet through this route.

Else

Source node starts new rout discovery.

EndIf

EndIf

EndIf

End

This approach is to improve the route maintenance process by repairing the route locally, i.e. the intermediate node on the route that detects the link failure must take the initiative to repair the route if there is no sub route for the destination. The intermediate node will look for an alternate path at a single hop distance so that it can reach the node that has experienced link failure. Once the local path is discovered, it then send the packets via an alternate single-hop path and the rest of the nodes follow the previous path. Thus local repairing may save route maintenance time.

In addition, data packets cached at intermediate node will not be deleted and the source node will not send the data again. So this mechanism will decrease delays more effectively than AOMDV.

Ⅳ. Ship Movement Pattern

This section details the analysis of the mobility pattern of ships near port. We have extensively analyzed the AIS (Automatic Identification System) data[6] to determine the mobility pattern of ships traveling along the shoreline area near the Pusan port in South Korea. Besides aiding in the dimensioning of the network, the mobility pattern will also be used in the maritime ad-hoc network simulator that we applied to network topology, as shown in Figure 5.

We focused on the distribution of speed for all ships crossing a given liner line across the surface of the planet. Figures 6 and 7 show the number of ships that cross the line of longitude E-129,16 hourly heading northest and southwest as shown in Figure 10. The figures show that there was no significant trend in hourly distribution. Also, there is no significant difference in ship arrival patterns from both directions. The total numbers of ships heading northeast and southwest in 24-hour periods are 102 and 119, respectively.

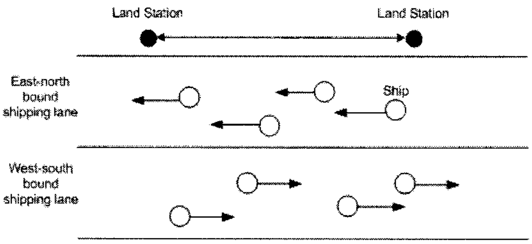

Fig. 5. General topology for maritime Ad-hoc Network

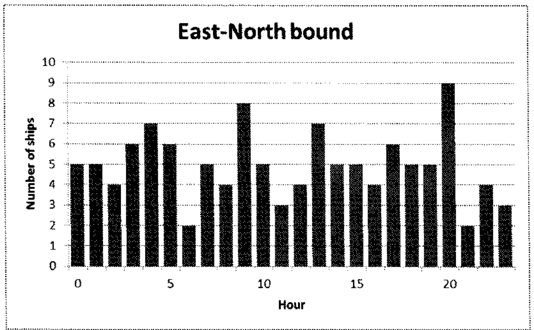

Fig. 6. The number of ships that cross the line of longitude E-129.16 hourly northeasterly

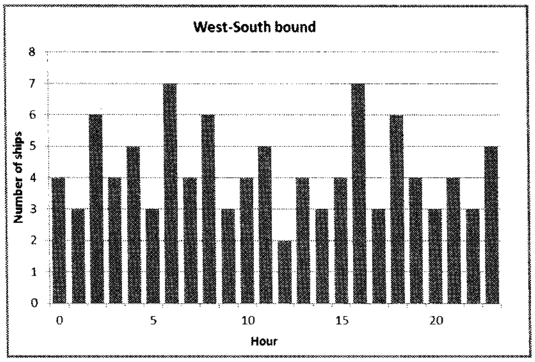

Fig. 7. The number of ships that cross the line of longitude E-129.16 hourly southwesterly

Figures 8 and 9 show the probability densities of the velocities of ships that cross the line of longitude E-129.16. We observed that there was no significant difference in the velocity distributions of both directions. The majority of the velocities were under 30 knots, which is the maximum speed allowed in the shipping lane and ships in the port area are expected to more slowly.

By using commercially available curve fitting software DataFit[7], we performed non-linear regression to fit the probability density functions of the speeds in Figure 8 using the following factorized truncated normal function:

$$p(x) = a.e^{\left(\frac{-(x-b)^2}{2.c^2}\right)} \quad (1)$$

Where x is speed, a, b, c are other fixed arbitrary parameters. However, the p(x) above is not ready

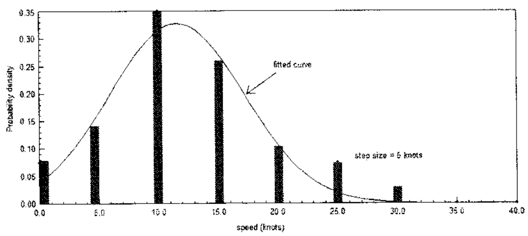

Fig. 8. The speeds of ships that cross the line of E-129.16 in northesterly

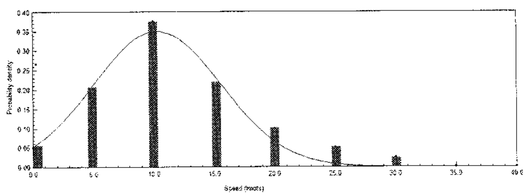

Fig. 9. The speeds of ships that cross the line of longitude E-129.16 southwesterly

for use as the probability density function conservation rule. Let p(x) be defined as follows :

$$p(x) = \int_0^x a.e^{(\frac{-(y-b)^2}{2.c^2})} dy \qquad (2)$$

Then, the speed probability distribution functions for a,b and c can be written as follows:

$$F(x) = \begin{cases} \frac{p(x) - p(0)}{p(V_{max}) - p(0)}; if\, 0 < x \le V_{max} \\ 0; otherwise \end{cases} \qquad (3)$$

Where p(V_{max}) is used in the denominator as a result of the observed maximum velocity V_{max} = 30 knots = 15 m/s. The speed of a new arrived ship is determined using the F(x) in the equation (3) above.

This analysis is unique because it is based on actual mobility traces of ships derived from AIS data observed in a specific region. The region of interest is shown in Figure 10 above, which is a rectangular area near Pusan Port.

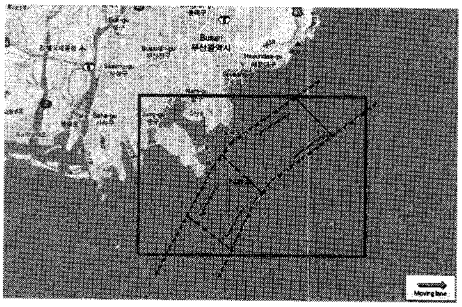

Fig. 10. Region of interest -near Pusan port

V. Performance Evaluation

Using NS2[8], we evaluated the performance of the Modified-AOMDV (M-AOMDV) protocol. Also, we used an ad-hoc network mode in the mobile WiMAX environment[9,10] to simulate the proposed method[11]. Based on Section IV, which describes the mobility pattern near Pusan port, we have written a function to generate the ships movement patterns for the generic topology.

Table 2. Main network parameters

Parameter type	Value
Channel	Channel/Wireless Channel
Propagation model	Propagation/OFDMA
Interface type	Phy/WirelessPhy/OFDMA
Interface queue	Queue/DropTail/PriQueue
MAC	Mac/802_16
Link layer	LL
Antenna	Antenna/OmniAntenna
Interface queue length	50
Routing protocol	AOMDV,M-AOMDV
Ending Time	2000 seconds

4.1 Simulation scenario

In our simulation, Ship 12 wants to connect to Base Station 2 (BS2). It starts route discovery with destination BS2 on the mainland. After route discovery, routes to destination BS2 are saved at Ship 12 and intermediate ships (ISs). The scenario is illustrated below:

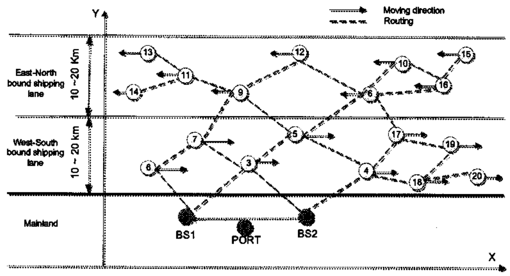

Fig. 11. Simulation scenario for M-AOMDV

Table 3. Scenario 1

Parameter type	Value
x topography	20000 m
y topography	20000 m
Number of nodes	20
Simulation Time	1800 seconds
Max Velocity	15 m/s
Number of off-ISs	1,2,3,4,5,6,7

Table 4. Scenario 2

Parameter type	Value
x topography	20000 m
y topography	20000 m
Number of nodes	20
Simulation Time	1800 seconds
Max velocity	0 2.5m/s 5m/s 7.5m/s 10m/s 12.5m/s 15m/s
Number of off- ISs	0

In Scenario 1, when Ship 12 is transmitting data to BS2 via route (12-9-5-3-1), we will gradually turn off different IS node, off-IS, such as node (3), (4), (5)··· and evaluate the performance results of this scenario. In this simulation CBR traffic was used.

In Scenario 2, we have 20 ships moving in opposite directions. In this simulation, CBR traffic also was used.

4.2 Results of performance evaluation

In order to evaluate the M-AOMDV performance, we increased the number of off-ISs from 1 to 7 in a simulation with 20 nodes. We measured the packet loss rate of communication between ships farthest from port and BS2 in comparison with that of the AOMDV routing protocol. Also, we evaluated the relationship between average end-to-end delay and velocity of the nodes (ships).

The results of Scenario 1 are shown in Figure 12. When there are fewer intermediate ships, the packet loss rate will increase. However, we can see that our method shows a lower packet loss ratio than that of the AOMDV.

From Figure 13 which is result of simulation scenario 2, we can see that the delay for the AOMDV protocol is longer than the M-AOMDV protocol, and the delay of these two protocols are basically consistent with speed fluctuations. The link repair mechanism of the M-AOMDV can reduce delays to a certain extent by requesting routing to forward data packets as quickly as possible in order to complete link repair to the destination node when the node detects that the link has been interrupted.

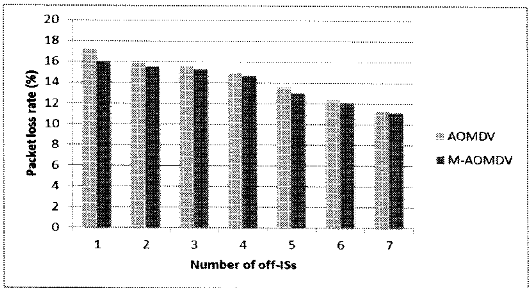

Fig. 12. Packet loss rate vs. Number of off-ISs

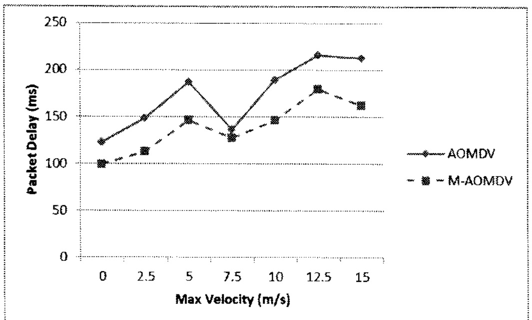

Fig. 13. The relationship between speed and time delay

V. Conclusion

In this paper, we proposed a modified AOMDV local repair process. We evaluated the proposed protocol and compared the performances with those of the AOMDV protocol. The results show that the M-AOMDV protocol reduces the average delay and packet loss ratio. Also, our proposed method increases the potential for the ad-hoc network mode to be applied to ship networks in shoreline areas.

In the future, we will continue to improve the performance of the ad-hoc network for inter-ship communication.

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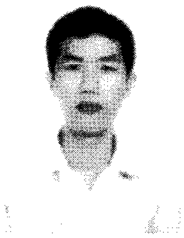

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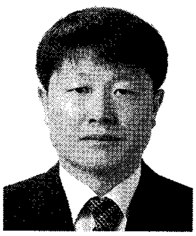

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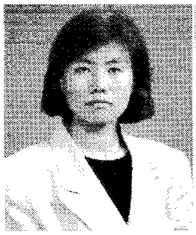

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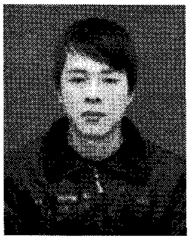

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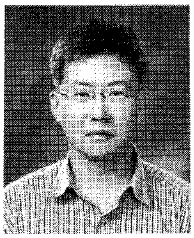

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