MANEMO for Fishing Trolleys in Deep Sea

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Submitted in May 2010; Accepted in November 2010

ABSTRACT

The present work considers a fleet of fishing trolleys. The MANEMO is the integration of mobile ad-hoc network technology and mobile network technology for maintaining the uninterrupted connectivity among the fishing trolleys in deep sea. It provides local connectivity among the fishing trolleys for offshore help using mobile ad-hoc network and global connectivity among the fishing trolleys for onshore help using mobile network. Each fishing trolley works as a separate node in case of local communication whereas all the fishing trolleys form a mobile network in case of global communication. The routing algorithm in MANET environment selects an optimal route for a session before starting transmission of data packets associated with that session. It uses route maintenance algorithm to detect whether a trolley associated with an existing route is going out of the communication range during the ongoing session in advance before the existing route fails completely. Such consideration helps to reduce the data packet loss. If the local communication among trolleys fails due to the change in network topology the rest of the communication can be maintained globally which helps to provide the uninterrupted connectivity to the fishermen in the deep sea. The performance of the proposed scheme is evaluated on the basis of initial path set up time and average packet delay.

KEYWORDS

MANET, MObile NEtwork, Basic POSANT routing algorithm, WLAN, WiFi/WiMAX

1.0 INTRODUCTION

In today's society many people spend a lot of time in vehicle. They need network connectivity for various safety and non-safety applications. The MObile NEtwork technology (NEMO) and Mobile Ad-hoc NETwork (MANET) technology are integrated in MANEMO to maintain global and local connectivity among vehicles. The vehicles can communicate using MANET when they are close enough. They can communicate using NEMO for getting help like weather forecast, accidents, and attack from intruder etc. They also use NEMO for communication in case the MANET technology fails to maintain local communication due to the change in network topology.

Several such integration schemes have been reported so far. The mobile routers (MRS) [1] deployed in car not only provide external communication access but also manage the mobility of the whole network transparently. In [2] the MANET routing protocol is used to achieve multi hop communication between a MANET node and an attachment point in case the attachment point is within the coverage area of MANET. The multi hop path between a MANET node and an attachment point is established through NEMO in case the attachment point is out of the coverage area of MANET. In this scheme NEMO environment provides infrastructure connectivity whereas the MANET environment deals with routing issues internally to a mobile network. The authors did not present any simulation results. A vehicular network integration of VANET with NEMO is proposed in [3]. In this scheme the receive on most stable group path and link expiration time threshold are used to find the most stable link in the VANET environment. But the proposed VANET routing is unable to offer best throughput. The in vehicle router system to support network mobility is proposed in [4]. This scheme is the combination of Mobile IPv6, Interface switching and Prefix Scope Binding update to achieve end to end permanent connectivity and migration transparency. A post-disaster network is formed in [5] by integrating NEMO and VANET to support streaming video, VoIP and short message equipped with global positioning system (GPS) to view the location of vehicles in Google map. The integration of NEMO and MANET is proposed in [6] to form rescue team communication and the experiment is conducted over a mountain rescue team. Tsukada et al. described the co-operation between MANET and NEMO [7] to support route optimization and multi homing. The authors used the optimized link-state routing (OLSR) algorithm for the MANET environment. But the transmission of control packets is required for route existence verification if the data packets are transmitted at a slow speed which increases the overhead of the OLSR algorithm. They mainly focused in defining the architecture and the purpose of integration. The authors did not consider the detailed usage of combination and their utility experimentally.

The present work considers a fleet of fishing trolleys as vehicle. All the fishing trolleys belong to the same fishing harbor, which is their home network associated with a Home Agent (HA). A MR is associated with each trolley. Each MR works as an individual node in case of local communication using MANET interface. All MRs form a mobile network which is connected with the HA through Internet. They communicate globally with HA through Internet using NEMO interface and MR-HA tunnel. One of the trolleys works as a

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special fixed node (SFN) for MANET and as a local fixed node (LFN) for NEMO. It maintains the optimal route (OR) information for both MANET and NEMO. It is not taking any part in communication. The access router (AR) installed in the island forms a foreign network for the fishing trolleys and is considered as Island Side Unit (ISU).The AR installed in the shore forms a foreign network for the fishing trolleys and is considered as Shore Side Unit (SSU). The ISU maintains connectivity between the fishing trolleys and the HA through Internet in case the fishing trolleys are closer to the Island. The SSU maintains connectivity between the fishing trolleys and the HA through Internet in case the fishing trolleys are closer to the shore.

The WLAN is preferred for MANET due to its lesser communication range and power consumption [8] whereas WiFi/WiMAX is preferred for NEMO due to its higher communication range and power consumption [8]. The cost and power consumption of maintaining local communication among trolleys is reduced by using WLAN for MANET in the present work. Moreover such communication among trolleys is secured as it does not need Internet access. So the communication among trolleys is maintained locally in most of the cases. But the route failure may occur in MANET during local communication among trolleys due to the change in network topology. In such a situation the rest of the communication among trolleys can be maintained through HA using MR-HA tunnel if it is not possible to select an alternative route in MANET. So the integration of MANET technology and NEMO technology in the present work helps to maintain the uninterrupted connectivity among the fishermen in the deep sea.

2.0 ROUTING ALGORITHMS FOR MANET

Two different routing algorithms for MANET are proposed in the present work. The algorithms are considered for discussion in the following sections.

2.1 HA POSANT ROUTING ALGORITHM

The HA is equipped with Google Map [9] and each trolley is equipped with GPS. A source node (S_id) sends route request message (RRM) (as discussed in section 2.1.1) to HA for the initiation of a session with a destination node (D_id). The HA triggers route selection algorithm (as discussed in section 2.1.2) to select an OR in response to RRM and sends the OR to S_id using route found message (RFM) (as discussed in section 2.1.1). The HA assigns a unique session identification (SS_id) to each session after selecting an OR for it. After receiving RFM, S_id generates Type 0 packet (T0 as discussed in section 2.1.3). The Route field of T0 contains the identification of all the nodes which are associated with OR as mentioned in the Route field of RFM by HA. S_id sends this packet to D_id through all the nodes which are identified in the Route field of T0. Each node maintains a routing table (RT) (as discussed in section 2.1.4) and inserts a record in RT after receiving T0. Both S_id and D_id associated with a particular session generate Type 1 packet (T1 as discussed in section 2.1.3) and send this packet to each other to maintain the bidirectional transmission of packets corresponding to a particular session among them using OR which is mentioned in RFM. The HA maintains a session table (ST) (as discussed in section 2.1.5) to store the information of all the ongoing sessions among nodes in MANET. The HA inserts a record in ST after selecting an OR. As soon as an ongoing session is over S_id associated with this session sends session over message (SOM) (as discussed in section 2.1.1) to HA. The HA searches ST for the record who's SS_id attribute matches with the SS_id field as mentioned in SOM and deletes that record from ST. The HA executes the route maintenance algorithm (as discussed in section 2.1.6) to detect node(s) which is associated with an existing route(s) and is going out of the communication range from its neighboring node associated with the same route during the ongoing session. In such a case the HA considers the existing route(s) as faulty and executes route selection algorithm for the selection of an alternate OR(s) to replace the faulty existing route(s). It sends the alternative OR to S_id(s) using route maintenance message (RMM) (as discussed in section 2.1.1). After receiving RMM, S_id(s) generates Type 2 packet (T2 as discussed in section 2.1.3). The N_Route field of T2 contains the identification of all the nodes which are associated with the alternative OR as mentioned in the N_Route field of RMM by the HA. S_id sends T2 to D_id through all the nodes which are identified in the N_Route field of T2 for necessary insertion or modification in their RT.

2.1.1 MESSAGE EXCHANGE AMONG VARIOUS NODES

RRM contains S_id and D_id fields. RFM contains S_id, D_id, SS_id and Route fields. SOM has SS_id and F_flag fields. The F_flag field of SOM is set to indicate the end of session which is identified in its SS_id field. RMM has SS_id, S_id and N_Route fields.

2.1.2 ROUTE SELECTION ALGORITHM

The GPS detects the current location in terms of longitude and latitude of each node. The GPS sends this information of each node to HA as soon as the current location of any node changes. The HA uses Vincenty's inverse equation [10] to calculate the distance between two neighboring nodes from their current location which is provided by GPS. The longitude and latitude of the fishing area is provided by the fishing authority to HA. The Google Map in HA shows the real time image of each node within the fishing area using the information provided by the GPS and the information provided by the fishing authority. The HA maintains a graph of nodes using their real time image which is provided by the Google Map continuously and creates a rectangular boundary around the graph of nodes. If any intruder node crosses the rectangular boundary from outside HA sends a special security signal to the node(s) closer to the intruder node. After receiving RRM the HA applies depth first search to the graph and finds all possible routes from S_id to D_id. The HA counts the number of nodes in each possible route and selects the route having minimum number of nodes as the best route. The HA uses basic POSANT [11] algorithm to determine OR in case of multiple best routes.

2.1.3 TYPE OF PACKETS

T0 contains SS_id, S_id, D_id, Type and Route fields. T1 contains SS_id, Node_id, S_No, Type and PAYLOAD fields. The Node_id field is S_id in case the packet is generated by S_id and D_id in case the packet is generated by D_id. The S_No field indicates the sequence number of the packet. The PAYLOAD field contains the data corresponding to the session which is identified by SS_id. T2 has SS_id, S_id, D_id, S_No, Type, N_Route and PAYLOAD fields. The Type field in T0, T1 and T2 indicates their type.

2.1.4 ROUTING TABLE (RT)

Each record in RT has 5 attributes as shown in TABLE-1.

S_id	D_id	SS_id	SN_NH	DN_NH
S	D	s	T	E

Table 1

Let TABLE-1 is RT which is maintained by j^{th} node and it shows a record for s^{th} session. S_id and D_id which are associated with the s^{th} session are identified as S and D respectively in TABLE-1. T indicates the next hop of the j^{th} node in case of transmission from S to D and E indicates the next hop of the j^{th} node in case of transmission from D to S in TABLE-1. After receiving T0 the j^{th} node inserts a record in TABLE-1. After receiving T1 the j^{th} node searches TABLE-1 for the existing record whose SS_id attribute matches with the SS_id field as mentioned in T1. Then it compares the S_id attribute and the D_id attribute of the existing record with the Node_id field as mentioned in T1. If the Node_id field in T1 matches with the S_id attribute of the existing record the j^{th} node forwards the packet to T and if the Node_id field in T1 matches with the D_id attribute of the existing record the j^{th} node forwards the packet to E. After receiving T2 the j^{th} node searches RT for the existing record whose SS_id attribute matches with the SS_id field as mentioned in T2. If found it updates the record by replacing the old route attribute by the new route attribute as mentioned in T2. Otherwise, it inserts a new record in RT. When a node is not participating in packet transmission corresponding to a particular session, it deletes the corresponding record from RT.

2.1.5 SESSION TABLE (ST)

Each record in ST has 3 attributes as shown in TABLE-2. The Route attribute is identical to Route field in RFM. The number of records in ST depends upon the number of ongoing sessions.

SS_id	S_id	Route

Table 2

2.1.6 ROUTE MAINTENANCE ALGORITHM

The HA computes the distance between the two neighboring nodes continuously using the information provided by GPS and using the Vincenty's inverse equation. The HA considers a node as MOVE_NODE in case its distance from the neighboring node crosses a threshold. The threshold distance is computed during simulation as discussed in section 4.1.2. As soon as HA detects such a node, it searches the Route attribute of all the records in ST. It selects the record(s) whose Route attribute contains the identification of the MOVE_NODE. If found it retrieves the selected record(s). It executes route selection algorithm for the selection of an alternative OR(s) before the existing route(s) fails completely. Such advance selection of an alternative route helps to reduce packet loss of a session. The HA updates the selected record(s) by replacing the old route attribute by the new route attribute in ST.

The installation of Google Map along with GPS increases the cost of the system. Moreover the GPS may not be able to work properly in situations such as underwater conditions e.g. within submarines. In such a situation radio detection and ranging (RADAR) works well. The RADAR POSANT routing algorithm is considered for discussion in section 2.2.

2.2 RADAR POSANT ROUTING ALGORITHM

Each node is equipped with two antennas, one at the front end and one at the rear end of the node. Both the antenna can work as transmitter as well as receiver to achieve bidirectional transmission of packets corresponding to a particular session.

S_id triggers route selection algorithm (as discussed in section 2.2.1) by forwarding ant packet towards D_id for the initiation of a session as in basic POSANT routing algorithm. D_id selects an OR and sends it to SFN (SFN_id) using D_to_SFN message (as discussed in section 2.2.2). The SFN sends OR to S_id using SFN_to_S message (as discussed in section 2.2.2). The SFN assigns a unique SS_id to each session after receiving OR from D_id. After receiving SFN_to_S message S_id generates T0 (as discussed in section 2.1.3). The Route field of this packet contains the identification of all the nodes which are associated with OR as mentioned in the Route field of SFN_to_S message by SFN. S_id sends T0 to D_id through all the nodes which are identified in the Route field of T0. Each node maintains RT (as discussed in section 2.1.4) and inserts a record in RT after receiving a T0. Both S_id and D_id associated with a particular session generate T1 (as discussed in section 2.1.3) and send T1 to each other to maintain the bidirectional transmission of packets corresponding to a particular session among them using OR as mentioned in SFN_to_S message. The SFN maintains a ST (as discussed in section 2.1.5) to store the information of all the ongoing sessions among nodes in MANET. The SFN inserts a record in ST after receiving D_to_SFN message. As soon as an ongoing session is over S_id associated with this session sends SOM (as discussed in section 2.1.1) to SFN. The SFN searches ST for the record who's SS_id attribute matches with the SS_id field as mentioned in SOM and deletes that record from ST. Each node associated with an existing route executes route maintenance algorithm (as discussed in section 2.2.3) to detect whether its neighboring node associated with the same route is going out of the communication range during the ongoing session and sends an alarming signal to the neighboring node. In response the neighboring node sends its identification to SFN. In such a case the SFN considers the existing route as faulty and sends SFN_ALT_ROUTE message (as discussed in section 2.2.2) to S_id which is associated with the faulty route for the execution of the route selection algorithm. S_id executes route selection algorithm for the selection of an alternative OR to replace the faulty existing route. After selecting the alternative OR S_id generates T2 (as discussed in section 2.1.3). The N_Route field of T2 contains the identification of all the nodes which are associated with the alternative OR as selected by S_id. S_id sends T2 to D_id through all the nodes which are identified in the N_Route field for necessary insertion or modification in their RT.

2.2.1 ROUTE SELECTION ALGORITHM

S_id forwards the ant packet through all the possible routes between S_id and D_id associated with a particular session as in basic POSANT routing algorithm. The ant packet deposits pheromone value to each link. The maximum pheromone value is deposited to the link having smallest length. The ant packet has 6 fields as shown in Fig.1.

S_id	D_id	A_F	T_S	Route	P_C

Figure 1: Format of ant packet

The A_F field is set to indicate the type of the packet as ant. Let ith node receives an ant packet from kth node and jth node is the successor of the ith node. The ith node mentions the current time stamp in the T_S field of the ant packet and forwards it to the jth node. The ith node adds its identification in the Route field of the ant packet. The ith node computes the difference in time stamp (Diff_time) between the current time stamp corresponding to the time of receiving the ant packet by it and the time stamp in the T_S field of the ant packet as mentioned by the kth node. The ith node also computes its distance from the kth node (D_{ik}) by multiplying Diff_time and the speed of electromagnetic signal {mt./sec}(as packets constitute of digital bits and are sent using electromagnetic signals). The bit error rate increases rapidly when the distance between the two neighboring nodes in the WLAN environment is greater than 45 meters [12]. So in the present work the pheromone value of the link between the ith node and the kth node (P_value_{ik}) is assumed as 20 if $D_{ik}<45$ otherwise it is assumed as 1. The ith node also multiplies the value in the P_C field of the ant packet as mentioned by the kth node by P_value_{ik}. At ith node the value in the P_C field of the ant packet indicates the pheromone concentration of the route from S_id up to the ith node.

The D_id receives multiple ant packets through all possible routes between S_id and D_id. It compares the P_C value of all the received ant packets. The route field in the ant packet having maximum P_C value is selected as OR.

2.2.2 MESSAGE EXCHANGE AMONG VARIOUS NODES

D_to_SFN message contains S_id, SFN_id and Route fields. SFN_to_S message contains SS_id, S_id, SFN_id and Route fields. SFN_ALT_ROUTE message has S_id, SFN_id and SS_id fields.

2.2.3 ROUTE MAINTENANCE ALGORITHM

Each node associated with an existing route computes its distance from the neighboring node which is associated with the same route using mono-static equation [13]. The mono-static equation used by the RADAR antennas in this scheme is as follows:

$$P_r = 10 \log_{10}[(P_t G_t G_r \lambda^2 \sigma)/((4\pi)^3 R^4)]$$
$$= 10 \log_{10}[P_t G_t G_r \{(\sigma c^2)/((4\pi)^3 f^2 R^4)\}]$$

where, P_r = Received peak power, P_t = Transmitted peak power, G_t = Gain of transmitter antenna (dBi), G_r = Gain of receiver antenna (dBi), λ = Transmitted wavelength (m, cm, in, etc.), σ = Radar cross-section of target - RCS (m^2, cm^2, in^2, etc.), R = Range (m, cm, in, etc.), c = speed of light. The parameter values of the mono-static equation are assumed as follows: P_t = 20 dbm, $G_t = G_r$ =16 dbi, λ = 15 cm, σ = 2.5 m^2 and c = 3* 10^8 meter/sec. The parameter R indicates the distance between the two neighboring nodes. P_r is measured at the receiving antenna and R is computed using the mono-static equation using the known value of all the other parameters.

Each node associated with an existing route also computes its angle with the neighboring node which is associated with the same route using Pythagoras theorem. In ΔABC (Fig.2) the vertex B and the vertex C represent the location of the front end and rare end antenna in a node. The vertex A represents the location of the neighboring node. In ΔABC the side AB (=c) represents the distance between the neighboring node and the front end antenna. P_r is measured at the front end antenna and c is computed using mono-static equation. The side AC (=b) represents the distance between the neighboring node and the rare end antenna. P_r is measured at the rare end antenna and b is computed using mono-static equation. The side BC (=a) represents the length of the node (trolley). AP (=h) is perpendicular to BC.

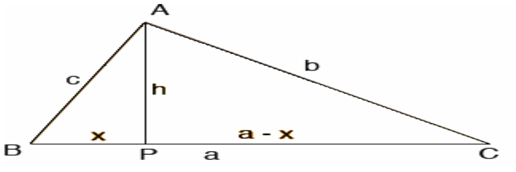

Figure 2: Triangular representation of the angle calculation process.

The angle between the two neighboring nodes (angle C) is $C= \cos^{-1}\{(a^2+b^2-c^2)/ 2ab\}$ using Pythagoras theorem. A node sends an alarming signal to its neighboring node (RECEIVED_NODE) in the direction of the angle as computed by the Pythagoras theorem in case its distance from the RECEIVED_NODE crosses a threshold. The threshold distance is computed during simulation as discussed in section 4.1.2. The RECEIVED_NODE sends its Node_id to SFN. The SFN searches the Route attribute of all the records in ST. It selects the record(s) whose Route attribute contains the identification of the RECEIVED_NODE. If found it retrieves the selected record(s) and sends SFN_ALT_ROUTE message to S_id(s) associated with the selected record(s) to execute route selection algorithm for the selection of an alternative OR(s) before the existing route(s) fails completely. Such advance selection of an alternate route helps to reduce packet loss of a session. S_id forwards the ant packet towards D_id. D_id selects an alternative OR and sends it to SFN. The SFN sends the alternative OR to S_id. The SFN updates the selected record(s) by replacing the old route attribute by the new route attribute in ST.

2.3 COMPARISON OF ROUTING ALGORITHMS

The performance of ANTNET, GPSR, ANTHOCNET and basic POSANT routing algorithms are compared on the basis of delivery rate, convergence time and algorithm overhead in [11]. In this section the basic POSANT routing algorithm [11], HA POSANT routing algorithm and RADAR POSANT routing algorithm are compared on the basis of storage requirement, RT searching time and time complexity of the algorithm.

2.3.1 STORAGE REQUIREMENT

In basic POSANT routing algorithm each node maintains a forward RT to send packets from S_id to D_id and a backward RT to send packets from D_id to S_id. Each record in RT has 3 attributes as shown in TABLE-3. Let TABLE-3 is the forward RT at j^{th} node. The Node_Address attribute is the address of D_id in case of forward RT. The Next_Hop attribute is the address of the next hop node from j^{th} node towards destination which is identified by the Node_Address attribute. The Pheromone_Value attribute indicates the pheromone value corresponding to the next hop node which is indicated by the Next_Hop attribute. The Node_Address attribute and the Next_Hop attribute are 128 bit IPv6 address. The maximum pheromone value which is deposited to a link is 20 as discussed in the section 2.2.1 and the number of bits require to represent the maximum pheromone value is 5. So the length of each record in the forward RT at any node is 261 bits. The number of records in the forward RT at j^{th} node for a single session depends upon the number of possible next hop nodes from j^{th} node towards destination. So the storage requirement per forward RT is (261*number of possible next hop towards D_id) bits.

Node_Address (128 bits)	Next_Hop (128 bits)	Pheromone_Value (5 bits)

Table 3

Let TABLE-3 is the backward RT at j^{th} node. The Node_Address attribute is the address of S_id in case of backward RT. The Next_Hop attribute is the address of the next hop node from j^{th} node towards source which is identified by the Node_Address attribute. The number of records in the backward RT at j^{th} node for a single session depends upon the number of possible next hop nodes from j^{th} node towards source. The storage requirement per backward RT is (261*number of possible next hop towards S_id) bits. So the storage requirement for each bidirectional session is 261*(number of possible next hop towards destination + number of possible next hop towards source) bits.

In HA POSANT routing algorithm and RADAR POSANT routing algorithm each node maintains a single RT as shown in TABLE-1. The S_id, D_id, SN_NH and DN_NH are 128 bits IPv6 addresses. Now for 1000 number of different bidirectional sessions the number of bits requires to represent SS_id is 10. So the length of each record in RT is 522 bits. There is a single record for each bidirectional session in RT and so the storage requirement for each bidirectional session is 522 bits. The storage requirement for each bidirectional session in basic POSANT routing algorithm is greater than the storage requirement in HA POSANT routing algorithm and RADAR POSANT routing algorithm if the number of next hop nodes from j^{th} node towards S_id or D_id is greater than unity in TABLE-3.

2.3.2 RT SEARCHING TIME

Let in case of basic POSANT routing algorithm the number of forward ongoing session through j^{th} node as an intermediate node is m and the number of next hop from j^{th} node towards D_id is n. So at j^{th} node the forward RT contains m*n number of records and the time complexity to select the desired record from the forward RT is $O(\log_2 m*n)$. The j^{th} node compares the pheromone value of all the n number of next hops and selects the optimal next hop having the maximum pheromone value. The link between j^{th} node and the selected optimal next hop is considered as the optimal outgoing link towards D_id. The time complexity to select the optimal outgoing link from the forward RT at j^{th} node is $O(n^2)$. So the total time complexity at j^{th} node for the selection of an optimal outgoing link is $O(\log_2 m*n+n^2)$.

In case of HA POSANT routing algorithm and RADAR POSANT routing algorithm RT at j^{th} node contains m number of records and the time complexity to select the desired record from RT is $O(\log_2 m)$.

So the time complexity of searching RT is higher in basic POSANT routing algorithm than in HA POSANT routing algorithm and RADAR POSANT routing algorithm.

2.3.3 TIME COMPLEXITY OF THE ALGORITHM

In case of basic POSANT routing algorithm RT at each node contains the possible next hop and their pheromone value. During the ongoing session RT at each node is searched for the selection of an optimal outgoing link. In case of HA POSANT routing algorithm and RADAR POSANT routing algorithm RT at each node contains OR. During the ongoing session RT at each node is searched for OR. So OR is selected during the ongoing session in basic POSANT routing algorithm which increases its time complexity than the HA POSANT routing algorithm and RADAR POSANT routing algorithm. The time complexity of the HA POSANT routing algorithm is higher due to the time complexity of the depth first search than the time complexity of the RADAR POSANT routing algorithm

3.0 ROUTING ALGORITHM FOR NEMO

The LFN inside the mobile network uses route optimization algorithm [14] for the selection of an OR to maintain global communication among trolleys in NEMO.

4.0 SIMULATION

The simulation experiment is performed in two different phases. The performance of the basic POSANT [11] routing algorithm, HA POSANT routing algorithm and RADAR POSANT routing algorithm are compared in Phase 1. The performance of MANEMO has been studied in Phase 2. The simulation experiment is conduced for 1280 number of packets and 6 numbers of trolleys in both the phases. The MANET in the proposed scheme is the combination of some interconnected processing units. The processing units are HA, S_id and intermediate nodes associated with OR in case of HA POSANT routing algorithm. The processing units are SFN, S_id, D_id and intermediate nodes associated with OR in case of RADAR POSANT routing algorithm. The NEMO in the proposed scheme is the combination of some interconnected processing units such as MNN, LFN and MR. Each processing unit in MANEMO is treated as thread and the MANEMO is considered as a producer-consumer problem in a large scale. In HA POSANT routing algorithm the send request thread at S_id sends RRM to HA. The receive request thread at HA searches for RRM. If found it selects OR and sends RFM. The receive route thread at S_id searches for RFM. If found the forward packet thread at S_id forwards packet to the ingress interface of its associated MR. The transfer packet thread at each node transfers the packet from the ingress interface to the egress interface of the associated MR. In RADAR POSANT routing algorithm the source request thread at S_id forwards ant packet towards D_id. D_id selects OR and sends D_to_SFN message using route send thread. The SFN send thread at SFN searches for D_to_SFN message. If found it sends SFN_to_S message. The receive route thread at S_id searches for SFN_to_S message. If found the forward packet thread at S_id forwards packet to the ingress interface of its associated MR. The transfer packet thread at each node transfers the packet from the ingress interface to the egress interface of the associated MR. The processing units and the corresponding threads in NEMO are discussed in [14].

4.1 EXPERIMENTAL RESULTS FOR PHASE 1

The simulation experiment is conducted to compare the performance of the three routing algorithms for MANET.

4.1.1 INITIAL PATH SET UP TIME

It is the time to set up an OR for the initiation of a session. Fig.3 shows the plot of initial path set up time for all the three routing algorithms. The basic POSANT routing algorithm needs the transmission of forward ant packets and backward ant packets for route selection. The HA POSANT routing algorithm needs the transmission of RRM and RFM among nodes for route selection instead of the transmission of forward ant packets and backward ant packets which reduces the initial path set up time of HA POSANT routing algorithm than basic POSANT routing algorithm. The RADAR POSANT routing algorithm needs the transmission of forward ant packets for initial route selection which increases the initial path set up time of RADAR POSANT routing algorithm than HA POSANT routing algorithm. But the transmission of backward ant packets is not required in RADAR POSANT routing algorithm which reduces the initial path set up time of RADAR POSANT routing algorithm than basic POSANT routing algorithm. It can be observed from Fig.3 that the initial path set up time of basic POSANT routing algorithm is higher and of HA POSANT routing algorithm is lesser. The initial path set up time of RADAR POSANT routing algorithm is higher than HA POSANT routing algorithm but lesser than basic POSANT routing algorithm.

4.1.2 AVERAGE PACKET DELAY

Fig.4 shows the plot of average packet delay vs. simulation time for all the three routing algorithms. It can be observed from Fig.4 that the average packet delay is higher in basic POSANT routing algorithm as it selects OR during the ongoing session than the other two routing algorithms.

Fig.5 shows the plot of average packet delay vs. the number of packets received for all the three routing algorithms. The speed of the node is assumed as 6 km/hr. If a node associated with OR of a particular session starts to move in the opposite direction of another node associated with the same route, their relative velocity becomes 12 km/hr. The communication range of WLAN is assumed as 100 m. So the failure occurs in the existing route when the two neighbouring nodes associated with the same route go out of the communication range with relative velocity 12 km/hr after 30 sec. It can be observed from Fig.3 that the initial path set up time for HA POSANT routing algorithm is 120 msec and for RADAR POSANT routing algorithm is 150 msec. The two neighbouring nodes having relative velocity 12 km/hr covers a distance of 0.4 m (≈ 1 m) in 120 msec for HA POSANT routing algorithm and .5 m (≈1 m) in 150 msec for RADAR POSANT routing algorithm. So the packet loss and average packet delay of an ongoing session can be minimized by triggering the route maintenance algorithm in advance when the two neighbouring nodes associated with the same OR are at a threshold distance of 99 m (100 m-1 m) from each other. During simulation it has been observed that the time requires to transmit a single packet using basic POSANT routing algorithm is 40 msec whereas the time requires for transmitting a single packet using HA POSANT routing algorithm and RADAR POSANT routing algorithm is 30 msec. So the number of packets that can be transmitted using basic POSANT routing algorithm in 30 sec is 700 whereas the number of packets that can be transmitted using HA POSANT routing algorithm and RADAR POSANT routing algorithm in 30 sec is 950 before the failure occurs in the existing route.

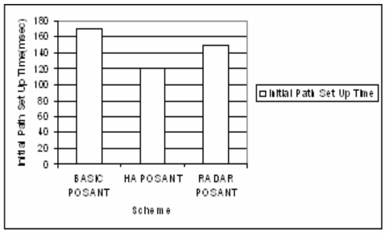

Figure 3: Initial path set up times

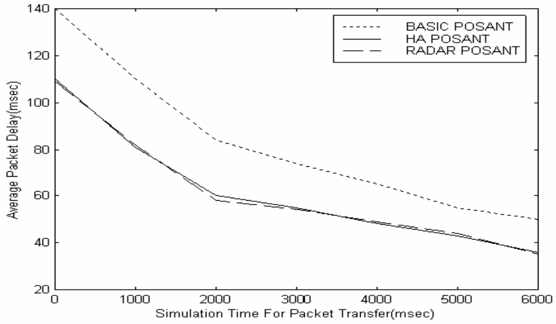

Figure 4: Average packet delay vs. Simulation time

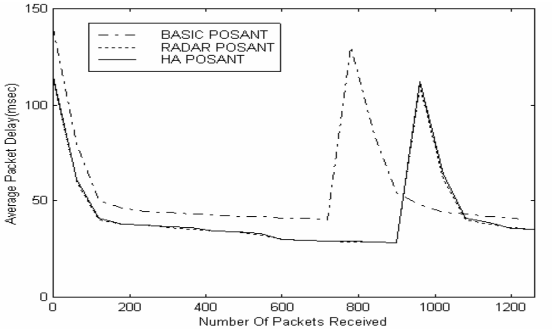

Figure 5: Average packet delay vs. Number of packets received

It can be observed from Fig.5 that the initial average packet delay is higher in basic POSANT routing algorithm due to its higher initial path set up time as discussed in section 4.1.1 than the other two routing algorithms. The new route is selected in basic POSANT routing algorithm after the transmission of 700 packets. The new route is selected in HA POSANT routing algorithm and RADAR POSANT routing algorithm after the transmission of 950 packets. The average packet delay in the new route for basic POSANT routing algorithm is also higher due to its higher initial path set up time than the other two routing algorithms.

4.1.3 PERCENTAGE OF SUCCESSFULLY DELIVERED PACKETS

TABLE-4 shows the percentage of successfully delivered packets for the 3 routing algorithms. The new route discovery process starts after the failure occurs in the existing route in basic POSANT routing algorithm. So the data packets that are generated during the time interval between the occurrence of route failure and finding out a new route are lost. The route maintenance algorithm selects an alternative OR in advance before the failure occurs in the existing route in HA POSANT routing algorithm and RADAR POSANT routing algorithm. So the percentage of successfully delivered packets is lesser in basic POSANT routing algorithm than the other two routing algorithms.

Scheme	Packet generated	Packet delivered	% of successfully deliver packets
13	1280	1203	94%
HA	1280	1280	100%
RADAR	1280	1280	100%

Table 4

4.2 EXPERIMENTAL RESULTS FOR PHASE

The simulation experiment is conducted to find the path set up time and average packet delay in MANEMO.

4.2.1 PATH SET UP TIME

Fig.6 shows the path set up time in MANEMO. When a S_id wants to initiate a session with D_id, MANEMO searches MANET for the selection of an OR. If found, OR is selected otherwise it searches NEMO for the selection of an OR. If the selected OR in MANET fails due to the change in network topology, MANEMO searches MANET again for the selection of an alternative OR. If found the alternative OR is used to maintain the rest of the communication. Otherwise NEMO is searched for the selection of the alternative OR. It can be observed from Fig.6 that the path set up time in NEMO is higher due to the Internet access overhead than the path set up time in MANET.

4.2.2 AVERAGE PACKET DELAY

Fig.7 shows the plot of average packet delay vs. the number of packets received in MANEMO. The maximum number of packets that can be transmitted using HA POSANT routing algorithm and RADAR POSANT routing algorithm for MANET is 950 as discussed in section 4.1.2. In the worst case no alternative route is found in MANET and the rest of the packets are transmitted using the alternative route in NEMO. It can be observed from Fig.6 that the initial path set up time in MANET is 150 msec and in NEMO is 191 msec. So the total time required to set up an alternate route is 341 msec. The two neighboring nodes having relative velocity 12 km/hr as discussed in section 4.1.2 covers a distance of 1 m in 341 msec. So the packet loss and average packet delay of an ongoing session can be minimized by triggering the route maintenance algorithm in advance when the two neighboring node associated with the same OR are at a threshold distance of 99 m from each other. But at heavy load the initial path set up time in both MANET and NEMO increases which needs a reduction in threshold distance to minimize packet loss and average delay in communication. So the threshold distance is assumed as 95 m during simulation. It can be observed from Fig.7 that the initial average packet delay is higher in NEMO due to its higher initial path set up time as discussed in section 4.2.1 than in MANET. The new route is selected in NEMO after the transmission of 950 numbers of packets using MANET which can also be observed from Fig.7.

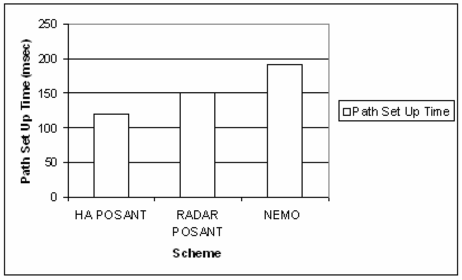

Figure 6: Path set up times for MANET (using HA MANET and RADAR MANET) and NEMO.

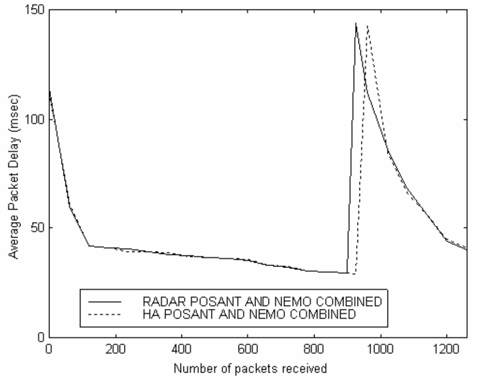

Figure 7: Average packet delay vs. Number of packets received in MANEMO

It can be observed from Fig.5 that the initial average packet delay is higher in basic POSANT routing algorithm due to its higher initial path set up time as discussed in section 4.1.1 than the other two routing algorithms. The new route is selected in basic POSANT routing algorithm after the transmission of 700 packets. The new route is selected in HA POSANT routing algorithm and RADAR POSANT routing algorithm after the transmission of 950 packets. The average packet delay in the new route for basic POSANT routing algorithm is also higher due to its higher initial path set up time than the other two routing algorithms.

8.0 CONCLUSION

The proposed work integrates MANET and NEMO technology to maintain the uninterrupted connectivity among fishing trolleys in deep sea. Two different routing algorithms are proposed for MANET and their performances are compared with the basic POSANT routing algorithm. Several such integrated schemes have already been proposed so far but most of the researchers define the architecture and the purpose of integration. They did not present any simulation results. But the proposed integrated scheme has been simulated to observe the initial path set up time and average packet delay. The performances of the proposed routing algorithms are evaluated considering only the data class of traffic. It can be extended by considering other traffic classes during simulation.

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