# Network Accessibility and Data Transport Performance of Interworking Mobile Ad Hoc Networks

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***Abstract***—Advances in mobile and wireless networking technologies have enabled mobile ad hoc networks applicable to a wide range of areas. Many cases of even such ad hoc networks demand to be accessible to the global network. Owing to be diversified in features depending on applications, however, some those networks may consist of devices or nodes which do not facilitate all the same transport protocols. This results in unreachable situations of establishing ad hoc network: such as non-existence of all required access points, faults or contention in a path of particular protocol communication. Interworking between different transport protocols can alleviate such problems. This paper proposes an interworking scheme to improve data transport performance and network accessibility, especially in such a mobile ad hoc network that is applicable to data communications among ships or user's convenient u-health services. Modeling and simulation analysis are used to verify the improvement.

***Index Terms***—Mobile Ad Hoc Network, Interwork Node, Transport Performance, Network Accessibility

## I. INTRODUCTION

Growing demands of network reachability as well as advances in technologies of mobile and wireless networking have enabled mobile and/or ad hoc networks applicable to a wide range of areas. Mobile ad hoc networks are thus diversified, with sharing some common characteristics, in features depending on applications, a type of nodes or network configurations, etc[1].

Data communications among ships sailing on the sea can become one domain to feature such a mobile ad hoc network. Owing to changing constantly in position, ships sailing on the sea pursue communication paths to keep seamless connections. Applying this case into a mobile ad hoc network which can be routed over the other node can improve data transport network performance and reachability to the global network.

A service of u-health in some cases can also become a mobile ad hoc network. A user device in the u-health service domain is connected in transferring data to the dedicated access point. The connection normally is not only of wireless but also configured of 1-to-N manner[2]. This, however, may restrict user's movement within a communication limit. Some cases, for the user's convenience, provide mobility with user devices and compose an ad hoc network to reach to the access point.

Such a mobile ad hoc network that is applicable to data communications among ships or user's convenient u-health services may consist of devices or nodes which do not facilitate all the same transport protocols to constitute the network. As such, this may be in such unreachable situations as non-existence or non-efficiency of all required access points, faults or contention in a path of particular protocol communication, etc. Interworking between different transport protocols can alleviate such problems[3][4][5]. Interposing an interwork element in the network can raise availability of transport paths, and then improve transport performance of the overall network.

This paper proposes an interworking scheme to improve data transport performance and network accessibility, especially in such a mobile ad hoc network that is applicable to data communications among ships or user's convenient u-health services. Modeling and simulation analysis are used to verify the improvement.

This paper organizes as follows. Section 2 explains mobile ad hoc network as service network especially for marine and u-health services. Section 3 describes transporting inefficiency of MANET due to deficiency of AP's and data contention, and proposes an interwork node to improve such a situation. Justification through simulation analysis is presented in Section 4, and this paper is concluded in Section 5.

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## II. MANET AS SERVICE NETWORK

### *A. Marine Featuring a MANET*

Figure 1 shows that communications among ships sailing on the sea become one typical domain to feature a mobile ad hoc network.

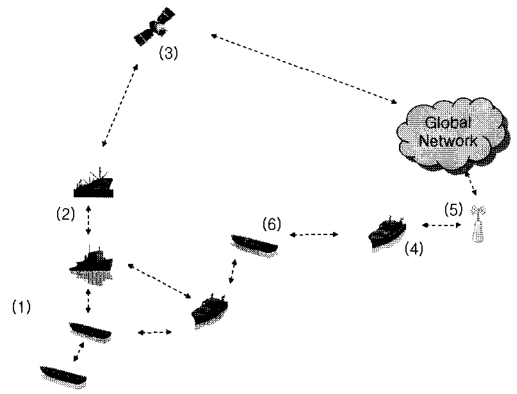


Fig. 1 Marine Featuring a MANET

Ships existing in a domain (1) can communicate with each other by establishing a mobile ad hoc network, which can adopt (2) as a gateway and are finally reachable to the global network through the satellite(3). Owing to positioning near to AP(5), the case of (4) is directly accessible to the global network. Depending on the communication distance, (6) moving around can join into (1) or (4). In case of joining into (1) it could be reachable to the global network through the gateway(2) and the satellite (3), while through AP(5) in case of joining into (4).

In order to communicate with each other or reach to the global network by establishing an ad hoc network or mobile ad hoc network, every node included in the network is homogeneously transported. In other words, all nodes transport data with the same mechanism or protocol. In Figure 1, (2), as a gateway of the network(1), has to not only be facilitated for communicating with the satellite(5) but also transport data with the same mechanism as (1)'s. Thus (2) has to possess interworking functionality between two different transport mechanisms. The case of (6), in order to join into (4) and access the global network via AP(5), also transports data with the same protocol as (4)'s. If (5) and (6) work with different transport protocols, the node (4) should adopt both protocols of (5)'s and (6)'s and interwork between them.

### *B. u-Health Service Network Featuring a MANET*

In a service of u-health, user devices are connected in transferring data to the dedicated access point. These connections are not only with relatively short distances but also normally wireless and configured of 1-to-N manner. Data collected into AP is transported through the global network to a server of the health care center.

Figure 2 shows data transport network for establishing u-health services. In Figure 2, the user device area of (1) transfers data to AP A with A transport method, and the user device area of (2) to AP B with B transport method.

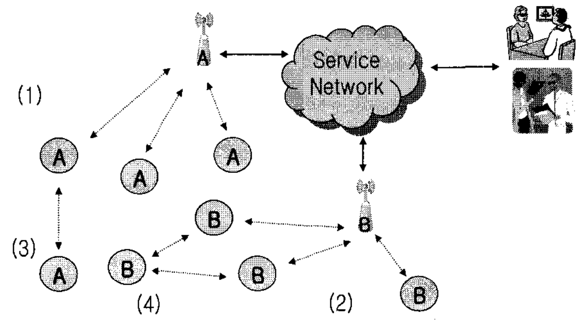


Fig. 2 Data Transport Network Establishing u-Health Services

If user devices in this network have communication paths to AP in existing 1-to-N manner, users' movement should be confined to the propagating limitation of AP. If the mobility is given for the user's convenience, some users, like (3) and (4) in Figure 2, are away from AP propagating range and out of accessibility.

Constituting ad hoc network which can route over the adjacent node, such a node can be reachable to AP or the global network in a node-by-node manner. If Figure 2 is configured of ad hoc network, the nodes (3) and (4) are reachable to AP's A and B via (1) and (2) respectively. Service network in this case is accessible even to two such nodes. Therefore, mobile ad hoc network can alleviate user's moving restriction as well as cost of constructing AP's. Thus MANET becomes a sound network solution even to the case of u-health services.

## III. TRANSPORTING INEFFICIENCY AND IMPROVEMENT

As described above, both ships sailing in the sea and user devices in u-health services can be considered as MANET in the view of data communication network. Such MANET usually consists of nodes which operate in a homogeneous transport protocol. In order to access the global network, AP also supports the same transport protocol and mechanism. Since nodes, however, included in the network has mobility, one MANET could occasionally be overlapped or merged with another one which use different transport protocols. If there exist two MANET's overlapped and each uses different transport protocol, each has own AP connected with supporting transport protocol.

However, all kinds of AP's are not available. The more kinds of transport protocols are used, the more kinds of AP's should be constructed. It results in more cost required. In addition, gathering nodes which support one transport protocol may cause traffic contention to the specific AP. Unavailability or faults of AP in any reason leads to performance degradation or even impossibility of communications.

Interposing an interwork node in the network, which can interwork between different transport protocols, can alleviate such problems as non-existence or insufficiency of facilities, faults, and traffic contention, which are occurred in accessing the global network.

In Figure 3, in case that one AP is not available in any reason, an I-node can bridge nodes, which are inaccessible due to AP unavailability, to access the other side AP. Thus I-node can raise availability of transport paths, and then improve transport performance of the overall network, accessibility and reachability to the global network.

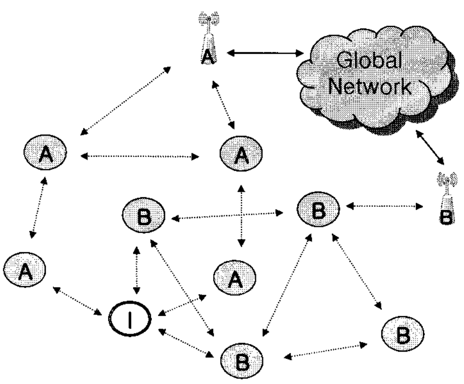


Fig. 3 MANET's Including an Interwork Node

## IV. SIMULATION ANALYSIS

### *A. Simulation Modeling*

Dynamics of network transport performance can effectively be abstracted with event based system states rather than execution details of the protocol. In this paper we consider the network as a discrete event system to analyze dynamics of network transport performance. Therefore, we use DEVSim++ simulation environment which not only provide a rigorous modeling methodology based on the Zeigler's DEVS(Discrete Event System Specification) formalism but also ease-of-use facility based on object-orientation[6][7].

The target network is abstracted for the given performance index. The abstraction excludes mobility of nodes. Because mobility of nodes mostly affects on the network topology, and this paper mainly concentrates on comparing dynamics of network transport performance. Since such comparison does not directly affected by the network topology, it is well enough that one topology becomes the focus of simulation analysis.

### *B. Three Target Models of Simulation*

Table 1 shows applied simulation conditions and parameters. Simulation analysis has done with respect to three target models.

Table 1 Units for Magnetic Properties

| Parameter | Value |
|---|---|
| Simulation Tool | DEVSim++ v3.0 |
| Real-time Simulation | True |
| Multi-Thread | True |
| HLA | False |
| Total Operation Time | 10 sec |
| Time Tick | 0.01 sec |
| Packet Generation Tick | 1 packet/0.05 sec |
| Limited AP Resource | 20 packets (accumulated) |
| AP Resource (common) | 2 packets/0.5 sec |
| AP Resource (congestion) | 2 packets/0.2 sec |

Figure 4 shows the first target model which consists of two different MANET's using different transport protocols, A and B, each of which includes its own access point, A-AP and B-AP, respectively.

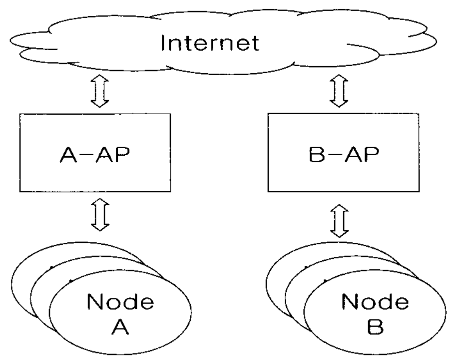


Fig. 4 Target Model 1

Figure 5 shows the second target model which is the case that includes a node interworking between A and B transport protocols in the first target model. Even a node which is not reachable to its own AP in any reason can reach to the global network through the interwork node and the other side AP in this model.

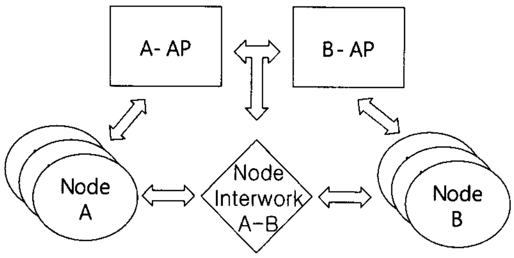


Fig. 5 Target Model 2

Finally, the third target model, as shown in Figure 6, consists of three different MANET's transporting with A, B and C protocols. This model contains two access points, A-AP and B-AP, and two interwork nodes, Node Interwork A-B, and Node Interwork B-C. By means of such AP's and interwork nodes, the global network is accessible to any node included in the MANET transporting with C protocol.

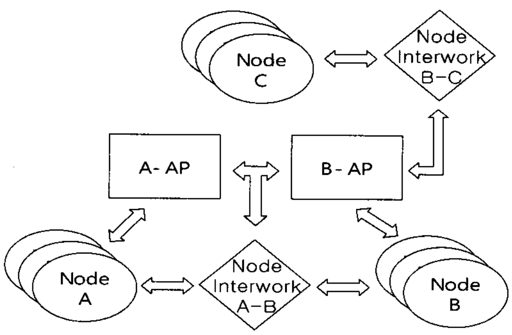


Fig. 6 Target Model 3

### *C. Simulation Results*

Figure 7 shows arrival rates, as simulation results of three target models, on each AP with respect to the generated traffic.

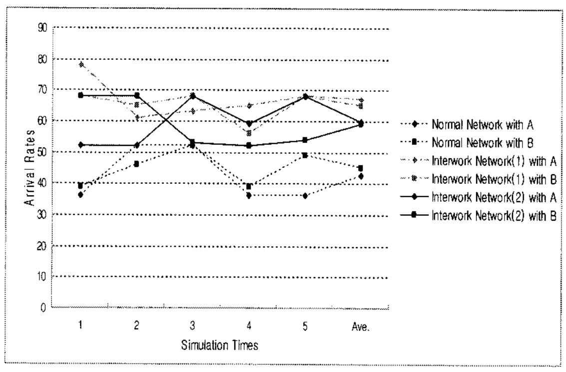


Fig. 7 Arrival Rates on AP's

Arrival rates of the target model 2 are 67.0 and 65.0 on A-AP and B-AP respectively, while ones of the target model 1 are 42.4 and 45.0. This verifies better arrival rates of about 58.0~44.4% in the target model 2, which includes an interwork node, than in the target model 1 which has no interwork facility. In addition, the target model 3, which consists of three different MANET's with two AP's and two interwork nodes, shows arrival rates of 59.8 and 59.0 on A-AP and B-AP respectively.

Figure 8 shows traffic accumulation dynamics in time on the access points, A-AP and B-AP, for the target model 1.

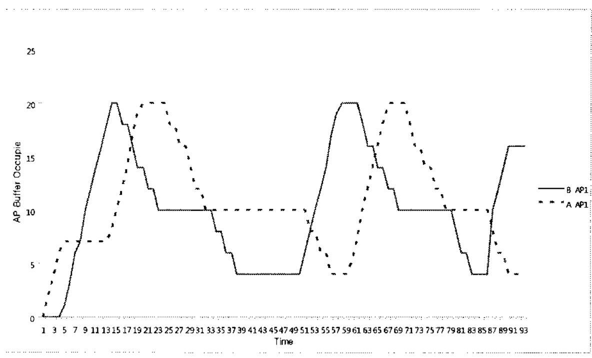


Fig. 8 Traffic Accumulation Dynamics for the Target Model 1

Figure 9 shows that traffic accumulation dynamics in time on the access points, A-AP and B-AP, for the target model 2. Traffic is alternatively accumulated on the access point A-AP and B-AP. Growing traffic accumulation on A-AP leads to congestion, and then B-AP traffic accumulation is growing and A-AP traffic accumulation is decreasing. Congestion of B-AP gives rise to increasing on A-AP again. This pattern of alternative accumulation is repeated in time.

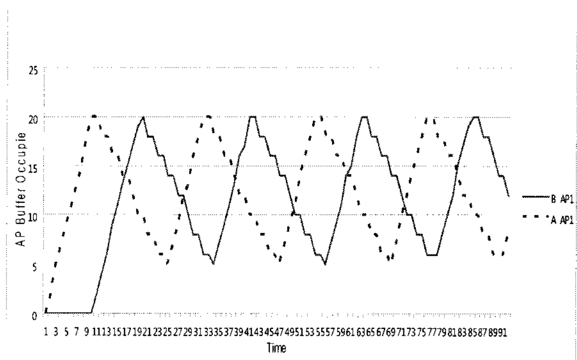


Fig. 9 Traffic Accumulation Dynamics for the Target Model 2

Figure 10 shows that traffic accumulation dynamics in time on the access points, A-AP and B-AP, for the target model 3. The pattern of alternative accumulation is similar to the one of target model 2 except time shift on the turnover point.

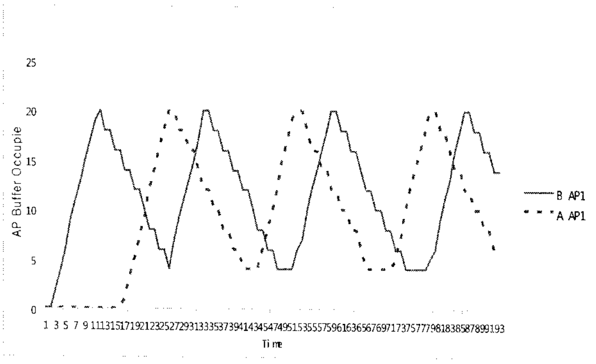


Fig. 10 Traffic Accumulation Dynamics for the Target Model 3

Simulation results justify that interposing an interwork node in the MANET's transporting with different protocols can improve not only transport performance of the overall network but also accessibility and reachability to the global network.

## IV. CONCLUSIONS

This paper proposes an interworking scheme to improve data transport performance and network accessibility, especially in such a mobile ad hoc network that is applicable to data communications among ships or user's convenient u-health services. Modeling and simulation analysis are used to verify the improvement. In order to achieve rigorous results and focus mainly on dynamics of transport operations rather than protocol execution details, we employ the DEVS (Discrete Event Systems Specification) methodology and the DEVSim++ simulation environment to experiment. The DEVS methodology is based on the Zeigler's DEVS formalism which can formally specify a discrete event system, and the DEVSim++ simulation environment is a C++ implementation of the Zeigler's DEVS methodology.

Simulation analysis has done with respect to three target models: the first target model which consists of two different MANET's using different transport protocols, A and B, each of which includes its own access point, A-AP and B-AP respectively, the second target model which includes a node interworking between A and B transport protocols in the first target model, and the third target model which consists of three different MANET's transporting with A, B and C protocols and contains two access points, A-AP and B-AP, and two interwork nodes, Node Interwork A-B, and Node Interwork B-C.

Simulation results compare arrival rates on each AP with respect to the generated traffic. Arrival rates of the target model 2 are 67.0 and 65.0 on A-AP and B-AP respectively, while ones of the target model 1 are 42.4 and 45.0. This verifies better arrival rates of about 58.0~44.4% in the target model 2, which includes an interwork node, than in the target model 1 which has no interwork facility. In addition, the target model 3, which consists of three different MANET's with two AP's and two interwork nodes, shows arrival rates of 59.8 and 59.0 on A-AP and B-AP respectively.

Simulation results justify that interposing an interwork node in the MANET's transporting with different protocols can improve not only transport performance of the overall network but also accessibility and reachability to the global network.

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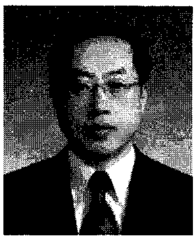

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