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수중 음파 통신 네트워크를 위한 Step-wised Out-test 메커니즘

(Step-wised Out-test Mechanism for Underwater Acoustic Networks)

무흐리딘 이브라기모브*, 윤 남 열*, 신 수 영*, 남궁 정 일*, 김 창 화**, 박 수 현*

(Mukhridinkhon Ibragimov, Nam-Yeol Yun, Soo-Young Shin, Jung-Il Namgung, Changhwa Kim, and Soo-Hyun Park©)

요 약

수중 음파 센서 네트워크의 다각적인 발전에도 불구하고 네트워크상에서의 연결이 손실되는 경우가 여전히 존재한다. 특히 해양 환경에서 네트워크상의 연결 중에 발생할 수 있는 연결 단절을 유발하는 많은 다양한 문제점으로 인해 이를 보완하기 위해서 수중 음파 통신 네트워크를 위한 새로운 테스트 메커니즘이 필요하다. 본 논문에서는 통신 프로세스의 문제점 및 에러가 발생하는 위치를 식별하기 위해서 장애 없이 네트워크 배포시 가장 중요한 부분들에 대해 조사할 수 있는 방법을 제안한다. 수중 음파 통신 네트워크(UWASN)를 위한 Step-wised Out-test 메커니즘을 도입하고 실험을 통하여 out-test 기능을 이용한 수중 단말의 작동을 엄격하게 점검하였다. 구현 및 실험 결과를 통해서 Out-test 기능의 유용성 및 우수성을 입증하였고 향후 가능한 개선을 제시하였다.

Abstract

Despite a series of various developments in underwater acoustic sensor networks, there are still occasions of loss of connection over the network. Because sufficient amounts of drawbacks causing disconnections posed particularly in the middle of connection over the network emerge in the ocean environment, there is a need of new testing mechanism for underwater acoustic networks. In this paper, we proposed to investigate the most vital parts of the network deployment whether they function well in order, without any failure so as to identify where exactly communication process problems and failures are. We introduce step-wised out-test mechanism for UWASNS and accomplished the mechanism by implementing experiments and rigorously checked all the underwater devices utilizing out-test function. Experimental results and out-test function are evinced by implementing, in order to explain our system and conclude with possible future improvements.

Keywords : Out-test mechanism, Medium Access Control (MAC), UANs(Underwater Acoustic Networks), Test-bed, Cluster based network

* 정회원, 국민대학교 대학원 금융정보보안학과
(Graduate School of FIS, Kookmin University)
** 정회원, 국립강릉원주대학교 컴퓨터공학과
(Department of Computer Science&Engineering, Gangneung-Wonju National University)
© Corresponding Author (E-mail: shpark21@kookmin.ac.kr)
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Ⅰ. INTRODUCTION

It is common knowledge that round 70% of the surface of our planet Earth is covered by oceans and of course that has captured the attention of the researchers who have been executing researches who have been conducting their research to explore on the related domains with great interest. These views have been envisioned in the field of monitoring aquatic environments for a wide specter of applications such as data collection for scientific exploration, disaster prevention, surveillance applications and so on. The technology enabling these applications is underwater sensors and Autonomous vehicles (AUVs) with acoustic communication. The environment of underwater Acoustic Networks (UANs) is quite different from terrestrial wireless sensor networks in terms of the physical media for communication (acoustic communication) and operating environment. UANs consist of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area[1].

1. Issues of UANs.

UANs pose many challenges in terms of the bandwidth, node mobility, error rate, propagation delay, memory, battery power and so on. There are sufficient amounts of drawbacks and vulnerabilities causing disconnections posed particularly in the middle of connection over the network, which emerge in the ocean environment. Furthermore, the features of many sensor networks and nodes must be taken into consideration in this type of environment, namely, the need of large number of nodes, their limited energy capacity, short-distance radio communications, large propagation latency, low bandwidth capacity and high error rate. All these constraints make underwater sensor networks a special case unlike the regular ones[2~3].

2. Solution.

Hence, there is a need of new testing mechanism for the nodes over underwater acoustic networks. In reality, there are already a multitude of research works on testing communication nodes, which are not suitable to examine the nodes in a specific purpose. However, our research is much more different from other research works, as it is based on and designed for testing the nodes specifically. In this work, we investigate OUT-TEST mechanism for underwater acoustic sensor networks. The basic idea is to test and learn unknown and possibly random disabilities of both mobile and fixed nodes. Although it is largely understood and explored by the research community of related fields, regarding testing and investigating the disabilities and drawbacks of a network to improve network scalability, no previous work has been done in such emerging unique testing mechanism. Our out-test mechanism is the first step in underwater research world to investigate the problems of a node.

3. Main motivation.

Additionally taking into consideration the fact that there exist such threats and issues posed and taken place by these undersea and terrestrial drawbacks, such as low Link Quality Indicator (LQI), harsh environment, battery operations[3]. We indeed need out-test mechanism that is designed for testing the ability and disability of the nodes and defined as investigation of underwater communication devices. Those that are utilized in deploying underwater acoustic communications are namely, gateway, relay node, sensor nodes and AUVs. With respect to this out-test architecture, it is a vital question for us to unearth and detect if the devices of sensor and AUVs and the ones utilized in deploying networking work and act well, morever, there is a need to monitor where problems appear to be exact once the devices or nodes are out of order and work or fail to send and receive data[1].

It would be in accordance with the original aim to point out cluster based architecture it is because we investigate out-test mechanism based on the network relating to cluster nodes. In most UAN, network lifetime depends on battery lifetime. Clustering has long been considered as an effective approach to reduce network overhead and improve scalability, therefore by reducing energy consumption, network lifetime can be prolonged. In many cluster based UAN, cluster head nodes consumes more energy than ordinary sensor nodes. Therefore estimating energy consumption for each cluster head can help to estimate the network lifetime[4].

In this section, we present network architecture and system model. To accomplish energy consumption estimation, we consider clustered network architecture, in which we have three different types of nodes, cluster head, base station and sensor nodes, as shown in Figure 1. In this network architecture, the whole network is divided into several clusters and in each of those clusters, ordinary sensor nodes will mainly be used for the sensing task[5]. The ordinary sensor nodes are assumed to have less battery energy than cluster head nodes. The ordinary sensor nodes are cheap sensor nodes which cannot directly communicate with the base station, as typically, they can only connect to its one hop cluster head. Cluster heads are powerful nodes that can gather data from ordinary sensor nodes and forward it to the base station[6].

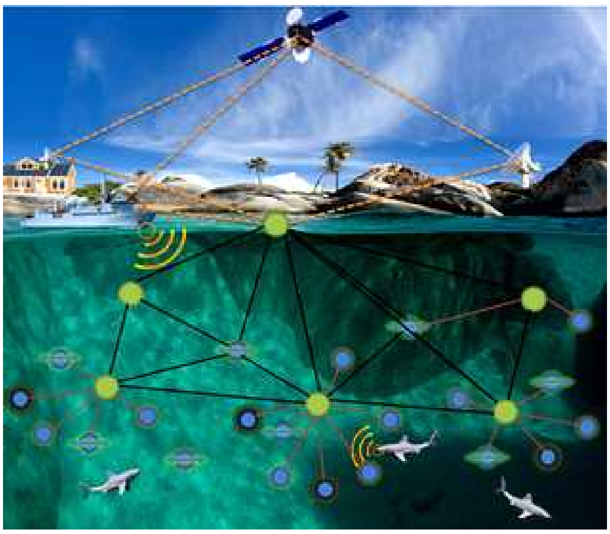

그림 1. 수중 음파통신망의 구조
Fig. 1. Architecture of Underwater Acoustic Network.

II. SYSTEM ARCHITECTURE FOR APPLYING OUT-TEST FOR CLUSTER BASED UANs

The distributing ping command here is a Command Prompt command used to test the ability of the nodes to reach a specified destination node. The ping command is usually used as a simple way of verifying that a base station can communicate over the network with other nodes or network device. The ping command is operated by sending Internet Control Message Protocol (ICMP) Echo Request messages to the destination node and waiting for a response. How many of those responses are returned, and how long it takes for them to return, are the two major pieces of information that the ping command provides[7].

Our out-test mechanism idea is inspired by the ping command concept that is showed above. In the architecture Figure 2 drawn above we accomplished the out-test mechanism by implementing experiments. This is a general architecture concerning out-test mechanism. Mobile and fixed nodes are given in the architecture. As it is shown in Figure 2, we send commands to the nodes from the base station to the node numbered with 3 in sequence using the way of ping message forwarding.

We commence forwarding ping messages with the gateway in the first place and it performs looping and gives back response to the base station if it is functioning in order. Then we keep on sending ping messages to the next nodes that are relay node, mobile nodes and fixed nodes in sequence. In the second place, ping messages are forwarded to the relay node whether that too is acting well. It also does looping and replies to the base station if it goes on in order.

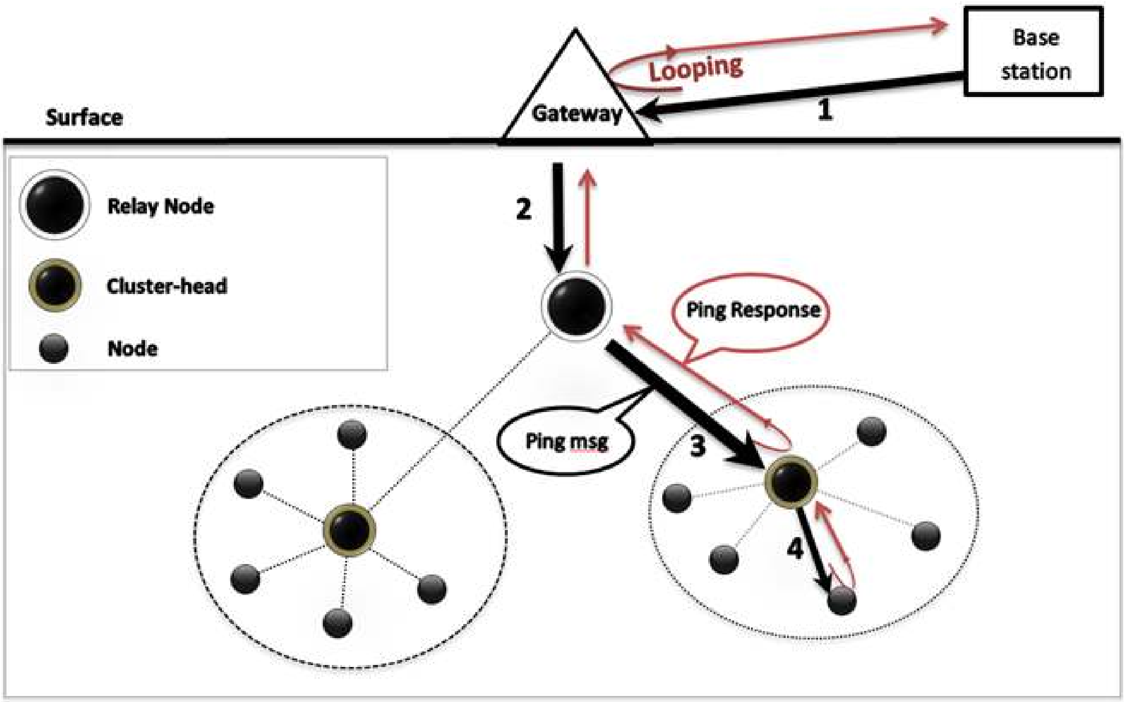

그림 2. 수중 Out-test 통신 시스템의 구조
Fig. 2. Architecture of Underwater Out-test communication system.

The reason and purpose why this architecture is deployed and explored explicitly as well as approached closely is that we intend to act out the idea devised and deemed to be one of the essential issues that might be encountered and resolved as though it appears to be a tiny matter in terms of being looked through hitherto, that is, it is to get to know and discover whether all the devices appertaining to the fields that have been being carried out the researches upon work appropriately and in sequence. With regard to being cited a good instance sufficiently, it is a vital question for us to unearth and determine if the devices in the AUVs and the ones utilized in deploying network, work and act well.In addition to this, there is a need to monitor where problems appear to be exact once the devices are out of order and work or fail to send and receive data.

In the first place if command from BS (Base station) is forwarded to the devices and they provide us with positive results, it means that they are working well as expected. On the contrary, if the devices do not respond or send data to the destination in the expected time, there would be a concern coming into existence that some particular factors are not proper and failing to fulfill the tasks.

With respect to our architecture, by and large command is sent to the devices in a proper sequence, in order to investigate and find if they are working adequately well and the parts, applications and other layers of the devices meet failure to process. Tp point out, we firstly send commands to Gateway, so that it checks the gateway by sending a ping message, also identifying if the node is functioning in order. The gateway receives a response and has to return a response to the sender in order to inform it is working. Unless the sender receives any responses from the following node it implies the node is not in function. We can verify other node devices in this order and way. There are some examples cited with a figure here to make a better understanding in detail.

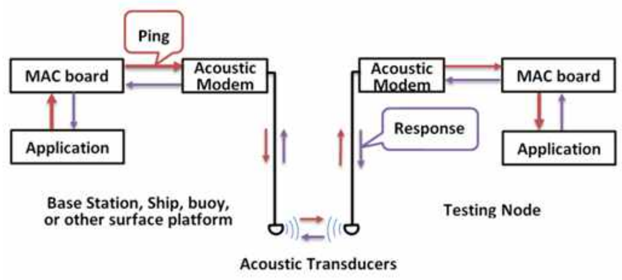

그림 3. Ping 메시지의 흐름
Fig. 3. Ping message flows.

표 1. Ping 메시지 타입의 정의
Table 1. Ping Message Type Definition.

Flag 1byte	Header (2bytes)		Control Type (1byte)	Flag 1byte
0xF0	Sender ID	Receiver ID	0x50: ping 0x60:response	0xF0

Figure 3 presents our simple out test mechanism using one hop communication. In the figure, a ping message is sent by the sender in the surface to check the underwater node that possesses a modem as a physical layer, MAC (Media access control) board acted as MAC layer and main board as an application layer. Firstly, the physical layer receives a ping message as a command from the sender so as to examine if the physical layer is functioning. If the layer functions well in order, the sender gets response from it. Otherwise, it means that part of the node is not functioning unless the sender is provided with a back response. In the second turn, a ping message is sent to the MAC board to get information of its functioning status. The application layer is also examined by the same process. In this way we can get to know which part of the node does not function well in order and has drawbacks and faults.

This pseudo code describes how ping message flows.

```
CASE    MSG
1: IF    Gateway is working well THEN
    Send response msg to BS 3 times;
    check Gateway;
    END IF
    break;
2: IF    Relay node is working well THEN
    Send response msg to BS 3 times;
    check Relay node;
    END IF
    break;
3: IF    CH is working well THEN
    Send response msg to BS 3 times;
    check CH;
    END IF
    break;
4: IF    Node is working well THEN
    Send response msg to BS 3 times;
    check the Node;
    END IF
    break;
```

III. EXPERIMENTAL RESULTS

In this section, we show our test bed environment for implementing out-test mechanism and experimental results.

The test bed is illustrated in Figure 4. It is designed to conduct the research works related to the underwater communication. Hardware resources are carefully selected to offer a real underwater environment, as well as the freedom to customize environmental parameters with affordable budgets. The water tank whose dimensions are 250 cm, 80 cm and 70 cm in length, width and height respectively is used to represent the underwater environment. Underwater transducers and modems are utilized to provide acoustic communication channels in the water tank.

As for Out-test mechanism implementation, there are three nodes (Node A, Node B and Node C in Figure 4) communicating with each other, one is a sender and the others are receivers (Node A's ID is 91, Node B's ID is 92). Each node has a transducer, a modem and a MAC board. We develop this mechanism for the MAC board as MAC layer and the mechanism was developed by using C programming language. Node A sends ping message to Node B to check its communication. This ping message is defined as 919250. Control type is 50

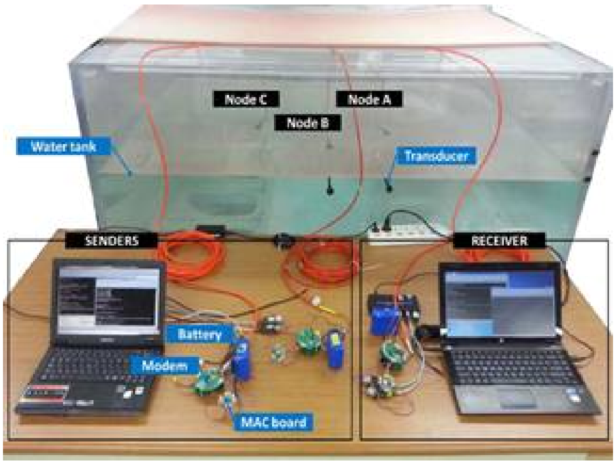

그림 4. 테스트베드 설정
Fig. 4. Test-bed setup.

which is fixed for easily recognizing the ping message and compared to the full type of the message there is data due to the absence of transmitting.

Node B receives the message and checks it whether it is ping or not by using control type part of the message and compares the destination ID in the message with its own ID. If those match each other, Node B makes sure that the ping is real. Then it should send back a response message 929160 to the source (Base station (BS) in our architecture) three times.

As for the response message, it is fixed as 60 for control type. Source and destination change in the response message due to changing direction to Node A from Node B.

Even though Node C can receives the ping message, but it does not send the response back to the Node A due to differences of the destination address in the ping.

This simple mechanism was tested in our system and this can be ported for any node, including relay node, cluster header, mobile nodes and fixed nodes as illustrated in Figure 5 and Figure 6. We can check any node we want if it is working or not by using out-test mechanism. As a first step, we designed and implemented an adaptive MAC protocol for UANs[8].

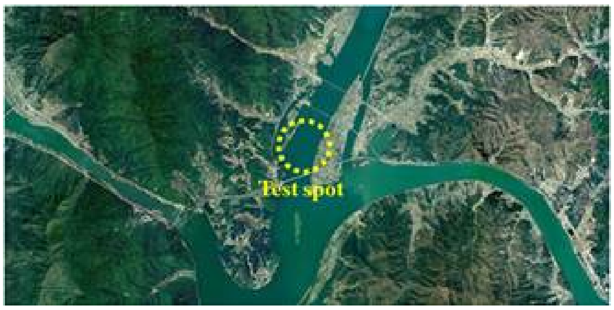

그림 5 테스트 환경
Fig. 5. Test environment.

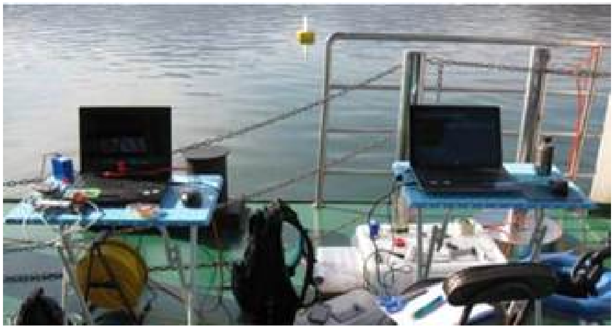

그림 6 한강에서의 Out-test 수행
Fig. 6. Out-test implementation in Han River, South Korea.

Now we implemented Out-test mechanism for the existing MACA protocol and show the performace of the protocol with out-test mechanism.

In our test-bed, the probability of failure in the transmission is very low, but in real experiment it can be quite high. We implemented out-test mechanism for our protocol. We measured energy consumptions of the protocol with and without out-test mechanism. With the use of out-test, we check the path before transmission starts and we can have a reliable communication. The results also show that the transmission whose path is checked consumes energy less than the simple MACA protocol (Figure 7). In the figure, the red curve shows the energy consumption of existing MACA protocol and the blue curve demonstrates the modified MACA protocol with out-test mechanism. We use the words “MACA” and “Out-test” in the figure for short.

Transmission time is also very important metric

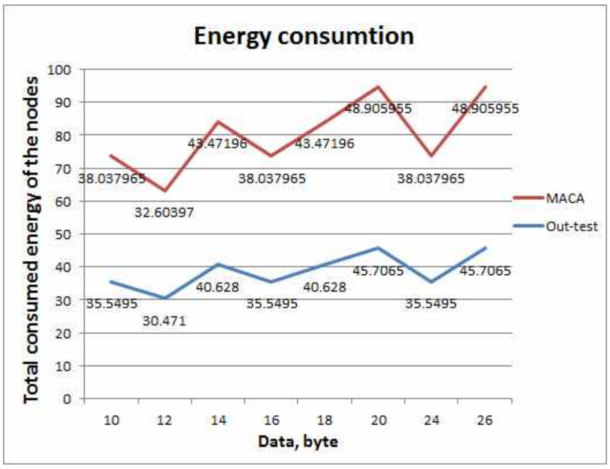

그림 7 에너지 소모 비교
Fig. 7. Comparison of energy consumptions.

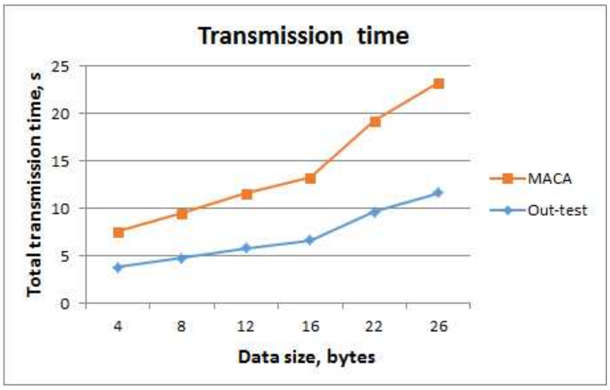

그림 8 전송시간 비교
Fig. 8. Comparison of transmission time.

for all the communications. Figure 8 plots the results and demonstrates the performance of the protocols with and without out-test mechanism, showing the changes within the increase of the data size. The curve of the protocol that includes Out-test mechanism shows the results less than MACA protocol without out-test by the propagation delay. This indicates "out-test" is more suitable for UANs with dynamic data size in harsh environment.

Ⅳ. CONCLUSION

In this paper, we propose out-test mechanism for underwater networks, which has an importance for the current underwater researches that suffer from non-rechargeable battery supply, low bandwidth, low propagation delay and extreme environment. We tested this approach in our system and applied for our project which includes more nodes and gateways in Han River, Seoul, South Korea[8]. We demonstrated the results that are obtained in the test bed.

The protocols with step-wised out-test mechanism have many advantages: a) we can identify which node has problem to receive or transmit data; b) mobile nodes can move anywhere; c) we can economize the energy of nodes energy; d) the transmission time can be reduced; e) the mechanism can be applied for any protocols; f) it is can check not only the workability of the node, but also whether layers of a node do not have any problems in transmission.

We would like to pursue our work with adding security mechanism and using out-test mechanism we are going to identify malicious nodes. Furthermore, we want to apply this mechanism for other protocols that are different from MACA protocol.

REFERENCES

[1] Akyildiz, Ian F., Dario Pompili, and Tommaso Melodia. "Underwater acoustic sensor networks: research challenges." *Ad hoc networks* 3.3 (2005): 257-279.

[2] Mpitziopoulos, Aristides, et al. "A survey on jamming attacks and countermeasures in WSNs." *Communications Surveys & Tutorials,* IEEE 11.4 (2009): 42-56.

[3] Manjula, R. B., and S. M. Sunilkumar. "Issues in underwater acoustic sensor networks." *International Journal of Computer and Electrical Engineering* 3.1 (2011): 101-110.

[4] Keshtgary, Manijeh, et al. "Energy Consumption Estimation in Cluster based Underwater Wireless Sensor Networks Using M/M/1 Queuing Model." *International Journal of Computer Applications* 43 (2012).

[5] Domingo, Mari Carmen, and Rui Prior. "A distributed clustering scheme for underwater

wireless sensor networks." *Personal, Indoor and Mobile Radio Communications, 2007. PIMRC 2007. IEEE 18th International Symposium on.* IEEE, 2007.

[6] Freitag, Lee, et al. "Acoustic communications for regional undersea observatories." *Proceedings of Oceanology International, London, UK* (2002).

[7] Donnet, Benoit, and Timur Friedman. "Internet topology discovery: a survey." *Communications Surveys & Tutorials*, IEEE 9.4 (2007): 56-69.

[8] Jeon, Jun-Ho, et al. "A moving underwater communication system with bio-inspired fish robots." *Proceedings of the Seventh ACM International Conference on Underwater Networks and Systems*. ACM, 2012.

저 자 소 개

무흐리딘 이브라기모브(정회원)
2013년 우즈베키스탄 타슈켄트 정보기술대학교 IT학부 졸업
2013년～현재 국민대학교 대학원 금융정보보안학과 석사과정
<주관심분야 : Underwater Delay/Disruption Tolerant Networks (UWDTNs), 보안 알고리즘 및 메커니즘, Internet of Underwater Things (IoUT), M2M and smart devices, 임베디드 시스템 소프트웨어.

신 수 영(정회원)
1998년 방송통신대학교 교육학사
2002년 덕성여자대학교 정보통신 이학석사
2007년 국민대학교 비즈니스IT 전문대학원 이학박사
현재 강릉원주대학교 전임연구원
<주관심분야 : 무선·수중 MAC 프로토콜, USN, 유비쿼터스 시스템>

김 창 화(정회원)
1985년 고려대학교 수학교육과 이학사
1987년 고려대학교 전산학과 석사
1990년 고려대학교 전산학과 박사
1994년～1995년 캐나다 토론토 대학교, Enterprise Integration Lab. Post-Doc. & Visiting Professor 교수
2002년～2004년 미국 텍사스 A&M 대학 Visiting Scholar
1989년～현재 강릉원주대학교 컴퓨터공학과 교수
2009년～현재 강릉원주대학교 정보전산원장
2005년～현재 강릉원주대학교 ITRC(해양센서네트워크시스템기술연구센터) 센터장
<주관심분야 : 무선 통신, 수중 음향통신, 통신 시스템 설계 및 구현, 무선 센서네트워크시스템>

윤 남 열(정회원)
2003년 안동대학교 정보통신 공학과 공학사
2009년 국민대학교 비즈니스정보통신 이학석사
2014년 국민대학교 비즈니스IT 전문대학원 이학박사
2014년～현재 해양센서네트워크기술연구센터 연구원
<주관심분야 : Underwater MAC 프로토콜, 유비쿼터스 네트워크, Underwater Sensor Network>

남궁 정 일(정회원)
1995년 인천대학교 기계공학과 공학사
2005년 국민대학교 비즈니스정보통신 이학석사
2011년 국민대학교 비즈니스IT 전문대학원 이학박사
2014년～현재 국민대학교 금융정보보안학과 연구교수
<주관심분야 : M2M/IoT, 인공지능, 극한환경 통신프로토콜 등>

박 수 현(정회원)
1988년 고려대학교 컴퓨터학과 학사
1990년 고려대학교 전산학과 석사
1998년 고려대학교 컴퓨터학과 박사
2002년～현재 국민대학교 정보시스템전공 교수
<주관심분야 :유비쿼터스 네트워크, Underwater Sensor Network>