A Call Procedure Design for Underwater Celluar Networks

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***Abstract*—In this paper, we design a call procedure between underwater base station controller (UBSC) and underwater base station (UBS) in cellular-type underwater networks. For reliability and stability, the procedure is initiated by UBSC. Then, data is transferred in three distinctive modes so that data can be collected in more efficient way according to the application services.**

Keywords-underwater cellular networks; call procedure; initialization; medium access control.

I. INTRODUCTION

In recent years, research on underwater wireless networks has been actively conducted for many applications, such as disaster prevention, tactical surveillance, and ocean exploration [1]. Since signals suffer from high propagation delay, severe multipath fading, and narrow bandwidth in the underwater channel, systematic resource management is highly required. Depending on the presence or absence of infrastructure, we can categorize the underwater wireless networks into two types: cellular networks and sensor networks, respectively. Although constructing the infrastructure in underwater is expensive, the cellular-type networks have very efficient resource management [2] compared to the sensor networks. In this paper, we design a call procedure between underwater base station controller (UBSC) and underwater base station (UBS) in underwater cellular networks.

Figure 1 shows an architecture of underwater cellular network. On the seabed, UBSs are installed and communicate with a UBSC buoyed on the surface. The UBSC manages the UBSs by disseminating downlink (DL) data and gathers uplink (UL) data from the UBSs. Similarly, each UBS takes charge of multiple user equipment (UE) and delivers UL data from the UEs to the UBSC.

In Sections 2 and 3, we explain the proposed call procedure between the UBSC and the UBSs and conclude the paper, respectively.

II. CALL PROCEDURE

The call procedure consists of initialization and data transfer phases as shown in Figure 2. The initialization phase is divided into two sub-phases—UBS search and system configuration.

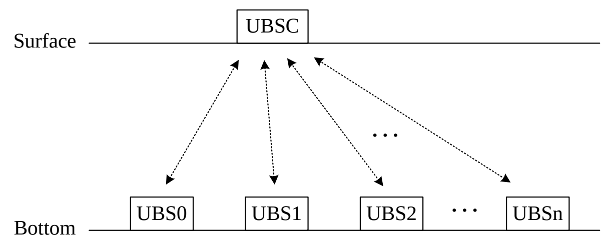

Figure 1. Network structure.

A. Initialization phase

In the UBS search sub-phase, the UBSC broadcasts an *echo request* (ERQ) packet to search for UBSs, and the UBSs respond with an *echo response* (ERP) packet. Since the UBSs do not have their own dedicated UL frequency band, they send the ERP using a shared band. To prevent packet collision, each UBS defers the ERP transmission for a certain time. Through the ERQ–ERP exchange, the UBSC knows the number of available UBSs and distances from each of them. During the system configuration sub-phase, based on aforementioned knowledge, the UBSC allocates dedicated UL bands of the UBSs in such a way that a nearer UBS gets a higher frequency band and then notifies them of this information using a *system parameter configure* (SPC) packet in the next system configuration phase. Since the SPC contains system parameters, such as data transfer mode as well as the allocated UL band, the UBSs can configure the system for a subsequent data transfer phase. As a response to the SPC, the UBSs send a *system parameter configure complete* (SPCC) packet to the UBSC. The UBSs use their dedicated UL band from the moment they complete the system configuration.

Note that both sub-phases are initiated by the UBSC while the UBSs wait for UBSC's request packets such as ERQ and SPC. Additionally, only the successfully recognized UBSs by UBSC during the UBS search can transit to the system configuration phase.

B. Data transfer phase

In this phase, based on the previous system parameter setting, UL or DL data is exchanged between the UBSC and the UBSs. Once the network initialization is completed, the UBSC broadcasts a *data transfer start* (DTS) packet to announce the move to the data transfer phase. When the

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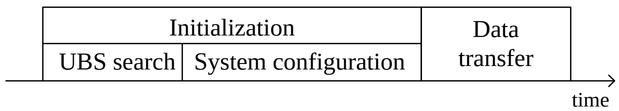

Figure 2. Call procedure between UBSC and UBS.

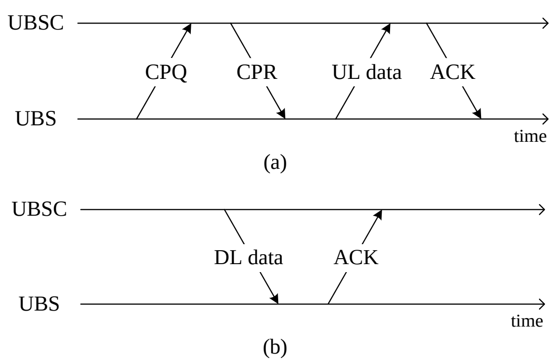

Figure 3. Procedures of data transfer: (a) UL data, (b) DL data.

UBSs receive the DTS, they recognize transition to the data transfer phase and then respond with a *data transfer start complete* (DTSC) packet. As mentioned earlier, only the successfully recognized UBSs by the UBSC during the system configuration phase can transit to the data transfer phase. Therefore, even though a UBS sends a SPCC to the UBSC after system configuration, it may not join the data transfer phase if the SPCC is lost.

The protocol has three different data transfer modes 1, 2, and 3. The modes 1 and 2 are normal mode but they are distinct from each other, depending on whether the UBSs sleep or not. On the other hand, the mode 3 is ad hoc mode where the UBSC establishes a direct link and communicates with a mobile UE (e.g., a diver).

In modes 1 and 2, a session for UL or DL data comprises a 4-way or 2-way handshake, respectively, as shown in Figure 3. In the case of UL session, the UBS and the UBSC first exchange channel probe request (CPQ) and channel probe response (CPR) packets. On receiving the CPQ, the UBSC measures the UL channel quality and responds with the CPR that carries the most appropriate modulation and coding scheme (MCS) level for UL data. Then, the UBS sends the UL data using the corresponding MCS level and are acknowledged by the UBSC. A large amount of UL data can be transmitted with a chain of consecutive data packets (packet train) within a single UL session. Meanwhile, note that there is no CPQ–CPR handshake in DL data session, thus reducing the delay caused by channel quality estimation. Instead, since the DL data normally carry important control information, the lowest MCS level is applied by default. As an automatic repeat request (ARQ) method, the UL session employs the selective ARQ. When UL data are erroneous, the UBSC selectively requests retransmission of the erroneous data by sending a negative acknowledgment (NACK) packet to the UBS. Referring to this NACK, the UBS resends the corresponding packets only. On the other hand, the simple stop-and-wait ARQ is used in the DL session.

Compared to the mode 2, the mode 1 additionally introduces UBS's sleep for energy saving. The UBSC calculates the sleep time for each UBS at the end of every UL session and includes it in the ACK packet. Then, the UBS sleeps during the specified time, which means that no UL and DL sessions can be established until the sleeping ends. Depending on application type or traffic pattern, the sleep time can be fixed or variable.

In the mode 3, the UBSC makes conversation directly with a UE, without passing through the UBSs. The UE does not have a dedicated UL band but borrows one of the UBS's UL bands. Throughout the mode 3, all of the UBSs keep silence not to interfere with UE's communication. This mode consists of three procedures: call setup, conversation, and call termination. To set up a call, the UBSC sends a *call setup* (CS) packet to the UE, which responds to this with a *call setup complete* (CSC) packet. After the CS–CSC exchange, the UBSC and the UE can talk to each other until the call is terminated. If the conversation is over, the UBSC requests call termination to the UE by sending a *call terminate* (CT) packet. When receiving the CT, the UE acknowledges with a *call terminate complete* (CTC) packet and disconnects the link. Note that the call setup and call termination procedures are also initiated by the UBSC.

III. CONCLUSION

In this paper, a call procedure between the UBSC and the UBS of underwater cellular networks was proposed. The procedure is centralized by the UBSC to achieve reliability and stability. In addition, the data transfer phase has three distinctive modes so that the network can adaptively choose one according to the application. For further work, we will design a UBS–UE call procedure and then combine it with the UBSC–UBS call procedure. Additionally, we will conduct field experiments to verify the proposed procedure.

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