CAMA-UAN: A Context-Aware MAC Scheme to the Underwater Acoustic Sensor Networks for the Improved CACA-UAN

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***Abstract*—Acoustic Communication is one of the most common and popular techniques used for Underwater Sensor Networks. The design of its communication protocol becomes a challenge due to its features of high delay and low bandwidth. Relevant research work has been conducted on possible communication at the MAC layer for highly efficient allocation and utility of communication channels. In this paper, a communication solution is designed called Context-Aware Mac-layer Approach to Underwater Acoustic Networks (CAMA-UAN), where a competitive mechanism is presented to determine the structure of scheduled MAC frames. According to the results, the CAMA-UAN has shown performance on delay and dropped packet ratio (DPR) when the rearrangement of frame slots is performed.**

Keywords- CACA-UAN; Context-Aware; Media Access Control Layer; Competition Mechanism;

I. INTRODUCTION

Underwater Acoustic Sensor Networks (UANs) are multi-hop ad-hoc networks made by large-scale wireless sensors populated in interested areas [1]. The deployed sensor nodes in a UAN collaboratively perceive, collect and process data from the sensed objects in the area, and then transfer the data to the sink/gateway. Recent research work has been conducted on the UANs and its relevant communication techniques, so as to apply to the fields such as military tracking, ocean surveillance, pollution monitoring and prediction, as well as disaster detection and warning.

Due to its particular application environment and features, design of communication protocols in UANs meets more challenges than traditional wireless sensor networks (WSN) on network mobility (e.g. current movement), obstacles (e.g. marine organisms), and other factors (salinity, water pressure, sound attenuation, etc.) [2]. A UAN can be further classified into three types according to its topology, i.e. two-dimensional UANs (2D-UANs), three-dimensional UANs (3D-UANs), three-dimensional UANs with Autonomous Underwater Vehicles (AUVs-based 3D-UANs). In a 2D-UAN, sensor nodes are deployed underneath the ocean with fixed positions. An ad-hoc topology is therefore formed via clusters by the nodes, so that data can be retrieved and forwarded via multiple hops from nodes to cluster headers, and then to the control centre via anchored relay nodes and/or naval gateways. 3D-UANs have their own reference nodes, either anchored or via AUVs, so can depict more efficient communication than 2D-UANs.

Recent research work has been conducted with more concern on the communication at the MAC layer for better network utility and high-efficient data transmission [3], where two types of MAC communication protocols can be defined, i.e. competition-based and schedule-based MAC communication [4].

In this paper, a hybrid MAC communication protocol based on our previous work, CACA-UAN [12] is presented to improve channel utility and efficiency.

II. RELATED WORK

Compared to traditional design of MAC protocols in a wireless ad-hoc network, a UAN has more complicated environment to optimise, such as higher delay, more limited bandwidth, environmental noise, higher energy consumption and error rates. Table I has depicted major differences of UANs and traditional WSNs.

TABLE I. DIFFERENCES BETWEEN UANS AND TRADITIONAL WSNS

Factors	UANs	Traditional WSNs
Communication Speed (m/s)	$1.5*10^3$	$3*10^8$
Bandwidth	Low	High
Delay	High, Dynamic	Low, Stable
Noise	Frequecy Related	White Noise
Energy Consumption	TX > RX > Idle > Sleep	TX ≈ RX > Idle > Sleep
Error Rate	High	Low

Aloha is a competition-based MAC protocol with most simplicity [5], which can be used in a UAN but suffers high collision. Slotted Aloha (S-Aloha) was therefore presented to reduce the collision by allocating proper slots for senders [6]. According to [7], timing management and positions of receivers determine whether collisions happen in a high-contention network, so a trade-off was given to maintain the transmission delay in [8]. In parallel, a delay-tolerant protocol was presented for optimised network utility and receiving rates [9].

UWAN-MAC [10] was presented as a distributed energy-efficient protocol based on competition and CSMA. It aimed at local synchronisation with high transmission delay by sacrificing network utility. It has been improved in [11] by adding energy management and control policies.

Compared to Schedule-based MAC protocols, Competition-based protocols can improve transmission speed in a UAN, but suffer from collisions and re-transmissions. A hybrid solution is therefore presented in this paper to avoid possible collisions with better transmission performance.

III. Design of CAMA-UAN

A. Baseline: CACA-UAN

In [12], a model called Context-Aware Communication Approach in an Underwater Acoustic Network (CACA-UAN) has been presented to implement interaction and exchange of context information using a service discovery protocol and TCP transactions. The frame design of the CACA-UAN includes an integrated frame header, which is made by a beacon and multiple slots, as shown in Figure 1.

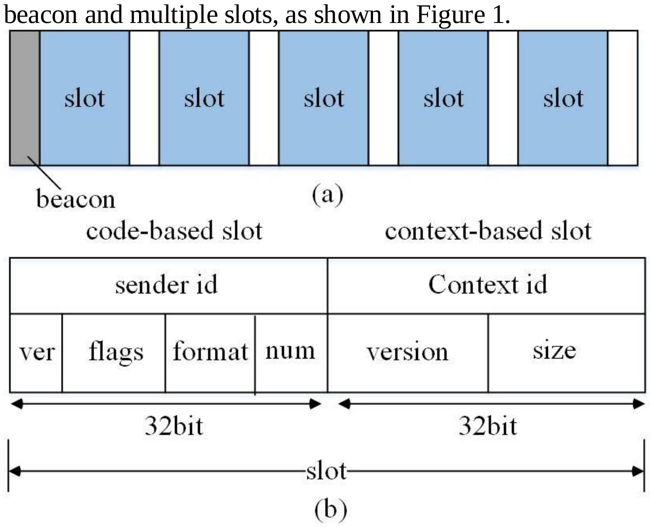

Figure 1. Segments and Slots of a CACA-UAN frame [12].

Slots in a CACA-UAN frame can be further divided into two parts, i.e. a code slot for the id and control information of the sender, and a context slot for contextual information used for the improvement of communication.

B. Design of CAMA-UAN

Based on the CACA-UAN, a CAMA-UAN is proposed in this paper by adding a competition mechanism. A CAMA-UAN frame is made by three parts, i.e. a beacon, a contention section and slots. A superframe can then be made by its header, a contention section, frames, reserved and inactive section, as shown in Figure 2.

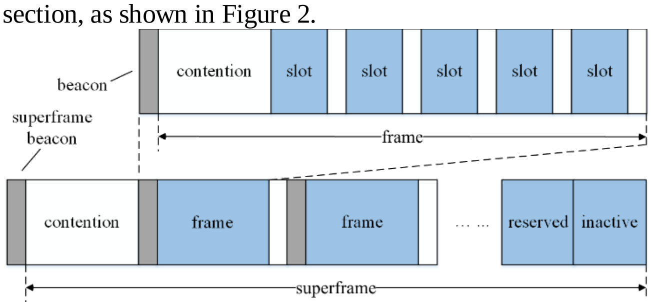

Figure 2. Segments and Slots of a CACA-UAN frame and its superframe.

In the CAMA-UAN, slots can be rearranged according to received context information with an updated context-aware mechanism, usage of inactive and reserved section.

1) An Updated Context-Aware Mechanism

During the inner-cluster communication, the cluster header will examine the broadcast frame for update information from the control centre. The header of communication frames will be updated, as shown in Figure 3.

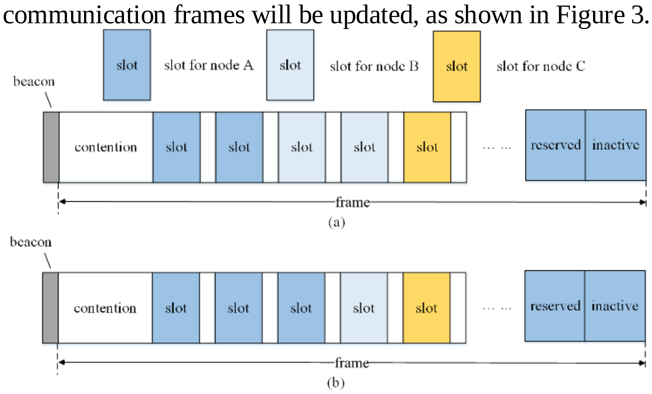

Figure 3. Rearrange and updates of a CAMA-UAN frame: a) the structure of an orignal frame; b) rearrange of context-awre piority.

Context-aware information, including energy usage, communication range, etc. can be retrieved from slots of a CAMA-UAN frame, so as to achieve the rearrange of context-aware priority as shown in Figure 3b. Its detailed processes can be depicted in Table II.

TABLE II. Algorithm Description of Updated Context-Aware Priority

Algorithm Description: Inner-cluster Updates of Context Information
Start
[Initiation]
A new frame is generated originally; Node's awaken; Check whether new update information found in the broadcast from;
Loop
if no new update information received **then**
keep the current frame structure; the node goes to sleep;
else
retrieve update context informat from the frame;
rearrange of slots and sections, form the new frame structure;
endif
endloop

IV. Simulation and Performance Evaluation

Aqua-Sim has been used to simulate the experiments and evaluate the performance. UWAN and The CACA-UAN [12] are employed for the comparison purposes.

A. Simulation Environment

The simulation environment built for CAMA-UAN is kept the same as in CACA-UAN, as shown in Table III.

TABLE III. SIMULATION ENVIRONMENT FOR CAMA-UAN

Parameter	Value
Simulated Area	100 * 100 * 100 m^3
Simulated Duration	500 seconds
Node Speed	0.5 m/s
Transmission Power	2.0 mW
Receving Power	0.75 mW
Ideal Power	8 μW

B. Performance Evaluation

Delay and Dropped Packet Ratio (DPR) have been used to examine the performance of the CACA-UAN compared to CACA-UAN and UWAN, as shown in Figure 4 and 5.

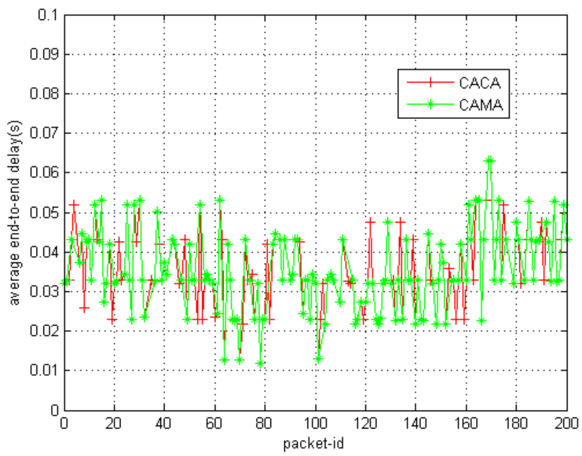

Figure 4. Communication Delay of CAMA-UAN Compared to CACA-UAN.

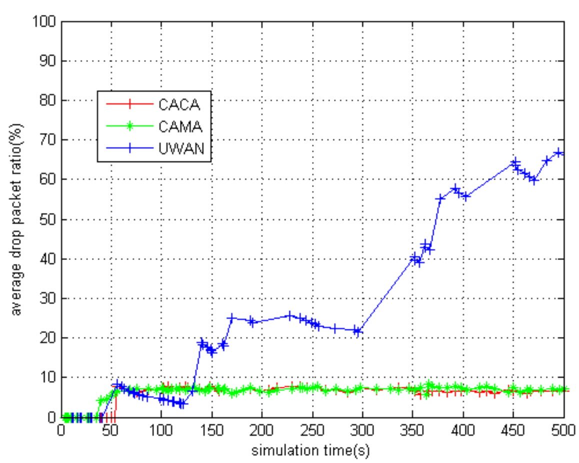

Figure 5. Dropped Packet Ratio of CAMA-UAN Compare to CACA-UAN and UWAN.

According to Figure 4, the CAMA-UAN shows similar communication delay as the CACA-UAN, except packet-id from 90 to 120, where slots have been rearranged according to updated context-aware information. Figure 5 illustrates the DPRs of UWAN, CACA- and CAMA-UAN, where the CACA- and CAMA-UAN outperform the UWAN. Compared to the CACA-UAN, the CAMA-UAN shows more collision when the packet-id is between 40 and 80, and then refined afterwards due to the updated processes accordingly to context-aware information.

V. CONCLUSION

In this paper, a refined MAC-layer communication approach called Context-Aware Mac-layer Approach to Underwater Acoustic Networks (CAMA-UAN) is presented for Underwater Acoustic Sensor Networks. Based on CACA-UAN, a contention mechanism is presented in the CAMA-UAN by rearranging frame slots using context-aware information. According to the experiment results, the CAMA-UAN shows lower delay than the CACA-UAN when the rearrangement processes are performed. In terms of Dropped Packet Ratio (DPR), the CAMA-UAN outperforms the UWAN and illustrates similar results as the CACA-UAN approach. When the rearrangement happens during the packet-id varies between 90 and 120, the DPR of CAMA-UAN performs better than the CACA-UAN.

Further improvement work on the CAMA-UAN includes collision avoidance and reduction, so that the performance can be further improved. In addition, jittering will be calculated for performance evaluation to examine detailed collision issues.

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