Cost Effective Acknowledgement Mechanism for Underwater Acoustic Sensor Network

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Abstract

In this paper, we proposed Cost Effective Acknowledgement (CEA) method which was based on Multiple Acknowledgement (MA) [1] method and proposed by Smart Block Medium Access Control (SBMAC) [2]. The proposed method can reply the information of transmission error states of all Senders within smaller storage space. Especially, the number of transmission and the frame length was minimized to reduce transmission error. The performance of the proposed method and conventional methods such as Normal Multiple Acknowledgement (NMA) and Selective Multiple Acknowledgement (SMA) method [3] was calculated and compared with each other. The calculation results showed the best performance in case of the proposed method.

Keywords: *SBMAC, Cost Effective Acknowledgement, SMA, NMA, MA, Underwater MAC*

1. Introduction

Recently, reliable communications in an extreme condition, such as underwater environment, have been studied consistently [4, 5]. Research on modem as transmission device has been successes after several years and underwater Medium Access Control (MAC), efficient error recovering and re-transmission techniques have been drawing much interests [5, 6]

Especially, the authors have been trying to reduce transmission numbers and frame sizes by enhancing conventional method such as Automatic Repeat-reQuest (ARQ) [7-13] and Block Acknowledgement (BA) [10]. Our research works is an another results of best performance and efficiency on the line of those trial.

A few knowledge is required to understand CEA and SMA. We have to understand that it is possible to use various transmission and error recovering methods in SBMAC system, which is developed for underwater network. And the theme of this paper is about error detection and re-transmission mechanism. We used MA concept, which is able to reduce the number of transmissions significantly by broadcasting via kinds of feedback way. The transmitted information contains Acknowledgement (Ack) information about transmitted sensor nodes. Especially, this paper proposed CEA method by enhancing conventional NMA and SMA method. And then the core contents of the paper is the changed frame structure, which has significantly reduced CEA frame size and improved transmission efficiency [3, 4].

In Chapter 2, MA method is explained. In Chapter 3, the proposed method is compared with conventional SMA method to explain mathematical model and performance evaluation. Conclusion is in Chapter 4.

2. MA

MA method is to transmit Ack to many objects simultaneously [1]. In unit cluster, Cluster Head(master, coordinator) conducts Broadcasting of Ack information of data transmitted from many receivers from Super-frame(round) within Beacon signal, which is a control frame transmitted at periodically transmitting Beacon interval. Figure 1 shows an example of Normal ARQ and Multiple Ack method in case of Multiple Access. S1~S3 is senders and sensor nodes. CH is a cluster header and a receiver. In case of MA, frame including control frames is transmitted 4 times (Beacon 1 + data 3) within super-frame. On the other hand, ARQ transmitted 7 times (Beacon 1 + data 3 + Ack 3). In Figure 1, MA and ARQ is compared with each other. Ack transmitting time and Guard time for Acks transmission were reduced. Red dotted line of Figure 1 shows the possible energy reduction sections. With MA method, the total number of frame transmission, transmission time and Guard time is reduced. The reduced Duty cycle, which was resulted from the increased possible energy reduction section, contributes to the increased Network lifetime. In addition, It removes the network complexity so it is a efficient method in case of poor condition such as underwater environment [1, 3].

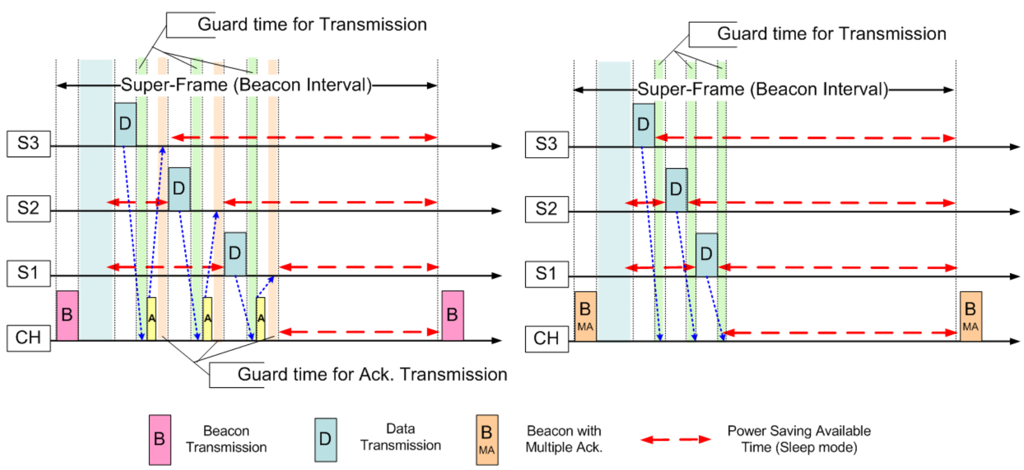

Figure 1. An example of Super Frame; ARQ and MA

3. Proposed Cost Effective Mechanism

3.1 SMA and Cost Effective Mechanism

The difference between CEA and SMA is whether it contains partial information or total information. SMA selectively reply Ack or Nack information, and CEA conducts node numbering and transmit 0 in case of Ack and 1 in case of Nack in a sequential way in 1 bit.

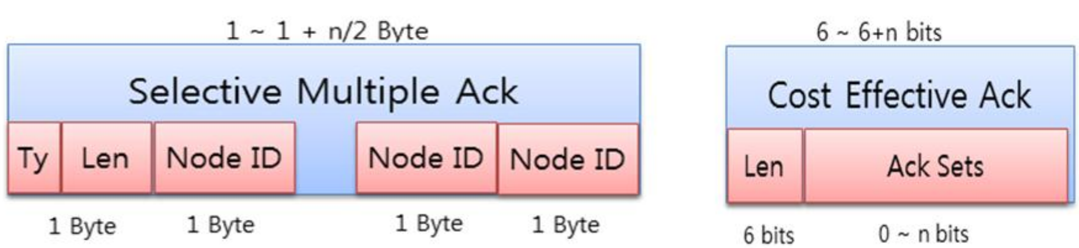

Figure 2. Frame format of SMA and Cost Effective Ack

Figure 2 shows frame format and their differences. If Ack/Nack is not very small such as 0~2, CEA can more reduce the frame size. With CEA, Ack type, which is needed in SMA, is not necessary. Since it has all the information of Ack/Nack, it is not necessary to classify types. Length is stored in 6 bit information and it is used for the efficient transmission. Figure 2 shows Beacon frame format containing CEA. Green colored part is different part with SMA and Ack/Nack information is stored as 1 bit per node.

3.2. Analytical Formula of SMA/CEA Scheme

Variables for deduction of the formulas are listed in Table 1.

Table 1. Variables

Notation	Definition	Notation	Definition
C	Network Bandwidth	$L_{payload}$	Length of MSDU(Payload)
R	Data Rate	$L_{control}$	Length of control
B	Number of Blocking Acks	L_{ack}	Length of ACK
data	Data Frame with control info,	ΣL_{ack}	Total length of ACK on link
SET	BA control Frame	N_{total}	Number of total Tx
int()	Function of integer	N_{data}	Number of data Tx
ACK	ACK Frame	N_{ack}	Number of ACK Tx
L_{total}	Length of total frame	$N_{control}$	Number of control Tx
L_{data}	Length of data	*Len()*	Function of frame length
BEACON	Master driven periodic Broadcasting Frame		

3.3. Numerical Computation Model

Channel usability can be expressed as *R/C* - Frame transmission rate over the total bandwidth. The efficiency of the channel being used means the rate of data length over the total transmitted frame. This can be expressed by $L\_payload/L\_total = (L\_total - L\_control)/L\_total$. The length of the total transmitted frame is the payload length plus the control information length. The control information length is expressed in equations *(1) and (2)*:

$$L_{total} = L_{payload} + L_{control} \tag{1}$$

$$L_{control} = \left(L_{data} - L_{payload}\right) + L_{ack} + BEACON \tag{2}$$

Equations *(3)~(8)* show the component fields in the conventional Ack and data transmission frame. Five variants of Ack length are expressed in equation *(3)*. Equations *(4)~(8)* show the ARQ, BA, NMA, SMA and proposed CEA method, respectively. The size of the address and control field are the same for fair comparison.

$$Len(ACK_{CEA}) < Len(ACK_{SMA}) < Len(ACK_{NMA}) < Len\left(ACK_{ARQ}\right) < Len(ACK_{BA}) \tag{3}$$

$$ACK_{ARQ} = Frame\ Control + Duration\ ID + Dstination\ ID + CRC \tag{4}$$

$$ACK_{BA} = Frame\ Control + Duration\ ID + Destination\ ID + (BA\ Control + Block\ Ack\ Sequence\ Control + Block\ Ack\ Bitmap) + CRC \tag{5}$$

$$ACK_{NMA} = Normal\ Multiple\ Ack\ field\ (Len + Len(Corresponding\ ID * Slaves)) \tag{6}$$

$$ACK_{SMA} = Selective\ Multiple\ Ack\ field(Type + Len +$$

$$Corresponding\ ID\ *\ int(\#\ of\ Slave\ /2)) \quad (7)$$

$$ACK_{CEA} = Cost\ Effective\ Ack\ field(Len + \#\ of\ Slave\ bits)) \quad (8)$$

The data frame lengths of ARQ, BA, NMA, SMA and CEA are the same. This means that channel efficiency is derived from the difference of the Ack methods and control frame length. Thus, *data.ARQ*, *data.BA* and *data.MA* denote the Data Frames for ARQ, BA, NMA, SMA and CEA, respectively (see equations *(9)~(11)*).

$$L_{data.CEA} = L_{data.SMA} = L_{data.NMA} = L_{data.BA} = L_{data.ARQ} \quad (9)$$

$$data.ARQ = data.BA = Frame\ Control + Duration\ ID + Source\ ID + Destnation\ ID + Sequence\ Control + Payload + CRC \quad (10)$$

$$data.CEA = data.SMA = data.NMA = SmartBlock + SourceID + DestinationID + Sequence\ Control + Payload + CRC \quad (11)$$

The number of transmissions of the Ack Frame and Control Frame and the total length of messages are explained. Equations *(12)~(13)* are for the ARQ method, equations *(14)-(15)* are for the BA method, equations *(17)~(19)* are for NMA, SMA and CEA method.

$$N_{ack.ARQ} = N_{data} \quad (12)$$

$$\sum L_{ack.ARQ} = Len(ACK_{ARQ}) \cdot N_{ack.ARQ} \quad (13)$$

N_{data} is the number of data transmissions and N_{data} / B is used to calculate the number of transmissions of BA. The number is converted into an integer value by *int()*. In equation *(15)*, the number of transmissions is multiplied by 3 due to the two additional frames required for the start and end of BA (=*SETBA*):

$$N_{ack.BA} = 3 \cdot int(\frac{N_{data}}{B}) \quad (14)$$

$$\sum L_{ack.BA} = Len(ACK_{BA}) \cdot int\left(\frac{N_{data}}{B}\right) + 2 \cdot Len(SET_{BA}) \cdot int(\frac{N_{data}}{B}) \quad (15)$$

MA does not need to transmit additional control frames, such as *SETBA* for Ack. This efficiency improvement is the consequence of the minimization of information inside Ack and Data. There is no transmission number for Ack in the cases of NMA and SMA, since all *ACK* information is transmitted with *BEACON*. Additionally, the sum of the *ACK* length is less than that in the other three methods. Equations *(16)-(19)* are for NMA, SMA and CEA, respectively:

$$N_{ack.CEA} = N_{ack.SMA} = N_{ack.NMA} = 0 \quad (16)$$

$$\sum L_{ack.NMA} = Len(BEACON(Normal.Ack.Field)) \quad (17)$$

$$\sum L_{ack.SMA} = Len(BEACON(Selective.Ack.Field)) \quad (18)$$

$$\sum L_{ack.CEA} = Len(BEACON(Cost\ Effective.Ack.Field)) \quad (19)$$

3.4 Numerical Result

Numerical simulation results using Matlab is shown in Figure 3.

Based on the comparative analysis of ARQ, BA, NMA, SMA and CEA, it is verified that the Ack transmission length is increased as the number of nodes increase. In this case, the efficiency of CEA increased significantly and the overall performance also increased.

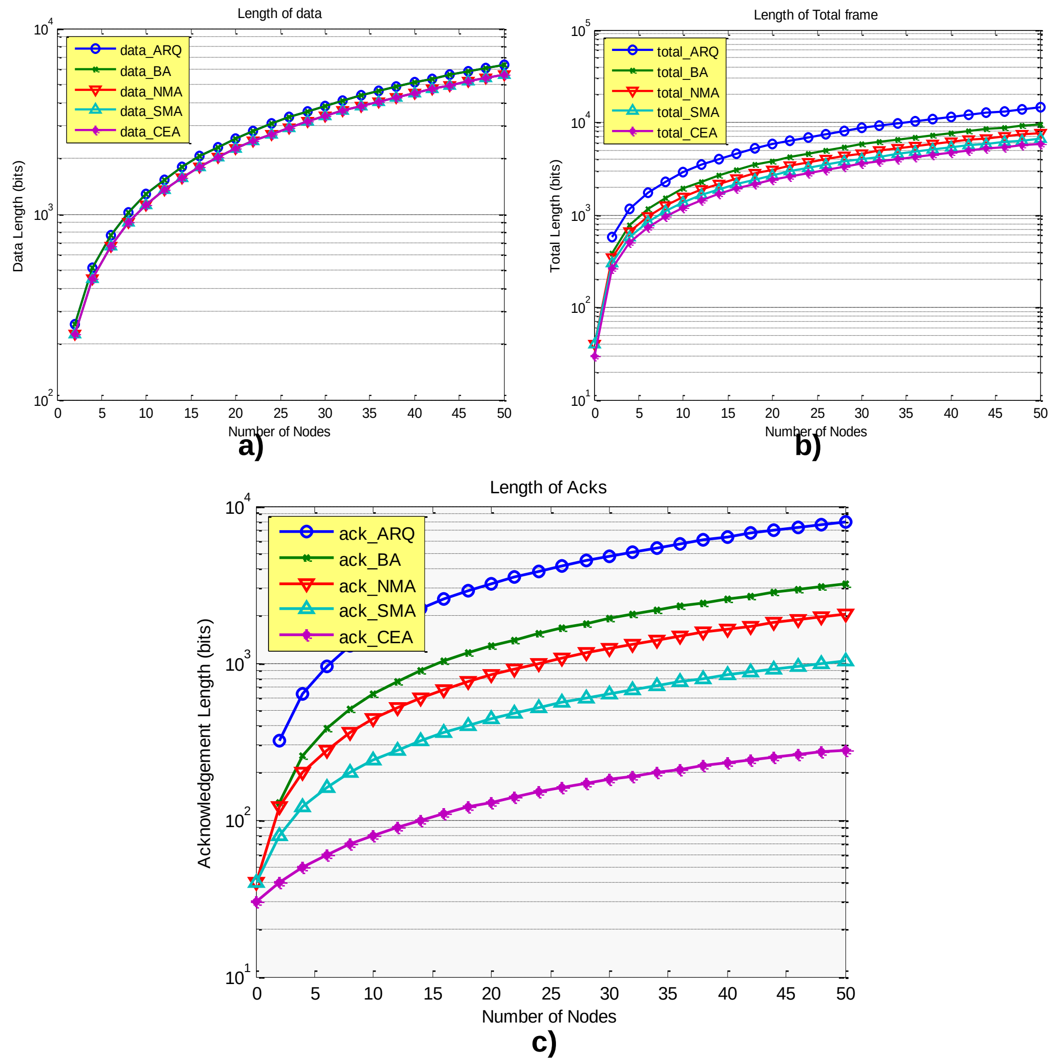

Figure 3. Frame Length, a) data frame length; b) total frame length; c) Ack frame(Beacon) length

4. Conclusion

In this paper, CEA method was proposed for underwater communications. With the proposed method, the information of whether the transmission was succeeded or not of all sending Senders can be replied within minimum space. In addition, the method minimizes frame length as well as the number of transmission which is necessary for minimization of transmission failure in an extreme condition such as underwater environment. Performance of the proposed CEA method and conventional methods, such as NMA, SMA, was compared. The comparison results showed that the proposed method can transmit Ack information minimized especially in case that the number of nodes increased.

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