PBA: A New MAC Mechanism for efficient wireless communication in Underwater Acoustic Sensor Network

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Abstract: - There are considerable serious propagation delay rate and high error rate in case of data transmission in the poor and causal environment, such as underwater. Like this environment usually has heavy fluctuation of error rate and limited wireless communication state. Therefore, mechanism using in such environment has to be efficient and simple. This paper suggests a novel block ack mechanism, called the Pervasive Block ACK (PBA), which transmits aggregated ACKs. This mechanism takes effect on reducing the amount of traffic, decreasing overhead and delay rate in poor environment networks like underwater. Additionally, we are able to look forward to reducing the energy consumption of whole network. We can find the proposed PBA is more efficient than other methods, such as BA and ARQ through analyzing numerical result based analytical formula in this paper.

Key-Words: - UW-ASN (Underwater Wireless Acoustic Sensor Network), PBA (Pervasive Block Ack), Block Ack, ARQ

1 Introduction

The wider wireless communication is utilized in new ranges according as developing telecommunication techniques. Wireless communication can be inevitably needed in various and extremely poor environment, for example, in the North Pole, the South Pole, the typhoon area, and even deep underwater. Of course, quality of transmission has no choice but to have a quite gap with a medium. Also, the skill of medium access may be changed by appropriate transmission environment. It is noteworthy that international researches about underwater communications set to work recently.

Generally, underwater wireless communications get accomplished with an acoustic signal. Speed of acoustic is faster than of air in underwater, so it can propagate up to several kilometers. Acoustic signal is able to be detected from long distance, but on the other hand it is worried about those problems in poor environment just like season and the depth of water. Underwater acoustic communications are mainly influenced by path loss, noise, multi-path, Doppler spread, and high and variable propagation delay effects. The majority of underwater acoustic channels are characterized by a poor quality physical link, caused by time-varying multi-path propagation and motion-induced Doppler distortion [1]. As a result, the bit error rate (BER) of an acoustic link is often high. Moreover, it can vary with time as the propagation conditions change. Especially in shallow water, there are severely acoustic dispersion and reflection. Also, probability of wrong detection is high because feature of medium from fresh water is different each other [2]. Underwater sensor networks do not revitalized than the ground yet. However, underwater acoustic sensor networks can be applied to applications for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications [3].

There are several important points concerning improvement of data transmission rate and minimization of error detection and recovery in general processes.

This paper proposes an epochal and efficient mechanism reducing the amount of transmission utilized in both underwater environment and wireless environment with diversity and fatal problems, called the Pervasive Block ACK (PBA). PBA introduces and modifies Block Ack (BA) for reducing number of ack traffic occurrence. Also, PBA is not necessary another control packet for start request, transmission request, and data gathering or managing in order. Reducing overhead through decreasing number of transmission traffics raises network efficiency, then delay rate is able to be fallen off. Additionally, effect of power saving is expected.

We therefore investigate five areas. In Sections 2, we explore the ARQ mechanism and Block Ack mechanism in IEEE 802.11e as related works. In section 3 we introduce fundamental PBA mechanism, and define analytical formula for the theoretical thesis in section 4. In section 5 we verify propriety and efficiency of PBA through describing numerical result based analytical formula from section 4. Finally, in section 6 we draw we draw the summary and indicate future works as a conclusion.

2 Related Worls

The ARQ (Automatic Repeat Request) protocol is the simplest mechanism related to ACK.

In this protocol, each one of frame has to get an acknowledgment (ACK) to itself. The transmitter sends a frame to the receiver and waits for the ACK, as shown in (figure 1).

If the ACK does not arrived in a pre-specified amount of time, called the time-out, or a negative acknowledgment arrives, the packet is transmitted. When the ACK arrives, the transmitter sends to a new packet.

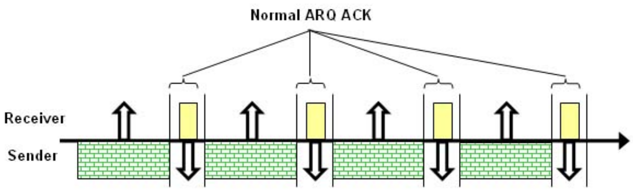


Figure 1. ACK in Normal ARQ

A positive acknowledgment (ACK) from the receiver indicates that the transmitted frame has been successfully received, and the transmitter sends the next frame in the queue. A negative acknowledgment (NAK) from the receiver indicates that the transmitted frame has been detected in error; the transmitter then resends the frame and again waits for an acknowledgment. Retransmissions continue until the transmitter receives an ACK [4]. ARQ technique is simple and provides high reliability [5], but the bigger size of packet is, the higher delay rate of propagation is. And link efficiency is low. ARQ has low transmission efficiency because next frame cannot be transmitted until receipt of ACK/NAK from receiver or occurrence of time-out (maximum time waiting response from receiver after arbitrary data transmission).

ARQ research and realization go on studying simultaneously in order to improve the system efficiency at present.

In IEEE 802.11e, the Block Ack (BA) mechanism - suitable Acknowledge technique – is used in order to reduce the channel wastes due to the ACK transmissions.

Basically, the block ACK mechanism allows a block of MPDUs to be transmitted, each separated by a SIFS period, and to be acknowledged by a final aggregated ACK frame, called block ACK [7].

Block Ack mechanism in IEEE 802.11e standard [8] has been devised in 802.11 group using bandwidth to spare. Since this mechanism has excessive overload caused by a lot of control packet in courses of setup and message sequencing, it is not suitable in underwater communication.

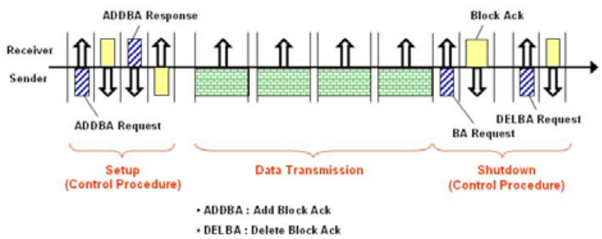
Besides, usable MAC mechanism in the ocean is in progress lively. Mostly the research related to ack mechanism is still based on ARQ technique.

3. Pervasive Block Ack (PBA)

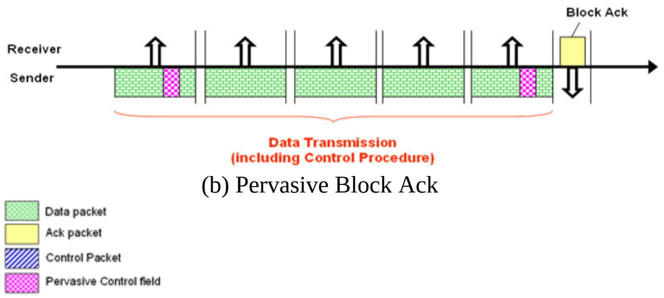
Pervasive Block ACK (PBA) can use in diversity topologies just like infrastructure topology and Ad-hoc network, and apply to all kinds of link-by-link with error control.

New PBA mechanism is more appropriate in poor condition as an underwater environment. In underwater, number of message has to be reduced more than in ground because of deterioration with message LQI (Link Quality Indication) ability.

If transmission is accomplished through proposed PBA technique, number of traffic deterioration is able to be reduced greatly compared with existed Block Ack technique in IEEE 802.11e. We can verify with (figure 2) such details.



(a) IEEE 802.11e Block Ack



(b) Pervasive Block Ack

Figure 2. Two concept of Block Ack

The basic flow of PBA mechanism is showed in (figure 3). PBA curtails initiation and shut-down steps boldly, and those steps are included in part of transmitting data frame. So, traffic transmission volume decreases and overhead is minimized.

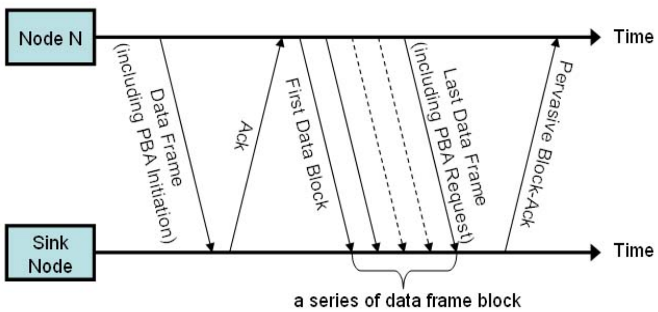


Figure 3. Sequence flow

Also, unnecessary fields are eliminated from frame format Frame than existing frame format in order to diminishing length and overload.

First of all, a sender transmits data frames in own queue, and there is no procedure of Initiation. Instead of the procedure, a sender forwards data frame containing flag and state field in the middle of transmission. The flag and state field indicate that next frame is a target of PBA. Namely, those frames play an important part as initiation. As the data frame including those fields performs initiation, it is transmitted by using existed ARQ mechanism for reliability guarantee in receiver side. As soon as Ack for that data frame arrives from receiver, next data frames are transmitted with PBA mechanism continually. A receiver stores a queue with data frames going through such a procedure. Likewise, this mechanism has no additional shut-down step. A sender transmits a last data frame including flag that indicates request PBA. If a receiver takes a data frame including that flag, PBA or PB-NAK (Pervasive Block NAK) is send to a sender through checking the data frames in a receiver's queue.

4. Analytical formula

We define analytical formula for the theoretical thesis of proposed Pervasive Block Ack mechanism in this section. Definition of terms used in this section is showed in (Table 1).

Table 1. Terms Definition

Terms	Definition
C	Maximum network process rate (Bandwidth)
R	Frame transmission rate (Data Rate)
B	Number of Blocking Acks
data	Data Frame including control information
SET	Frame informing the start and the end of Block Ack
ACK	One ack frame
L_{total}	The sum of frame length for data transmission success (Data frame + Ack frame)
L_{data}	Length of data frame including control information
$L_{payload}$	MSDU (=Payload) length
$L_{control}$	Total length of control information For data transmission success
L_{ack}	Ack frame length
ΣL_{ack}	The sum of ack frame length from one link
N_{total}	Number of total transmission
N_{data}	Number of data frame transmission
N_{ack}	Number of ack frame transmission
$N_{control}$	Number of control Frame transmission excepting ack (BA association + deassociation)
Len()	Function for calculating frame length
int()	Function converting a positive number (applying round up number)

(figure 4), (figure 5), and (figure 6) shows example of frame formats that are foundations with calculating a numerical formula in this section.

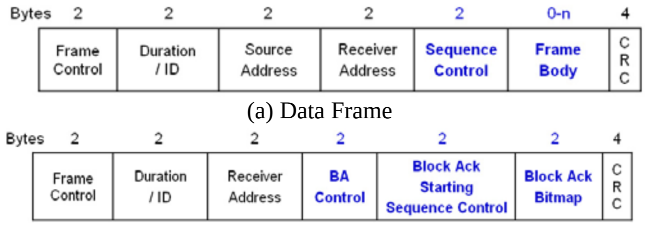
Bytes	2	2	2	2	2	0-n	4
	Frame Control	Duration / ID	Source Address	Receiver Address	**Sequence Control**	**Frame Body**	CRC

(a) Data Frame

Bytes	2	2	2	4
	Frame Control	Duration / ID	Receiver Address	CRC

(b) ACK Frame

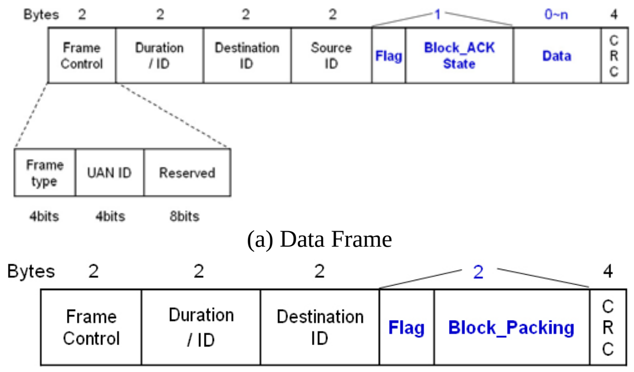
Figure 4. Frame Format in ARQ



(a) Data Frame

(b) ACK Frame

Figure 5. Frame Format in Block Ack



(a) Data Frame

(b) ACK Frame

Figure 6. Frame Format in PBA

At this point, Source Address and Destination (or Receiver) Address are defined each 2bytes. We defined a sensor network without necessity for long address as a basic environment.

Employment rate of channel can represent R/C dividing frame transmission into bandwidth. And, efficiency on using channel implies percentage occupying only data length in total transmission Frame. This is expressed $\frac{L_{payload}}{L_{total}} = \frac{L_{total} - L_{control}}{L_{total}}$ converting length (number of using bit in frame). Total transmission frame length includes length of data payload and the rest control information. $L_{control}$, control information length, is the sum of length subtracted payload from data frame and used for Ack transmission. (A numerical formula *(1) ~ (2)*)

$$L_{total} = L_{payload} + L_{control} \quad (1)$$

$$L_{control} = (L_{data} - L_{payload})) + L_{ack} \quad (2)$$

Next definitions show composition of fields in usual ack frame and data transmission Frame. Three kinds of ack length have relation to a formula *(3)* when all fields except for ack information are same. Formulas *(4)*, *(5)*, and *(6)* stand for composition of frame and example of calculation with frame length presented at (figure 4), (figure 5), (figure 6) of ARQ, Block Ack, and Pervasive Block Ack respectively.

$$Len(ACK_{ARQ})<Len(ACK_{PBA})<Len(ACK_{BA}) \quad (3)$$

$$ACK_{ARQ}=FrameControl+DurationID+DestinationID+CRC \quad (4)$$
$$2+2+2+4 = 10\ bytes = 80\ bits \quad / ACK\_frame$$

$$ACK_{BA}= FrameControl+DurationID+DestinationID+(BA\ Control+BlockAckSequenceControl+BlockAck\ Bitmap)+CRC \quad (5)$$
$$2+2+2+(2+2+2)+4 = 16\ bytes = 128\ bits \quad / Block\_ack\_frame$$

$$ACK_{PBA}= FrameControl+DurationID+Destination\ ID+(Flag+PBABitmap)+CRC \quad (6)$$
$$2+2+2+(2)+4 = 12\ bytes = 96\ bits \quad / Pervasive\_Block\_ack\_frame$$

Transmission data frame is next to same value in three techniques as follow formulas *(7) ~ (9)*. This implies that channel efficiency is decided through difference of frame length and ack method like ack frame length and number of transmission rather than data frame length. *data.ARQ, data.BA*, and *data.PBA* mean data frame for ARQ, BA, and PBA each.

$$L_{data.ARQ}=L_{data.BA}\geq L_{data.PBA} \quad (7)$$

$$data.ARQ=data.BA= FrameControl+DurationID+SourceID+DestinationID+SequenceControl+Payload+CRC \quad (8)$$
$$2+2+2+2+2+Payload+4 = 14+Payload\ bytes$$

$$dataPBA= FrameControl+DurationID+SourceID+DestinationID+(Flag+PBAState)+Paload+CRC \quad (9)$$
$$2+2+2+2+(1)+Payload+4 = 13+Payload\ bytes$$

Following part explains number of transmission with ack and control frame and total length according to message. Formulas *(10)~(11)* represent ARQ, *(12)~(13)* represent Block Ack, and *(14)~(15)* represent Pervasive Block Ack.

$$N_{ack.ARQ} = N_{data} \quad (10)$$
$$\sum L_{ack.ARQ} = Len(ACK_{ARQ}) \times N_{ack.ARQ} \quad (11)$$

N_{data}/B, B(number of blocked ack) into number of data transmission, is a formula for calculating number of transmission in Block Ack or Pervasive Block Ack. Number of transmission in (Pervasive) Block Ack is converted a positive number through *int()*. In *(12),* 에서 twice number of transmission is required, because two frame transmissions are added for Block Ack start and Block Ack shut-down as a SET_{BA} in the event of Block Ack transmission.

$$N_{ack.BA} = 3 \cdot int(\frac{N_{data}}{B}) \qquad (12)$$

$$\sum L_{ack.BA} = Len(ACK_{BA}) \times int(\frac{N_{data}}{B}) + 2 \cdot Len(SET_{BA}) \cdot int(\frac{N_{data}}{B}) \qquad (13)$$

PBA have no additional control frame for Ack like SET_{BA} compared with BA. Minimum information in data and ack can makes heighten efficiency like this.

$$N_{ack.PBA} = int(\frac{N_{data}}{B}) \qquad (14)$$

$$\sum L_{ack.PBA} = Len(ACK_{PBA}) \times int(\frac{N_{data}}{B}) \qquad (15)$$

In next section, we will analyze and compare number of transmission with control and all frames and frame length through describing numerical result based analytical formula from section 4.

5. Numerical result

First of all, we specify two fixed value for computing values in graphs from section 5; 10 is in case of requiring fixed number of blocked ack, and 100 is in case of requiring fixed number of data frame.

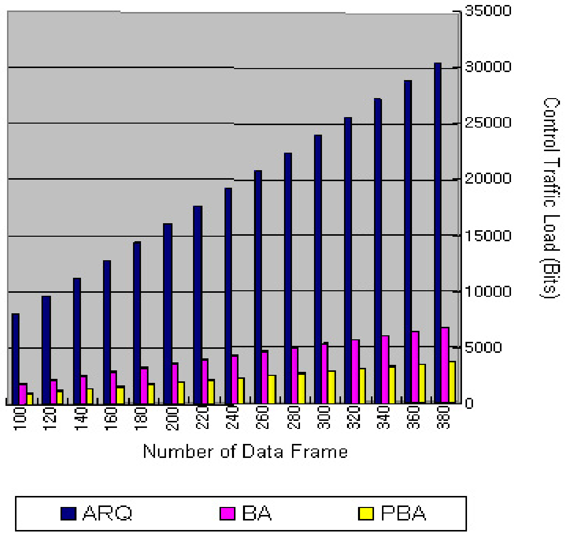


Figure 7. Control Traffic Load (1)

(figure 7) represents control traffic load following increase in number of data frame.
If number of frame grows, all graphs also grow. But the increase ranges of BA and PBA is smaller than ARQ. Increasing of control frame load in ARQ is proportioned to number of data frame beyond comparison with BA and PBA. Particularly, the growth of PBA is far smaller than BA because PBA itself has few control frames.

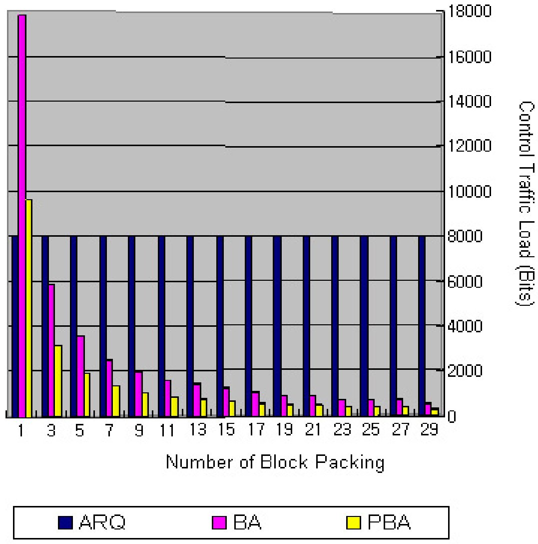


Figure 8. Control Traffic Load (2)

(figure 8) shows that control traffic load is able to reduce along by increasing number of Block Ack or data block included one Ack Set (That is, Block Ack includes more ack, so number of ack is reduced).
At this point, ARQ has equal values in the graph. The reason to output such result is that ARQ does not offer blocking ability.
(figure 9) represents total traffic load along to increase number of data frame.
The more increase number of data frame transmission is, the more increase total traffic load is each ARQ, Block Ack, and PBA. But difference of the increasing range appears obviously.
(figure 10) shows that total traffic load is reducing along by increasing number of Block Ack or data block included one Ack Set gradually. In peer-to-peer communication, Block Ack has a bit high load because of control frame for initiation and shut-down, however, the more increase number of Block Ack including one Ack Set is, the more decrease total traffic load is remarkably. Likewise, in peer-to-peer communication PBA has a little high load because PBA has a longer ack about 2 bytes than ack in ARQ mechanism. But if number of block ack included one Ack Set is

increasing, total traffic load of PBA is lots more reduce than Block Ack. As saying before, ARQ has equal values in the graph because of no applying blocking technique.

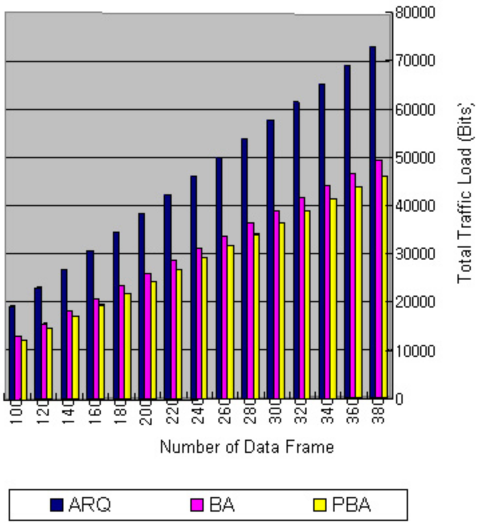


Figure 9. Total Traffic Load (1)

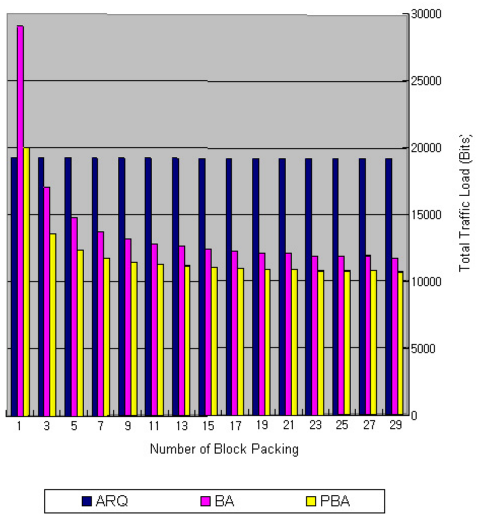


Figure 10. Total Traffic Load (2)

(figure 11) shows change in number of transmission with ack and control frame along by increasing number of Block Ack or data block included one Ack Set.

ARQ is not applicable blocking technique, so number of transmission is changeless that is not care about number of blocking ack or control frames.

In case of Block Ack, it has far more number of transmission for several control frames than PBA in the beginning, the frequency decreases gradually along to increase number of blocks.

Compared with BA, PBA has a same number of transmission as ARQ in the first because PBA has no another control frame. However, number of transmission decreases smaller than BA if number of blocks rises.

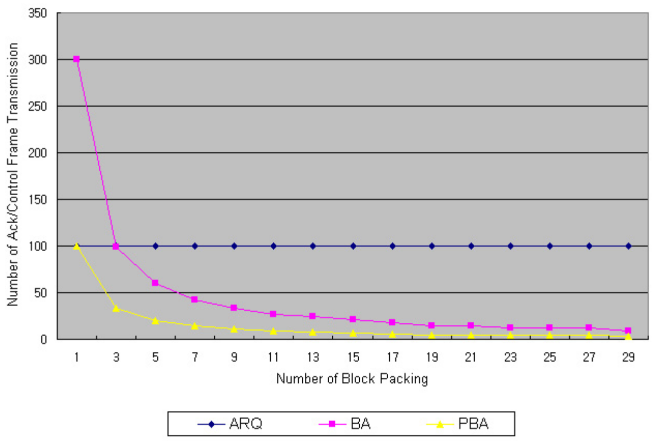


Figure 11. Number of Ack/Control Frame Transmission

6. Conclusion

In this paper, we suggested reducing overhead technique called Pervasive Block Ack mechanism that can support successful data transmission in poor transmission environment like underwater.

Proposed Pervasive Block Ack mechanism maintains proper data size, makes decrease overhead by reducing number of transmission with control frame including ack, and heightens network efficiency. As a numerical result show, the consequence in comparison with ARQ shows superior progress of performance. And number of transmission is considerably reduced compared with Block Ack mechanism.

Hereafter, we will apply time and prove efficiency along transmission. Also, reliable verification about diversity performance and channel efficiency will be demonstrated through simulation.

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