Block Based Window Retransmission ARQ Scheme for 100Mbit/s Infrared Links

Alam Mohammad Shah, Shawkat Shamim Ara and Mitsuji Matsumoto
Global Information and Telecommunication Studies, Waseda University,
Tokyo, Japan

Abstract— **With the increase of data transfer rates beyond 100Mbit/s over the infrared links, a robust automatic repeat request (ARQ) scheme is necessary to cope with the high speed environment. At high data rate, the Go-Back-*N* (GBN) ARQ scheme requires window and frame size adaptation to the corresponding optimum values for the correspondent Bit Error Rate (BER). But adaptive approaches always add a significant amount of complexity to the system. This paper presents a non adaptive Block Based Window Retransmission (BBWR) ARQ scheme that operates with a fixed size receiver buffer and achieves a significant improvement in the throughput efficiency over a wide range of BER at 100Mbit/s infrared links. Simulation results are presented which also reveal the effect of link layer parameters, such as window and frame data length, and physical layer parameters, such as minimum turn around time on the performance of the proposed scheme.**

I. INTRODUCTION

The communication environment is undergoing drastic changes in recent years. The wired access network is changing to IP-based network by xDSL or fiber based technology to support data rate over 100 Mbps. Unfortunately current wireless services offer data rates much less than 100Mbit/s. Moreover, as the trend of using larger files combined with the need for faster file transfer continues to become more important, there is a great need for high speed short range wireless links [1]. On the other hand, significant advantages have motivated recent interest into infrared wireless communication as a medium for point to point short range indoor communication [2]. But the majority of the infrared links currently employed offer data rates up to 4Mbit/s. Besides there has been a standardization of the 16Mbit/s data rate option, called Very Fast Infrared, (VFIr) [3]. VFIr links at 16Mbit/s enables Ethernet rate connections and fast image transfer between devices. But still this data rate is not sufficient for the users to access high-speed networks and its "last one meter" bottleneck exists. It is therefore a new standardization of the 100Mbit/s data rate option, called Ultra Fast Infrared (UFIr), has been proposed with a vision to enable the users to transfer bulky digital contents into/from mobile terminals within 10 seconds [4].

However, only a few works have been done to investigate the Infrared Link Access Protocol (IrLAP) for this future high speed infrared links. Boucouvalas and Vitsas [5] have examined existing IrLAP protocol operating at 100Mbit/s and concluded that it offers excellent performance even at 100Mbit/s, with high link layer throughput even at high data error rates, provided IrLAP window size and frame length values are adapted to the corresponding optimum values for the BER [5, 6]. But this adaptive approach adds significant amount of complexity to the system. Hence, in this paper, we present a Block Based Window Retransmission (BBWR) ARQ scheme for high speed infrared communication operating with a fixed size receiver buffer without adapting parameters to the optimum values. The throughput performance of the proposed scheme is also analyzed and simulated.

The rest of the paper is organized as follows: In section II we discuss our proposed block based window retransmission ARQ scheme. Section III presents our simulation results for analyzing the performance of the proposed scheme at 100Mbit/s. Finally we present our conclusions in section IV.

II. PROPOSED BLOCK BASED WINDOW RETRANSMISSION ARQ SCHEME

A. *Existing Go-Back-N scheme*

The basic Go-Back-*N* (GBN) ARQ error control scheme is the simplest continuous ARQ scheme to implement [7]. For this inherent simplicity, Infrared Link Access Protocol (IrLAP) uses Go-Back-*N* ARQ scheme as the error control scheme for data transmission over infrared links. The main drawback of this scheme is that, whenever a received frame is detected in error, the receiver also rejects subsequent *N*-1 received frames, even though many of them may be error free. As a result, they must be retransmitted and have the chance to be in error in the following retransmission. This signifies a waste of transmissions which results in severe deterioration of throughput performance especially in the case of high data rate transmission [8].

B. *Dividing Window in Blocks*

The key idea of the BBWR ARQ scheme is to store all error free but out of sequence frames received at the secondary station following the first erroneous frame in a small buffer and divide the next predicted window in *n* number of *b* blocks. If any block within the next window has all frames stored in the buffer of secondary station, it is ignored by the primary station from being retransmitted. The secondary station always informs the primary station about the next expected frame number and a bit map indicating the status of the blocks in its buffer. Based on this information, the primary retransmits or transmits only the expected blocks.

In our proposed scheme, the primary and the secondary station divides all the frames within a window in six predefined *b* blocks (Fig. 2(*c*)). The idea behind dividing in six blocks rather than any number is to take the advantage of the existing IrDA proposed extended control field of Supervisory frame (*S*-frame) which is explained in subsection *C*. The receiver assumes that the first and the last blocks always need to be retransmitted or transmitted because at least one frame within these blocks is always not stored in the buffer of the secondary station; unless the first frame in the last window transmission was erroneous. So, the secondary only needs to inform the status of the middle four blocks within the next predicted window. These four blocks are bit mapped by the four unused bits in extended control field of *S*-frame without making any modification to it. The size of first block b_1 equals to (window size+1)/4. The middle four blocks consist of the subsequent (window size+1)/8 frames each and are denoted by b_2, b_3, b_4 and b_5. The remaining ((window size+1)/4)-1 frames belong to the last block b_6.

C. Proposed Frame Format of SupervisoryFrame

IrDA has extended the control field of Information frame (*I*-frame) and Supervisory frame (*S*-frame) if the negotiated speed between the two stations is 4Mbps or higher [9]. For our proposed scheme we have only considered the extended control field format of *S*-frame as we assumed that the secondary has no information data to be transmitted to the primary station. Fig. 1 shows that the extended control field of S-frame has four unused bits (4-7) in the first octet. In our proposed BBWR scheme, these four bits are denoted as Block Status (*BS*) field and contains the bit map information for the middle four blocks of the next window i.e. bit 4, 5, 6 and 7 represents the status of block b_2, b_3, b_4 and b_5 respectively. The 2-bit *SS* field is used to identify the function of S-frame. For our proposed scheme, *SS*=11 indicates that the frame has the bit map information of blocks in BS field as well as the next expected frame number in N(R) field. Currently this value is not being used by IrLAP.

D. Retransmission Strategy of the Proposed Scheme

In this work, the transmission of a large amount of information data from the primary to the secondary station is considered. It is assumed that the primary station always has information data ready for transmission. Information frame (*I*-frame) carry data from primary to secondary station. The secondary does not transmit information to the primary and responds only with Supervisory frame (*S*-frame). It is also assumed that *S*-frames are small enough to be always received error free.

In BBWR scheme, the primary station sends Information frames (*I*- frame) until the number of transmitted frames equals to the maximum window size. In the last frame of the current window, the primary sets the P bit to poll the secondary and waits for the acknowledgement as well as the block status information for a certain period of time. If this time expires without any response from the secondary, it sends a Supervisory frame (*S*-frame) to force the secondary to acknowledge by sending the next expected frame number (E) and the block status information.

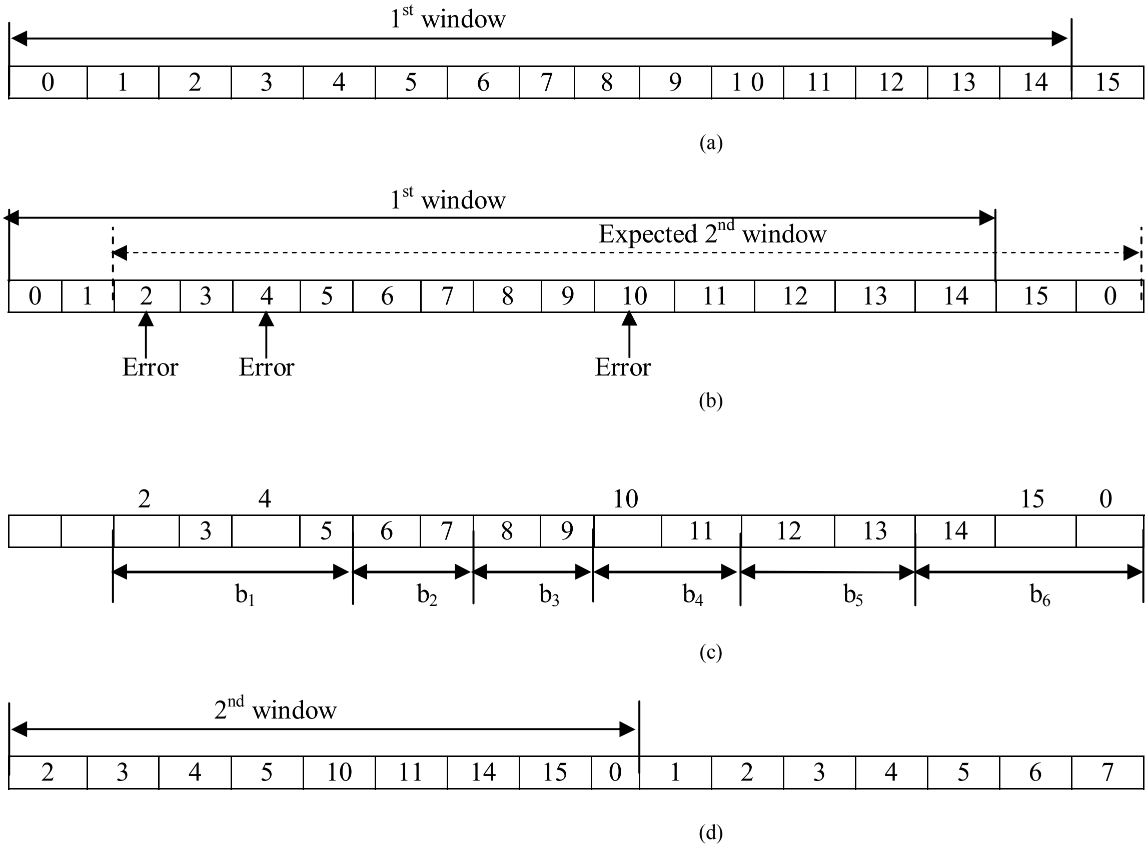
← Block Status →									
0	0	0	0	*S*	*S*	0	1	N(R)	P/F
7	6	5	4	3	2	1	0	1-7	0

Figure 1. Extended control field format of *S*-frame

At the receiving end, when the secondary station receives an *I*-frame, it extracts the frame sequence number and compares with the next expected frame number. If the numbers are equal implying that the received frame is in sequence, information data is extracted and passed to the upper layer. At the same time, the secondary station increases the next expected frame number by one (modulo *N* where *N* is the total sequence number). It also checks the buffer for the next expected frame whether it is already stored there for being out of sequence in the previous transmissions. If it finds the frame stored there, information data is extracted and sent to the upper layer to release the corresponding buffer position. The next expected frame number E is also increased by 1 and the same procedure continues until it can not find the next expected frame in the buffer. But, if the received *I*-frame is not in sequence, the system considers two cases. Either one of the previous *I*-frames in current window transmission was lost due to CRC error or the frame was stored in the buffer and is sent to the upper layer during the buffer check phase for an earlier expected frame as described earlier.

For the first case, the system enters into exception state and the frame is stored in the corresponding buffer position unless it is already occupied by the same frame during earlier window transmissions. E remains unchanged and all the subsequent error free frames within the same window are stored in the similar fashion. During the exception state, no information data is passed to the upper layer and this state exists until the frame sequence number of a received frame N(S) equals E. For the other case, the secondary simply discards the frame.

When the secondary gets the poll bit in the last frame of the current window, it predicts the next window of the primary station based on the expected frame number E and divides the whole window in *n* blocks which is already explained in subsection *B* of the following section. Then it checks the status of the blocks by comparing the corresponding frames stored in the buffer. If a block has all frames stored in the buffer, it is considered to be ignored by the primary station during next window transmission. The secondary informs this information to the primary by setting the corresponding bit of the Block Status (*BS*) field in the *S*-frame in which it also sends the next expected frame number. This has been also explained earlier in the subsection *C* of the following section. After receiving this S-frame which is assumed to be received error free all the time for its small size, the primary calculates the next window starting from the next expected frame number and divides the whole window into blocks which are already predicted by the secondary in advance. Then it checks the Block Status (*BS*)



(a)

(b)

(c)

(d)

Figure 2. (a) Primary station during first window transmission (b) Secondary station during receiving first window (c) Buffer state of the secondary station after first window transmission; Predicted next window is divided in six blocks b_1, b_2, b_3, b_4, b_5 and b_6. (d) Primary station during second window transmission

field of the received S-frame. If any bit position within the BS field is 1, the corresponding frames of that block are not retransmitted by the primary station and the current window size is reduced. Otherwise the primary transmits or retransmits all the frames of the current window and performs like the existing GBN scheme.

Fig. 2 explains the operation of BBWR ARQ scheme for W=15 frames and the maximum sequence number 15. In Fig. 2(*a*), the primary station selects the first window from frame number 0 to 14 and sends them accordingly. In Fig. 2(*b*), the secondary station receives frames error free up to frame sequence number 1 and extracts the corresponding information data to send it to the upper layer. But it receives frame 2 erroneously and therefore discards it. When it receives frame 3 correctly but certainly in out of sequence, it enters into the exception state and stores the frame in the corresponding position of buffer. Similarly it stores frame 5, 6, 7, 8, 9, 11, 12, 13 and 14 in the buffer but discards the erroneous frames 4 and 10. In Fig. 2(*c*), the secondary station predicts the next window starting from frame 2 and divides the whole window in six blocks. Then it calculates the block status information comparing its buffer. Block b_2, b_3 and b_5 have all frames stored in the buffer. So, the bit map for b_2, b_3, b_4 and b_5 equals 1101. Secondary sends this information as well as the next expected frame number, which is 2 in this case, to the primary. In Fig. 2(*d*), the primary sets the next window from frame 2 to frame 0 and divides it in the same blocks that secondary predicted in advance. Then it sends all the corresponding frames except the frames of blocks b_2, b_3 and b_5.

III. PERFORMANCE ANALYSIS

To examine the performance of the proposed BBWR scheme and the effect of different link parameters on it, a set of simulation runs was performed using the OPNET™ simulation package [10]. Our OPNET simulator simulates IrLAP station behavior for 100Mbit/s half duplex infrared links using BBWR scheme and GBN scheme.

Fig 3 plots throughput efficiency versus BER for the proposed BBWR scheme and the existing GBN scheme for 100Mb/s link data rate (C) with turn-around time (t_{ta}) 0.1ms and frame data length (L) 2KB. It shows that the BBWR ARQ scheme with window size (W) 127 frames provides an excellent performance over a wide range of bit error rates for 100 Mbit/s links. However, in the case of GBN scheme, the employment of large window size 127 results in high throughput (98%) for low BER only but renders the link operation very vulnerable to higher BER. But using the proposed BBWR scheme with this large window size of 127 frames results in the same throughput (98%) as using the GBN scheme with W=127 for low bit error rate and provides throughput in usable range for a wide range of bit error rate including high BER. The improvement of the throughput using the BBWR ARQ scheme Compared to the existing GBN scheme with W=127 is significant over a wide range of bit

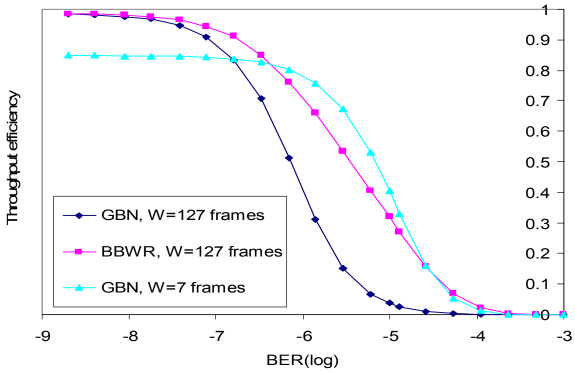


Figure 3. Throughput efficiency versus BER for t_{ta}=0.1ms, L=2KB and C=100Mbit/s

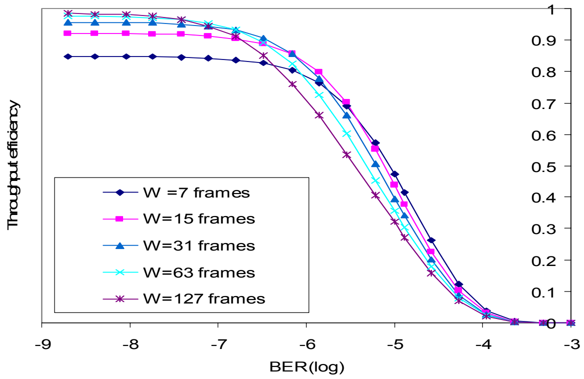


Figure 4. Throughput efficiency versus BER for BBWR ARQ scheme with t_{ta}=0.1ms, L=2KB and C=100Mbit/s.

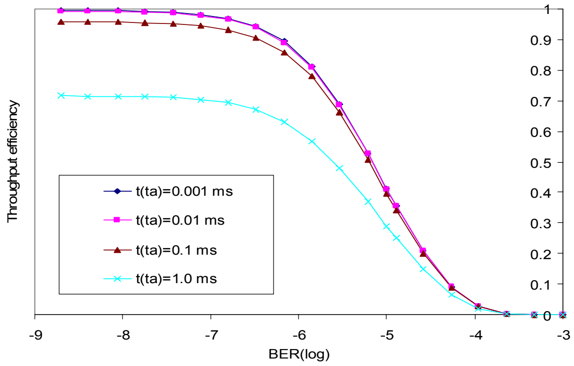


Figure 5. Throughput efficiency versus BER for BBWR with W=31 frames, L=2KB and C=100Mbit/s.

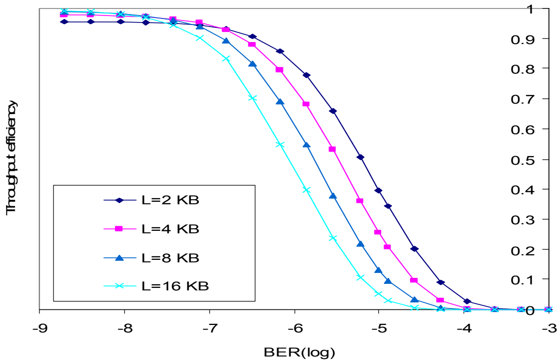


Figure 6. Throughput efficiency versus BER for BBWR with W=31, t_{ta}=0.1ms and different frame data length (L).

error rate (from10^{-7} to10^{-4}). It is also shown that the proposed scheme with W=127 provides almost the same robustness as using GBN scheme with W=7 but at the same time it provides almost 15% higher throughput than the GBN scheme for lower BERs. This improvement is achieved because in BBWR ARQ scheme, all the error free but out of sequence frames following the first erroneous frame are stored in the buffer and most of them are not retransmitted.

The effect of increasing window size on the throughput efficiency of proposed BBWR scheme for 100 Mbit/s link with t_{ta}=0.1ms and L=2KB is shown in Fig. 4. Window size increase results in some improvement in throughput efficiency for low BERs but significant decrease for high BERs. Excellent throughput efficiency at low BERs can be achieved for window size W=127 frames but the throughput is very much vulnerable to the high BER. The figure also depicts that window size W=31 frames can achieve almost the same throughput at low BERs and the performance degradation due to high BER is considerably less. So, for our proposed scheme, we will consider the window size as 31 as it provides an excellent performance over a wide range of bit error rate compared to the throughput using other window sizes. Another advantage of this lower window size is that it needs less sequence number, only 31 to be sufficient for maximum sequence number. As a result, the buffer size both at the primary and the secondary station decreases. Henceforth we will only consider the window size W=31 frames to analyze the performance our proposed scheme.

Fig. 5 shows throughput efficiency of BBWR scheme over 100Mbit/s links using W=31 for different minimum turnaround time t_{ta} varying from 1.0ms to 0.001ms. The figure shows that turn around time t_{ta} has significant effect on the throughput efficiency at low BERs. There is an immense improvement in throughput efficiency for decrease in t_{ta} from 1.0ms to 0.1ms. More than 30% increase in throughput efficiency is achieved at low BERs. Though the improvement is not at the same ratio for further decrease in t_{ta} from 0.1ms to 0.01ms, the throughput efficiency is achieved over 99% due to this decrement at BER= 10^{-8}. The figure also reveals that the throughput performance is almost the same if t_{ta} is decreased from 0.01ms to 0.001ms. Based on this, we can deduce that reducing t_{ta} from 0.01ms to 0.001ms does not improve throughput significantly and it is not therefore necessary.

The effect of frame data length (L) on the throughput efficiency at different BERs is shown in Fig. 6. The figure depicts that the throughput efficiency can be increased to the level of 99% using L=16 KB. But it degrades from a low BER (10^{-7}) and reaches less than 80% at BER=10^{-6}. As we decrease the data length by half of the previous size, the throughput also decreases to a narrow extent but the robustness to high BERs increases. For L=8 KB the throughput is 10% higher than that of the previous data length at BER=10^{-6}. For the data length

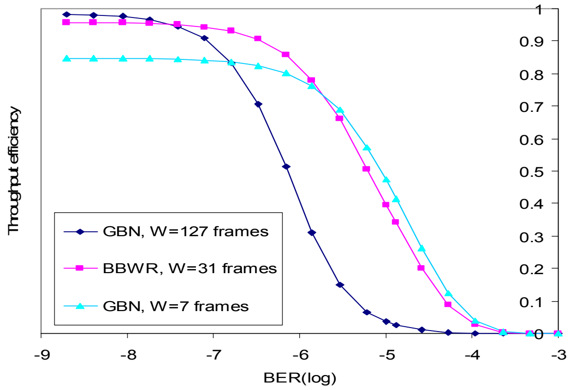


Figure 7. Performance comparison of BBWR with *W*=31 frames, t_{ta}=0.1ms and *L*=2KB.

L=2 KB the throughput is at the satisfactory level of 95% for very low BER (approximately 10^{-9}). But for this data length the throughput remains almost over 80% even at high BER 10^{-6}.

Finally, Fig.7 compares the throughput performance of BBWR at *W*=31 frames with GBN at *W*=127 frames and at *W*=7 frames. For this comparison we have considered the minimum turn around time t_{ta} to be 0.1ms and frame data length *L* to be 2 KB. Although the existing GBN scheme shows good throughput performance using *W*=127 frames for low bit error rate, it is very much vulnerable to high BERs. On the other hand, it shows less vulnerability to high BER when it operates at *W*=7 frames but the throughput efficiency remains 10% to 15% lower for low BERs (approximately 10^{-9} to 10^{-7}). However in the case of Block Based Window Retransmission ARQ scheme operating with *W*=31 frames can achieve some great extent of performance in terms of throughput and robustness to vulnerability. For low BER (approximately 10^{-9}), it achieves throughput efficiency at the satisfactory level of 96% which is only 0.02% less than the throughput efficiency of GBN with *W*=127 at same BER. Moreover the throughput efficiency of BBWR remains in the usable range of over 80% for a wide range of BER including high BER (approximately 10^{-9} to 10^{-6}). At higher BERs (10^{-6} to 10^{-4}), it provides almost the same robustness as using GBN scheme with *W*=7.

IV. CONCLUSIONS

This paper examines the performance of a new block based window retransmission ARQ scheme to alternate the existing GBN ARQ scheme for 100Mbit/s infrared links. Such a high data rate may be considered for next generation IrDA optical wireless point to point links. It has been shown that the proposed BBWR offers high throughput performance even at high bit error rates. So, this scheme can be strongly considered for future high speed infrared links. The simulation results indicate that a turnaround time of 0.1ms and window size of 31 frames for BBWR ARQ would yield excellent throughput results over wide BER range. Moreover, the additional buffer needed at the receiving end adds only a little complexity to the system as the size of the buffer can be reduced for window size 31. Finally the proposed scheme saves some energy consumption for the transmitter by reducing the number of correctly received out of sequence frames to be retransmitted.

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