

**SIMULTANEOUS OPTIMISATION OF WINDOW AND FRAME SIZE FOR**  
**MAXIMUM THROUGHPUT IrDA LINKS**

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**Abstract**

A new method for simultaneous optimisation of both window and frame size link layer parameters for maximum IrLAP throughput is presented. The significance of the F-timer value on throughput performance is explored. A protocol improvement that utilises special Supervisory frames (S-frames) to pass transmission control is proposed. This results in maximum throughput performance when both optimal window and frame size values are implemented.

**Introduction**

Millions of devices, such as laptops, printers, digital cameras and mobile phones, are shipped every year equipped with infrared wireless ports [1]. The devices follow standards defined by Infrared Data Association (IrDA) for their information transfer needs. IrDA addresses low cost, point to point, indoor links. The links are half duplex of data rates ranging from 115.2Kbit/s using standard serial hardware to 16Mbit/s with high-speed hardware extension. IrDA hardware is driven by IrLAP [2], the IrDA data link layer. Analytical models for IrLAP throughput are discussed

in [3] and an IrLAP performance analysis has been presented in [4]. Optimum IrLAP performance for maximum throughput for high BER can be achieved by adjusting link layer parameters, such as window and frame size. Use of optimum window size values for fixed frame size or optimum frame size values for fixed window size and the resulting throughput improvement are presented in [5]. This work studies the optimisation of IrLAP throughput performance by simultaneous adjustment of window and frame size parameters. Simple equations for simultaneously optimal window and frame size values for maximum throughput are derived by taking the first derivative of the throughput equation. Results indicate that the simultaneous adjustment reaches the maximum throughput performance for any BER and therefore better than the single adjustment of either window or frame size. Current analysis reveals that the time detriment due to  $t_{Fout}$  timer expiration significantly reduces throughput performance when window and frame size are simultaneously adjusted. A protocol improvement that reduces  $t_{Fout}$  timer delays is proposed. For this improvement, the analytical model based on the concept of ‘window transmission time’ [3] is modified and a new simple formula for IrLAP throughput is reached. Throughput performance is highly increased by employing the proposed protocol improvement and simultaneous optimal window and frame size values.

### **Optimum throughput analysis**

Table 1 lists the symbols used for IrLAP analysis. The symbols for  $t_s$ ,  $t_l$ ,  $t_{ack}$ ,  $p$  and  $D_b$  are defined by:

$$t_s = \frac{l'}{C}, \quad t_l = \frac{l+l'}{C}, \quad t_{ack} = 2t_{ta} + t_s, \quad p = 1 - (1 - p_b)^{l+l'}, \quad D_b = lD_f \quad (1)$$

Throughput  $D_b$  is given by [5]:

$$D_b = l \frac{1-p}{p} \frac{(1-(1-p)^N)}{Nt_l + p(t_{Fout} + t_s) + t_{ack}} \quad (2)$$

Optimum values for window size  $N$  for fixed  $l$  and optimum values for frame size  $l$  for fixed  $N$  are given by [5]:

$$N_{opt} = \sqrt{\frac{2t_{ack}C}{l^2 p_b}} \quad l_{opt} = \sqrt{\frac{2(Nl + t_{ack}C)}{N^2 p_b}} \quad (3)$$

Using (2), deriving  $\frac{\partial D_b}{\partial N}$  and  $\frac{\partial D_b}{\partial l}$  and solving for  $\frac{\partial D_b}{\partial N} = \frac{\partial D_b}{\partial l} = 0$ , we derive the simultaneous optimal  $N$  and  $l$  values for maximum throughput. To a good approximation, they are given by

$$\boxed{l_{opt} \approx \sqrt{\frac{l'}{p_b}}} \quad \boxed{N_{opt} \approx \sqrt{\frac{2t_{ack}C}{l'}}} \quad (4)$$

### Results and protocol improvement

Figure 1 compares throughput efficiency versus BER for 16Mbit/s links employing  $N=127$  frames and  $l=16$ Kbits with links employing optimal window and frame size values simultaneously. For links with  $N=127$  frames and  $l=16$ Kbits, throughput degrades with BER increase due to the large number of out of sequence frame transmissions [5], i.e. frames following an error frame in a windows transmission. By employing optimal window and frame size values simultaneously, the probability of out of sequence frame transmissions is reduced and a significant throughput increase is observed. The remaining factor that reduces throughput is the time detriment due to  $t_{Fout}$  timer expiration as shown in Figure 2. The situation is explained as follows. The primary station reverses link direction by setting the P-bit in the last I-frame it transmits. As BER increases, frame error probability is increased and many I-frames with P-bit set are lost. As a considerable amount of delay time (500ms) is used for every lost P-bit, throughput efficiency degrades seriously. A protocol modification is

suggested here to cope with this problem. The modification suggests that the primary station should not set the P-bit in the last I-frame in a window transmission but to transmit a new Receive Ready (RR) frame carrying the P-bit following this last I-frame. As RR-frames are very small, P-bits are seldom lost even for high BER. In this case the IrLAP throughput is given by

$$D_b = l \frac{1-p}{p} \frac{(1-(1-p)^N)}{Nt_I + t_s + t_{ack}} \quad (5)$$

Throughput efficiency for links employing the RR-improvement without the optimal window and frame size values is plotted in Fig 1. As RR-frames are very small, the additional RR frames introduce negligible delays for low BER. A slight throughput increase for high BER is observed as the main factor that reduces throughput is the transmission of out of sequence frames. If optimal window and frame size values are employed simultaneously along with the RR improvement, Fig 1 shows a significant throughput increase. In this case, the key factor that reduces the maximum throughput efficiency is the minimum turnaround time, a physical layer parameter.

Fig 1 presents a significant throughput increase by reducing  $t_{ta}$  to 0.01ms.

Figure 3 plots optimal window and frame size values for 16Mbit/s IrDA links with  $t_{ta}=0.1$ ms. It is observed that for a high range of BERs (less than  $10^{-6.5}$ ), equation (4) suggests that frame size values greater than 16Kbits (which is the maximum value allowed for IrLAP) should be employed. For this range, optimum  $N$  values are given by eq. (3) instead of (4) as frame size value is constant.

Equations (4) can be rewritten as

$$l_{opt} l_{opt} P_b = l' \quad N_{opt} l_{opt} P_b \frac{N_{opt} l_{opt}}{2} = t_{ack} C \quad (6)$$

Finally eq. (6) reveal that optimum throughput is achieved when a) the probability of a bit error in a frame ( $\approx l_{opt} p_b$ ), times the number of frame bits that have to be retransmitted due to this error ( $\approx l_{opt}$ ) must be equal to the frame bit overhead  $l'$  and b) the probability of a bit error in a window frame transmission ( $\approx N_{opt} l_{opt} p_b$ ), times the numbers of bits that have to be retransmitted in the following frames due to the error occurred, which on average is half the window  $\frac{N_{opt} l_{opt}}{2}$ , is equal to the acknowledgement time in bits  $t_{ack} C$ .

## References

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## Table and figure captions:

Table 1: Parameters used in modelling IrLAP throughput

Fig. 1 Throughput against BER for 16Mbit/s link,  $t_{Fout}=500ms$

- ◆  $N=127$ ,  $l=16Kbits$ ,  $t_{ta}=0.1ms$ , non optimum
- ◇ optimum  $N$  and  $l$ ,  $t_{ta}=0.1ms$
- ×  $N=127$ ,  $l=16Kbits$ ,  $t_{ta}=0.1ms$ , P-bit in RR, non optimum
- optimum  $N$  and  $l$ ,  $t_{ta}=0.1ms$ , P-bit in RR
- △ optimum  $N$  and  $l$ ,  $t_{ta}=0.01ms$ , P-bit in RR

Fig. 2 Time allocation of various IrLAP tasks against BER

Link rate = 16Mbit/s,  $t_{ta} = 0.1ms$ ,  $t_{Fout}=500ms$ , simultaneous optimal  $N$  and  $l$

- useful data transmission (throughput efficiency)
- ◇ retransmission of correctly received out of sequence frames
- × retransmission of error frames
- ◆  $t_{Fout}$  timer expiration
- reversing link direction (hardware latency)

Fig. 3 Simultaneous optimal values for window and frame sizes versus BER.

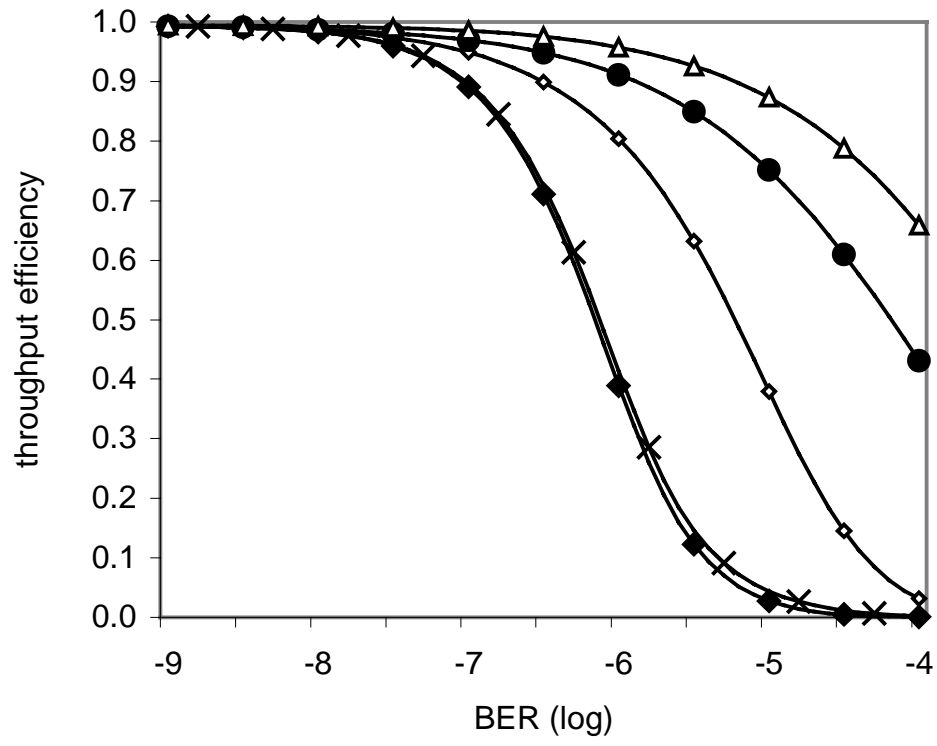
Link rate = 16Mbit/s,  $t_{ta} = 0.1ms$ .

- ◇ Optimum window size
- △ Optimum frame size

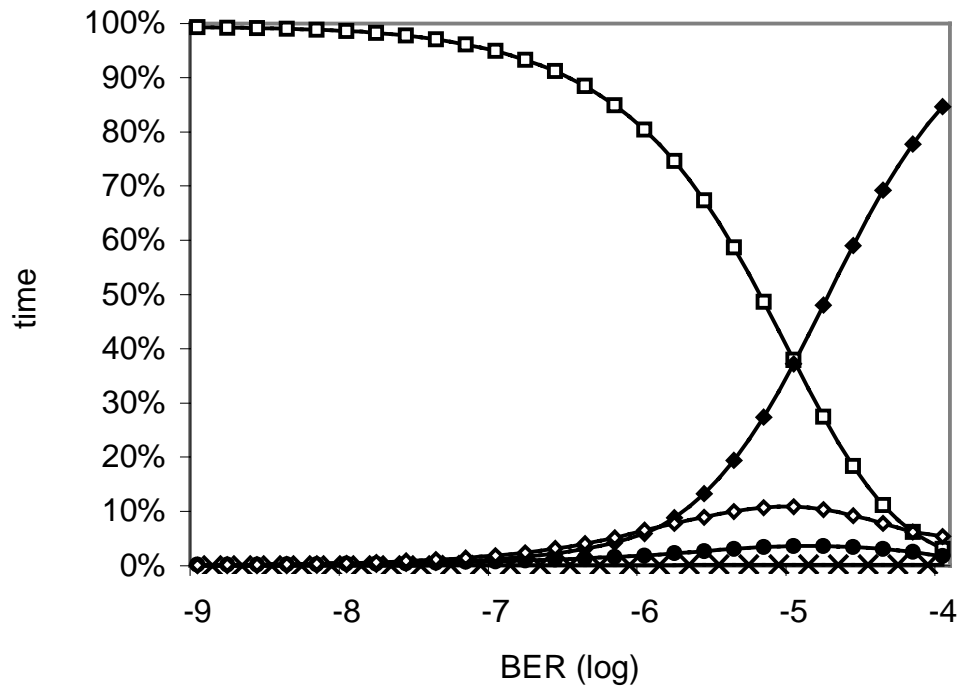
**Table 1**

<b>Symbol</b>	<b>Parameter Description</b>	<b>Unit</b>
$C$	Link data baud rate	bits /sec
$p_b$	Link bit error rate	-
$p$	Frame error probability	-
$l$	I-frame message data length	bits
$l'$	S-frame length / I-frame overhead	bits
$t_I$	Transmission time of an I-frame	sec
$t_S$	Transmission time of an S-frame	sec
$t_{ta}$	Minimum turn-around time	sec
$t_{ack}$	Acknowledgement time	sec
$t_{Fout}$	F-timer Time-out period	sec
$D_f$	Frame throughput	frames/sec
$D_b$	Data throughput	bits/sec

Figure 1



**Figure 2**



**Figure 3**

