IrLAP IrDA Protocol Throughput Dependence on Processor Speed

P. Chatzimisios and A. C. Boucouvalas

Multimedia Communications Research Group,
School of Design, Engineering and Computing,
Bournemouth University, Fern Barrow, Poole, Dorset, BH12 5BB, UK
{pchatzimisios, tboucouv}@bournemouth.ac.uk

ABSTRACT. In this work the effect of processor speed on the IrDA IrLAP throughput performance of 16 Mbit/s wireless infrared links is examined. An improved analysis is presented linking processor speed and throughput of IrLAP. The analytical results are being extended to derive simple equations for maximising throughput by optimising either frame or window size. Simple equations for the optimum values for frame and window sizes are derived which depend on processor speed and results are produced for different processor speed and BER values. The optimum values include delays due to preparation processing time of frames and acknowledgement packets during transmission and reception.

1. Introduction

As wireless networking grows rapidly, the human desire for accessing real-time information anywhere without the need to be linked with wires is increasing. Recent advances in wireless technology have equipped portable devices with wireless capabilities that allow networked communication even while a user is mobile. Portable devices range from laptops, digital cameras and personal digital assistants (PDAs) to mobile phones and printers.

The IrDA standard has been developed to address indoor, high speed, short range infrared links requiring low power provided with low cost. IrDA also offers the advantage of being easy to implement and simple to use, in addition to the high data rates achieved. The IrDA standard defines links offering half-duplex, point-to-point links of data rates ranging from 115.2 Kbit/s [1] to 16 Mbit/s with high-speed extensions [2].

IrLAP, the data link layer of the IrDA protocol stack, specifies the parameters that infrared devices must negotiate before establishing a link for data transfer. These parameters are data rate, maximum turnaround time, minimum turnaround time, maximum window size and maximum frame size. A more detailed description of IrLAP, which is derivative of the HDLC protocol [3], is given in [4].

2. IrLAP Protocol description and parameter definitions

In order to calculate the link throughput, a mathematical model has been developed in [7] using the concept of "Window Transmission Time" (WTT). WTT represents the time needed for a complete window frame transmission and for acknowledgements and delays concerning this transmission. It incorporates time needed for I-frame (information frame) transmissions, acknowledgements for the received frames, for reversing the direction of the link and time wasted in possible timer time-out delays.

For ARQ protocols, as described in [5], WTT also includes the time needed for preparing each frame for transmission (p_1), processing the received frames by the receiver (p_2) and time for processing the acknowledgement in the transmitter (p_3). According to [6], $p_1 = p_3 = 4x10^3/v$, where v is the processor speed in MHz. Since processing times p_1 and p_2 are mainly for calculating the 32-bit CRC upon preparation and reception of a frame respectively, it can be assumed that $p_1 = p_2$. Therefore, the processing times are assumed to be $p_1 = p_2 = p_3 = 4x10^3/v$.

In our work the saturation case is considered. The transmitter always has information ready for transmission. For that reason, a window of *N* frames will be transmitted before the link reverses direction.

We consider here a hardware architecture, which is represented by the timing diagram of figure 1, in order to derive the IrLAP throughput including the effect of processing time. A window transmission of 7 frames is considered.

The transmitter prepares the first frame *f1* consuming time p_1. The frame is transmitted and arrives at the receiver without delay as it is assumed propagation delay is very small and negligible. The receiver needs time equal to p_2 to process the frame and the transmitter prepares the next frame.

After sending the last frame, the transmitter waits for an acknowledgement packet. The receiver processes

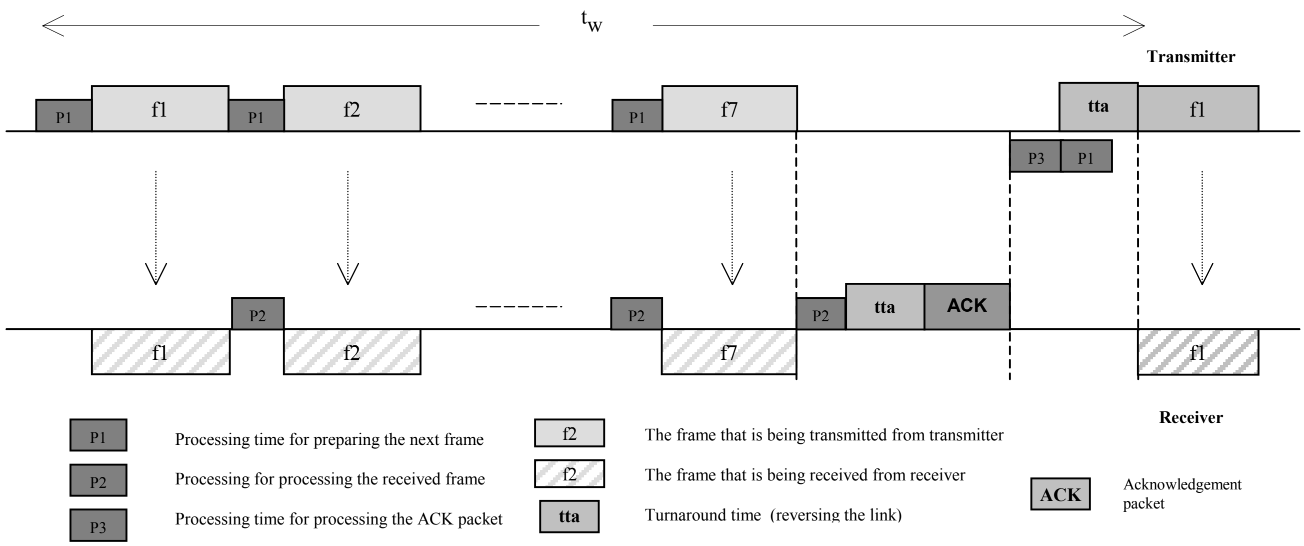

Figure 1. *Timing diagram of data frame transmission for window size of 7*

the last frame and the station's receiver circuit require time t_{ta} to recover after the transmission. Following this turnaround time, the receiver sends an acknowledgement packet and it takes p_3 time for the transmitter to process it. Subsequently, the sender can continue with a new window transmission of frames.

The parameters used in the current analysis are shown in Table 1.

The values for t_S, t_I, p and D_b are given by:

$$t_S = \frac{l'}{C}, \quad t_I = \frac{l+l'}{C},$$
$$p = 1-(1-p_b)^{l+l'}, \quad D_b = lD_f \tag{1}$$

Para meter	Description	Unit
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 turnaround time	sec
t_{ack}	Acknowledgement time	sec
t_{Fout}	F-timer Time-out period	sec
D_b	Data throughput	bits/sec
p_1	Preparation time of an I-frame	sec
p_2	Processing time of an received I-frame	sec
p_3	Processing time of an S-frame	sec

Table 1. *IrLAP analysis parameters*

3. IrLAP Throughput Analysis

In [7][8][9] link throughput was derived without considering the influence of processing time and it is given by:

$$D_b = l\frac{1-p}{p}\frac{\left(1-(1-p)^N\right)}{t_w} \tag{2}$$

Considering frame processing times, the window transmission time becomes:

$$t_w = Nt_I + p(t_{Fout}+t_s)+t_{ack}+(N-1)p_1 \tag{3}$$

where t_{ack} with processing times included is:

$$t_{ack} = 2t_{ta} + t_S + p_2 + p_3 \tag{4}$$

Consequentially, we derive the following equation for the data throughput D_b including the effect of processor speed as given by:

$$D_b = l\frac{1-p}{p}\frac{(1-(1-p)^N)}{Nt_I + p(t_{Fout}+t_s)+t_{ack}+(N-1)p_1} \tag{5}$$

Further and in order to achieve maximum throughput, optimum window size values for fixed frame size and optimum frame size values for fixed windows size are derived.

Equation (5) allows us to derive (by differentiation) optimum values for specific link layer parameters.

A. Optimum Window Size

In order to obtain maximum throughput, the optimum values for different link parameters are required. Equation (5) is differentiated and set equal to zero.

For small *p,* we can assume that:

$$(1-p)^N \approx 1 - Np + \frac{N(N-1)}{2}p^2$$

If $d = (pt_{ta} + pt_s + t_{ack} - p_1)/(p+1)$, it is derived:

$$(-pt_I)N^2 + (-2pd)N + 2d + pd = 0 \qquad (6)$$

If it is approximated that $pd << 2d$, $-2pd < 2d$, $-2pd < -pt_I - pp_1$, equation (6) becomes:

$$N_{opt} = \sqrt{\frac{2(t_{ack} - p_1)}{pt_I + pp_1}} \qquad (7)$$

Considering that for $l >> l'$, $p \approx lp_b$ and $t_I \approx \frac{l}{C}$, finally, optimum window size is given by:

$$\boxed{N_{opt} = \sqrt{\frac{2(t_{ack} - p_1)C}{lp_b(l + p_1C)}}} \qquad (8)$$

B. Optimum Frame Size

Reducing frame size decreases the discarding of correctly received information for every bit error occurrence. On the other hand, each frame transmission requires transmission of certain amount of overhead as flags, control field, FCS etc. As a result, optimum frame size values must balance between the time required to retransmit correctly transmitted data in frames containing error bits and the time required to transmit frame overheads [10]. The derivative of D_b versus l is taken and set equal to zero in order to calculate optimum l values. A number of approximations have to be considered. More specific, for small p_b values:

$$p = 1 - (1-p_b)^{l+l'} \approx 1 - (1 - (l+l')p_b) = (l+l')p_b \qquad (9)$$

$$(l+l')p_b t_{Fout} \approx 0 , \quad (l+l')p_b t_s \approx 0 \qquad (10)$$

We set the derivative equal to zero in order to obtain optimum values of l. Assuming that $N \approx N-1$ and after some algebra optimum frame size is found as:

$$\boxed{l_{opt} = \sqrt{\frac{2(Nl' + t_{ack}C + Np_1C)}{N^2 p_b}}} \qquad (11)$$

4. Analysis results and discussion

Figures 2,3 and 4 show throughput efficiency against BER for processor speeds 50MHz, 100MHz and 500MHz, respectively, using optimum and non-optimum parameter values for frame and window size. When optimum values are not employed, throughput decreases significantly as BER increases no matter what the processor speed is. However, employing optimum frame or optimum window size, optimises throughput. When optimum frame size is implemented, an improved performance can be derived for throughput, especially in the case of higher processor speeds. However, adapting the window size in accordance to N_{opt} (10), always results in the best link performance for low error rates and for any processor speed. Although throughput drops in all cases when the BER increases, better performance can be derived in high processor speeds.

Figure 5 plots throughput efficiency against processor speed for various BER values. For each BER, there are three different cases being plotted using optimum frame size, optimum window size and non-optimum values, with *N=127, l=16384*. By implementing optimum values for frame size *l* given by (13) or for window size *N* given by (10), an improved performance compared to non-optimum case is achieved. As shown in the figure, throughput increases as the processor speed increases for any BER value. However, if the processor speed is higher than 80 MHz, throughput doesn't increase significantly. For high BER values (BER=10^{-6}) it is necessary to have processor speed at least 10 times the data rate (160 MHz) before the throughput saturates.

For a 16 Mb/s link, figure 6 shows optimum values for frame and window size that maximize throughput for various BER values. The figure depicts that optimum frame size values are affected significantly from the processor speed. Alternatively, it is observed that optimum window values don't depend highly on processor speed. More specifically, if BER is 10^{-6}, l_{opt} is reduced to values under 4Kbits, to cope with transmission errors. For low BER (<10^{-8}), l_{opt} values are above the limit of 16K, which is not allowed in the IrLAP protocol. Moreover, if the processor speed is higher than 160 MHz, the optimum frame size isn't affected significantly. Finally, there is no substantial change on the optimum window size, if the processor speed is higher than 80 MHz.

5. Conclusions

In this paper, the influence of processor speed on throughput of a 16Mbit/s wireless link has been examined. It has been shown that using high processor speed results in a better performance of the link for all link BER values. Furthermore, the effect of processor speed on the optimum values of frame and window size that lead to maximum throughput has been studied. Results indicate that optimum values for frame size highly depend on processor speed. On the contrary, processor speed doesn't affect significantly optimum window size values. Although it depends on the design of each wireless device, there is no substantial increase in throughput if the processor clock frequency is 10 times higher than the data rate if optimum frame size values are used; if optimum window size values are employed and the processor clock frequency is 5 times higher than the data rate, the throughput doesn't increase significantly. This is a useful conclusion as high processor speed has important implications on the power consumption and the cost of the wireless device.

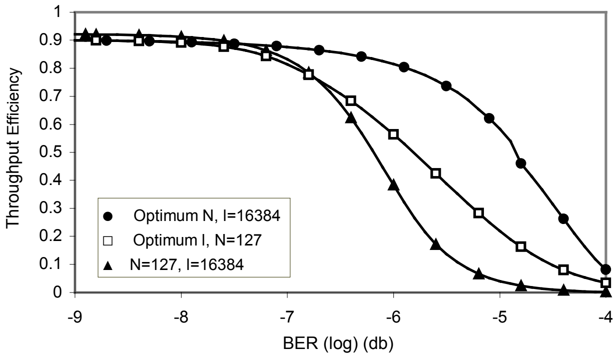

Figure 2. *Throughput vs BER for processor speed 50 MHz*

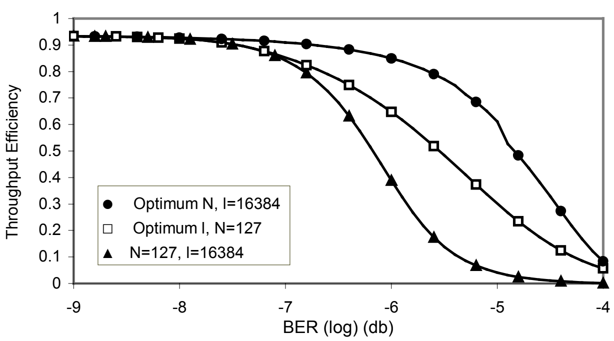

Figure 3. *Throughput vs BER for processor speed 100 MHz*

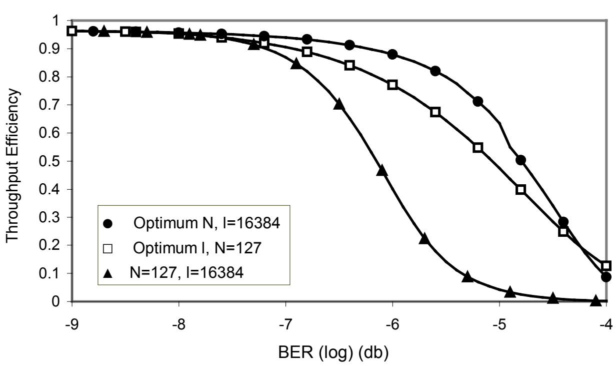

Figure 4. *Throughput vs BER for processor speed 500 MHz*

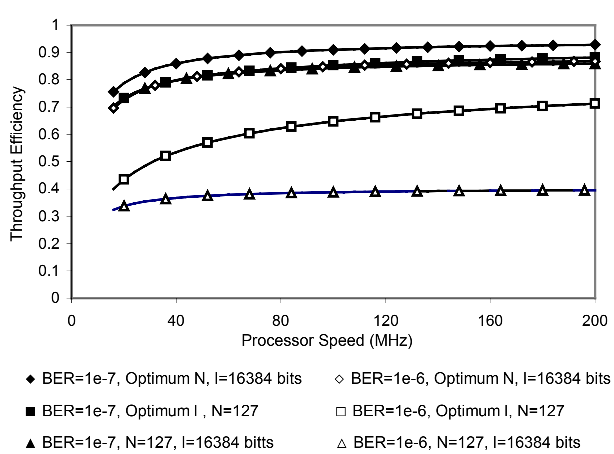

Figure 5. *Throughput vs for processor speed for various BERs*

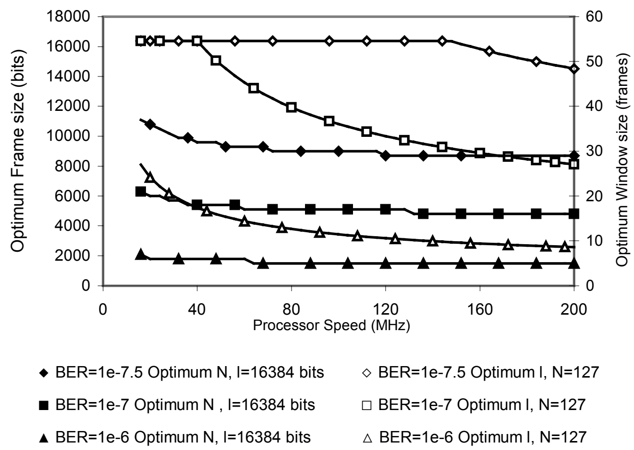

Figure 6. *Optimum frame and window size vs processor speed*

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