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Simultaneous optimisation of window and frame size for maximum throughput IrDA links

V. Vitsas and A.C. Boucouvalas

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 the 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 115.2 kbit/s using standard serial hardware to 16 Mbit/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 Letter 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 is 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 greatly 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_I, t_{ack}, p and D_b are defined by:

$$t_S = \frac{l'}{C} \qquad t_I = \frac{l+l'}{C} \qquad t_{ack} = 2t_{ta} + t_S$$
$$p = 1-(1-p_b)^{l+l'} \qquad D_b = lD_f \tag{1}$$

Throughput D_b is given by [5]:

$$D_b = l\frac{1-p}{p}\frac{(1-(1-p)^N)}{Nt_I + p(t_{Fout}+t_S)+t_{ack}} \tag{2}$$

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

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

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

$$l_{opt} \simeq \sqrt{\frac{l'}{p_b}} \qquad N_{opt} \simeq \sqrt{\frac{2t_{ack}C}{l'}} \tag{4}$$

Table 1: Parameters used in modelling IrLAP throughput

Symbol	Parameter description	Unit
C	Link data baud rate	bit/s
p_b	Link bit error rate	–
p	Frame error probability	–
l	I-frame message data length	bit
l'	S-frame length/I-frame overhead	bit
t_I	Transmission time of an I-frame	s
t_S	Transmission time of an S-frame	s
t_{ta}	Minimum turnaround time	s
t_{ack}	Acknowledgment time	s
t_{Fout}	F-timer time-out period	s
D_f	Frame throughput	frames/s
D_b	Data throughput	bit/s

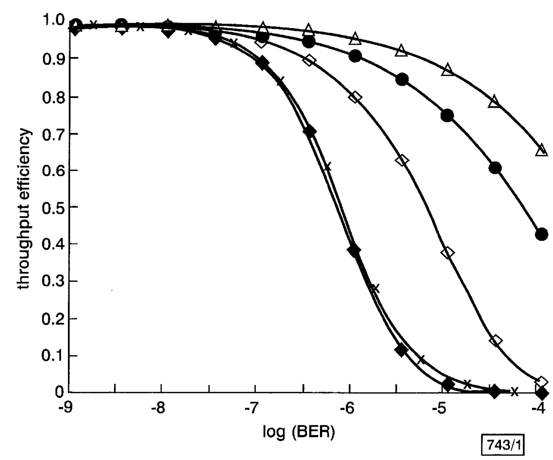

Fig. 1 *Throughput against BER for 16 Mbit/s link, t_{Fout} = 500 ms*

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

Results and protocol improvement: Fig. 1 compares throughput efficiency against BER for 16 Mbit/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 increase of BER owing 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 Fig. 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 (500 ms) 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 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

$$D_b = l\frac{1-p}{p}\frac{\left(1-(1-p)^N\right)}{Nt_I + t_S + t_{ack}} \qquad (5)$$

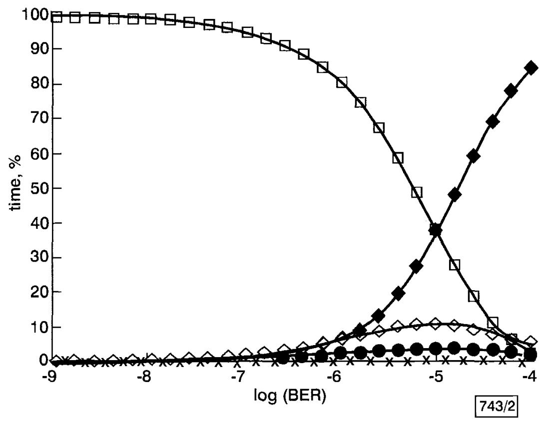

Fig. 2 *Time allocation of various IrLAP tasks against BER*

Link rate = 16 Mbit/s, t_{ta} = 0.1 ms, t_{Fout} = 500 ms, 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)

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, this being because 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, significant throughput increase results (see Fig. 1). 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 0.01 ms.

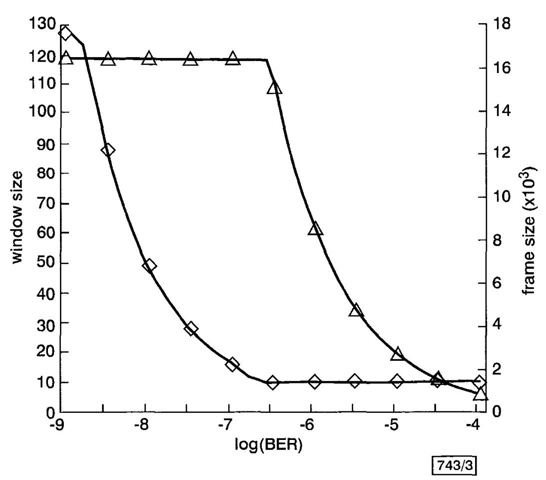

Fig. 3 *Simultaneous optimal values for window and frame sizes against BER*

Link rate = 16 Mbit/s, t_{ta} = 0.1 ms.
◇ optimum window size
△ optimum frame size

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

Eqn. 4 can be rewritten as

$$l_{opt}\, l_{opt}\, p_b = l' \qquad N_{opt}\, l_{opt}\, p_b \frac{N_{opt}\, l_{opt}}{2} = t_{ack} C \qquad (6)$$

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

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Technique for increasing optical spectral efficiency in millimetre-wave WDM fibre-radio

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A novel technique for increasing the spectral efficiency of millimetre-wave fibre-radio systems by employing wavelength interleaving in conjunction with optical single sideband modulation, is proposed and demonstrated. The technique has been demonstrated experimentally by employing a wavelength interleaved optical add-drop multiplexer and transmission of a 155 Mbit/s BPSK signal at 36 GHz over 20 km of fibre.

Introduction: Millimetre-wave (mm-wave) fibre-wireless networks have been proposed for the provision of future broadband services with data rates > 1 Gbit/s [1]. Proposed architectures for transportation of these radio signals over fibre include RF-over-fibre where the signal is distributed to and from the base station (BS) as a mm-wave modulated optical signal [1]. This approach has the advantage of simplifying the BS design; however, fibre chromatic dispersion can severely limit the performance of such links [2]. Modulation using the optical single sideband with carrier (OSSB+C) technique has been demonstrated as a means to overcome such dispersion-induced power penalties [1].

The use of wavelength division multiplexing (WDM) in mm-wave fibre-radio systems offers a number of advantages in terms of simplified upgrade and management of the radio network [1]. However the implementation of WDM in a mm-wave fibre-radio system incorporating OSSB+C modulation leads to poor spectral efficiency, as a WDM channel spacing in excess of 50 GHz is