EFFECT OF RANDOM ALIGNMENT SWAY ON THE PERFORMANCE OF IRDA HANDHELD DEVICES

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Abstract – We present the results from a performance simulation of an IrDA based infrared wireless link involving a handheld portable device in which there is a random variation of angular alignment due to natural directional hand 'sway' of the device operator. The variation in transmitter angle can affect the link bit-error-rate (BER) by going out of alignment with the receiver, thus affecting the link throughput and file transfer delay due to the requirement of retransmissions at the data link layer of the IrDA protocol if data packets are lost. Results are produced from a simulation model of the IrDA protocol using the OPNET™ package, with physical layer properties based on an analytical model of the link topology, and an angular sway model based on a Gaussian distribution of angular positions.

1. Introduction

Handheld portable computing devices such as palmtop computers and personal-data-assistants (PDAs) are becoming increasingly powerful and popular. Such devices commonly incorporate IrDA (Infrared Data Association) wireless infrared capabilities for file transfer, printing and even network connection [1]. IrDA links use a narrow transmission beam with limited optical power in order to be within eye safety regulations [2] and limit power consumption, which can be crucial for portable devices. The IrDA physical layer standard specifies that the transmission cone half angle is in the range 15° to 30°, and that the link bit-error-rate (BER) is no worse than 10^{-8} over a distance of 1 meter when correctly aligned [3]. In this paper we show how a variation in angular alignment of a handheld portable device transmitting data to a stationary device, can affect the BER of the link, and thus affect the throughput of the link, due to the natural hand 'sway' of the operator pointing the device. The data link layer of the IrDA protocol (IrLAP – Infrared Link Access Protocol) is closely based on the HDLC protocol operating in Normal Response Mode (NRM) which provides error recovery by retransmitting lost packets (i.e. those that fail the CRC due to bit errors) and following packets within the transmission 'window' that become out of sequence [4]. We determine the performance of the link with a simulation of the IrDA protocol using the OPNET™ package. The model normally determines packet loses from a specified BER. In this situation, the BER is calculated from an analytical model of the link topology and a model of angular 'sway' using a random angular variation from a normal distribution. We show the effect on file transfer delay with a variation of the 'broadness' of the extent of angular sway and of the transmitter radiation lobe.

2. IrDA Physical Layer Analysis

An analysis of an IR link topology can relate the receiver signal-to-noise-ratio (SNR) to link distance and receiver and transmitter alignment angles. The link BER can then be directly determined from the SNR. Consider the link topology as shown in figure1 where the transmitter with lobe cosine exponent *m* and alignment angle of θ, and the receiver with lobe cosine exponent *n* and alignment angle φ are at a distance *d*.

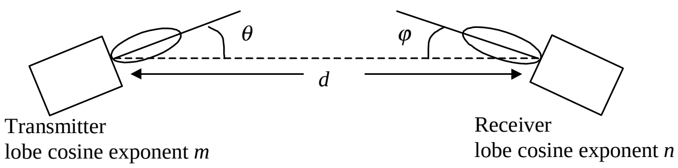

Figure 1: IR link topology

We consider an IrDA link for which the BER at a distance of 1 meter with $\theta = \varphi = 0$ is set at 10^{-9}. The BER of a link is related to the SNR using the *Q* function by $BER = Q(\sqrt{SNR})$.

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Since Q(6) ≈ 10^{-9} we can determine the general BER by:

$$BER = Q\left[\frac{6Cos^{m}\theta Cos^{n}\varphi}{d^{2}}\right] \qquad (1)$$

The formula given in (1) eliminates the need for transmitter and receiver characteristic values and background noise information by assuming that the link has been designed to meet the minimum requirements of the IrDA specification. Figure 2 below shows the transmission 'footprint' of angular alignment and distance required for a link BER of 10^{-9} for values of the transmitter cosine exponent *m* from 5 to 35. Figure 3 shows the variation in BER against the alignment angle at a link distance of 1 meter for the same values of *m*. This shows how narrowing the transmission beam affects the responsiveness of a receiver to transmitter angular alignment variation when the link distance is close to the maximum range.

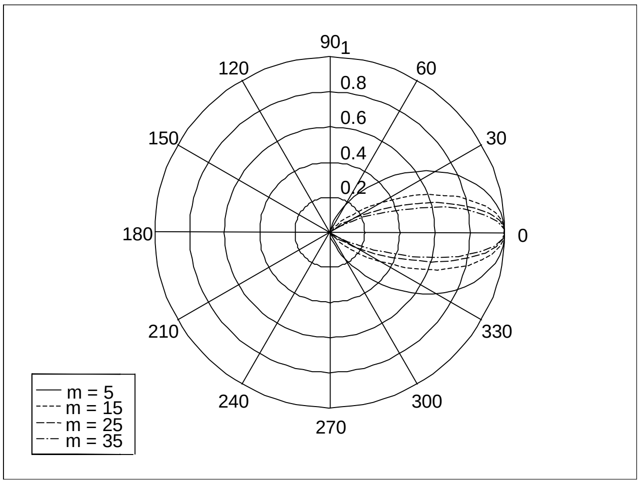

Figure 2: Profile plot of BER Vs distance and angle for IrDA link

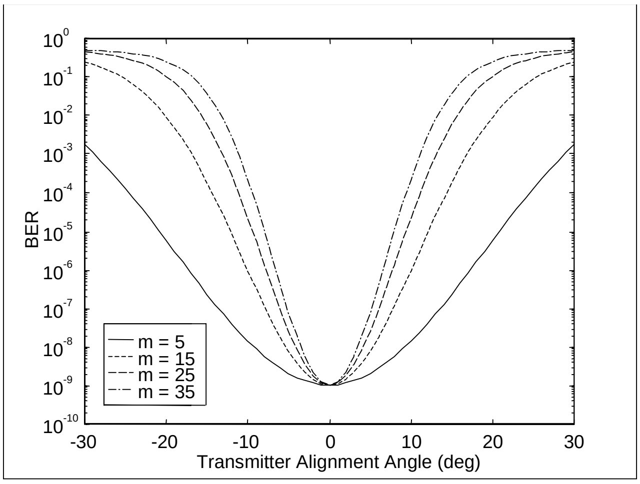

Figure 3: BER Vs Transmitter Angle for IrDA link with d = 1 meter

3. Angular 'sway' model

The angular 'sway' model is based on random angular end-points taken from a normal (i.e. Gaussian) distribution centred on 0° with a specified standard deviation σ as shown in figure 4. The angular movement is taken to be within a fixed plane. By specifying different values for σ, the 'broadness' of the angular sway can be set to simulate user characteristics. A set of steps of fixed angular size are taken to move between the endpoints, thus representing a constant rate of angular motion. A rate of 20 degrees per second was used in the simulation.

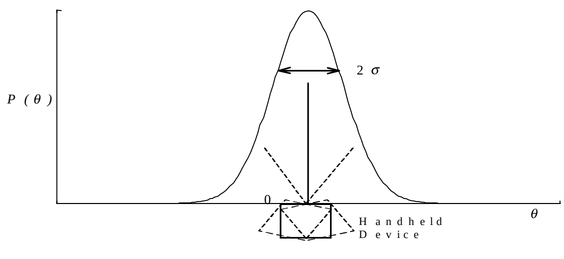

Figure 4: Gaussian distribution of handheld device alignment

4. Application of Alignment Sway Model to OPNET IrDA Model

The model developed is based on a simulation model of the IrDA protocol using the OPNET™ network modelling and simulation package. OPNET™ uses finite state machine processes to define C coded simulation routines [6]. The IrDA simulation model is principally based on the IrLAP protocol where lost or out-of-sequence packets are retransmitted [7]. The link BER is determined using the formula in (1) with the link distance set to 1 meter and the receiver alignment angle set to 0° and the lobe cosine exponent set to 1. The relevant transmitter alignment angle is taken from the Gaussian distribution sway model and updated at regular intervals. The bit-error-rate attribute of the primary to secondary link is set the value of the calculated BER. The resultant throughput is dependent on the set BER and also on the IrLAP link parameter settings of data rate, minimum turn-around time, maximum turn-around time, maximum window size, and packet data size. These values can be used in determining the time required to transmit a file of specified size bytes with no packet errors. This can be used in determining the percentage increase in file transmission time over that from an aligned stationary device.

5. Results and Analysis

The plots shown in figures 5, 6, 7 & 8 are from simulation runs of the model at 115200 bps (the maximum serial IR speed) and 4 Mbps (the maximum fast IR speed) and using angular distribution σ (standard deviation) of 5 and 10 degrees, which represent a narrow and broad angular 'sway' respectively. The transmitter lobe cosine exponent *m* is set to 15. The plots show the angular variation, the resultant BER (log10), the resultant throughput, and the resultant packet delay over the time required to transmit a file of 1 MB size for the 115200 bps link and 10 MB size for the 4 Mbps link. Figure 5 shows the output for the 4 Mbps link with σ = 5°. It can be seen that the BER is kept below 10^{-6} but increases above this monetarily on 5 occasions during the file transfer which in turn causes the throughput to reduce at these points. The final packet delay can be seen to be around 0.8 of a second. This represents an increase of only 4% of the base transmission time of around 20 seconds, which is not very significant. For the plot in figure 6, for which σ = 10°, it can be that the effect on the BER is much greater with value often being worse than 10^{-4}. The final packet delay is now around 7 seconds which represents in increase in transmission time of 35% which is much more significant.

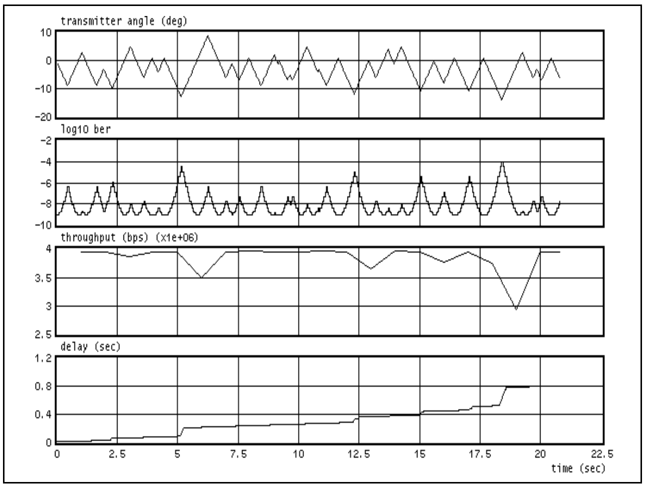

Figure 5: Simulation Output for 10 MB file at 4 Mbps with Angular Distribution σ = 5

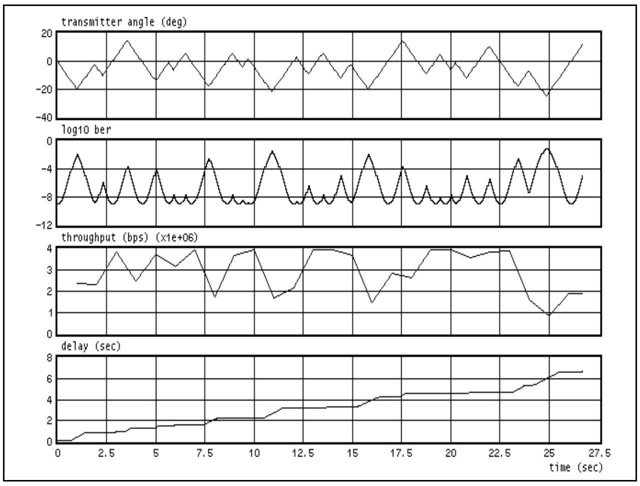

Figure 6: Simulation Output for 10 MB file at 4 Mbps with Angular Distribution σ = 10

For the plot in figure 7 which is for a 1 MB file transmitted at 115200 bps with σ = 5° it can again be seen that the final delay is now around 1.8 seconds which represents in increase of 2.5% over the base transmission time of around 70 seconds. For the plot in figure 8, which is for σ = 10°, it can be seen that the final packet delay is around 32 seconds which represents an increase in transmission time of 45%.

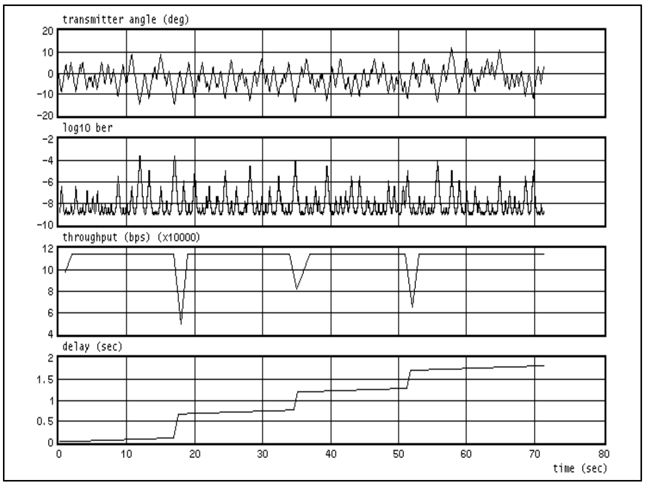

Figure 7: Simulation Output for 1 MB file at 115200 bps with Angular Distribution σ = 5

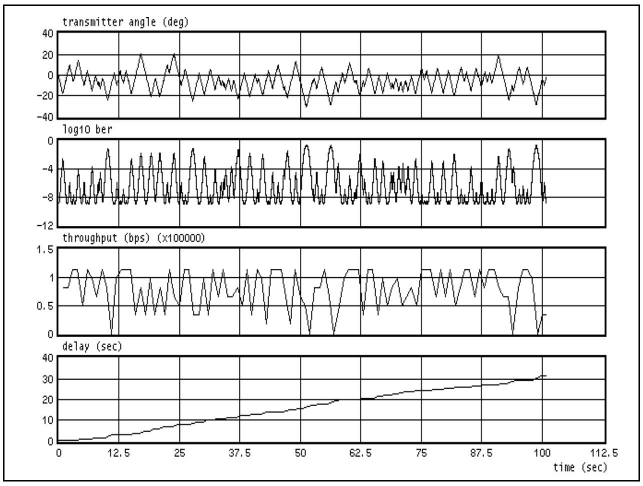

Figure 8: Simulation Output for 1 MB file at 115200 bps with Angular Distribution σ = 10

The plot in Figure 9 shows the % increase in file transmission time over the base transmission time (i.e. with no retransmissions) against ratio of σ to the half-power angle $\theta_{0.5}$ (for which $cos^m(\theta) = 0.5$) for the two data rate of 115200 bps and 4 Mbps, and for values of the transmitter lobe exponent *m* of 15 and 35. The overlaid curves are polynomial fitted 'trendlines'. This shows the same relationship for a particular data rate irrespective of the *m* value. It also shows that for the 115.2 Kbps rate, the file transfer time is approximately doubled when the value of σ approaches the half-power angle. It can also be seen that if the value of σ is approximately half the half-power angle, the file transfer time increases by around 20% regardless of the data rate.

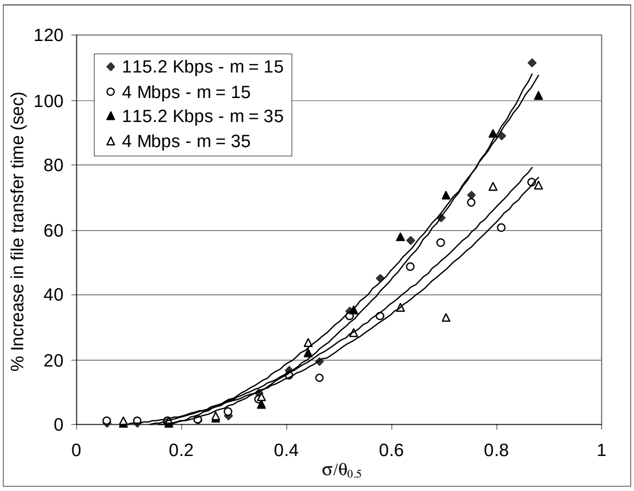

Figure 9: % increase in file transfer time Vs $\sigma/\theta_{0.5}$ for specified *m* value

6. Conclusions

We have shown how the effect of a random alignment variation from the natural hand 'sway' of a handheld infrared wireless device operator can affect the throughput of an IrDA based infrared link and therefore the transfer time of a file. This was achieved by applying a simulation of angular variation based on a normal distribution of angular end-points to a simulation model of the IrDA protocol. By varying the standard deviation of the angular distribution between broad and narrow it was possible to compare the affect for different link data rates.

Acknowledgements

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