

## Performance Analysis of Air-MAC Optical Wireless Protocol

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## Abstract

*A simulation model for the proposed IrDA Advanced Infrared (AIR) protocol is developed. Throughput performance of Air's Reserved mode, which employs an RTS/CTS reservation scheme, is explored. The importance of the CAS window size parameter for different network sizes is presented in relation to the large Slot Time value proposed by the Air standard. The effectiveness of the proposed adaptive Collision Avoidance Slots (CAS) window size, which bases the CAS window size employed on the experienced successful reservations and collisions, is examined.*

## 1. Introduction

The success of the Infrared Data Association (IrDA) in developing standards for indoor Infrared Wireless communications can be measured by the great number of devices, ranging from personal computers to digital cameras, manufactured each year containing wireless ports following standards defined by IrDA [1]. The first IrDA protocol standard is the IrDA SIR (Serial Infrared), suitable for short-range indoor optical wireless point-to-point links. It supports half duplex, point to point links [2], with maximum distance of 1m, an angle of  $\pm 15$  degrees and a Bit Error Ratio (BER) less than  $10^{-8}$ . The IrDA SIR link layer IrLAP [3], is an HDLC derivative. The adopted user model for IrDA SIR standard is 'point and shoot', (where a user aims a handheld device towards another and downloads information).

More recently IrDA worked on a different user model, which allows a pool of users to share the optical medium. This user model requires a medium

access protocol to allow users to access the optical LAN.

IrDA developed new protocol layers called Advanced Infrared (Air). A new Air physical layer (Air-PHY) is proposed [4] and the IrLAP layer was split into three sub-layers, the AIR Medium Access Control (AIR-MAC) [5], the AIR Link Manager (Air-LM) [6] and the Air Link Control (Air-LC) sub-layers.

The Air-PHY [4] uses a four-slot Pulse Position Modulation with Variable Repetition Encoding (4PPM/VR) format with a base data rate of 4Mbps. Transmission rate varies from 250 Kbps to 4 Mbps, trading speed for range. Long-range Air transceivers provide an effective range of 3.8m at 4 Mbps and an effective range greater than 7.6m at 250 Kbps. Wide angle infrared AIR devices operate at an angle of  $\pm 60$  degrees.

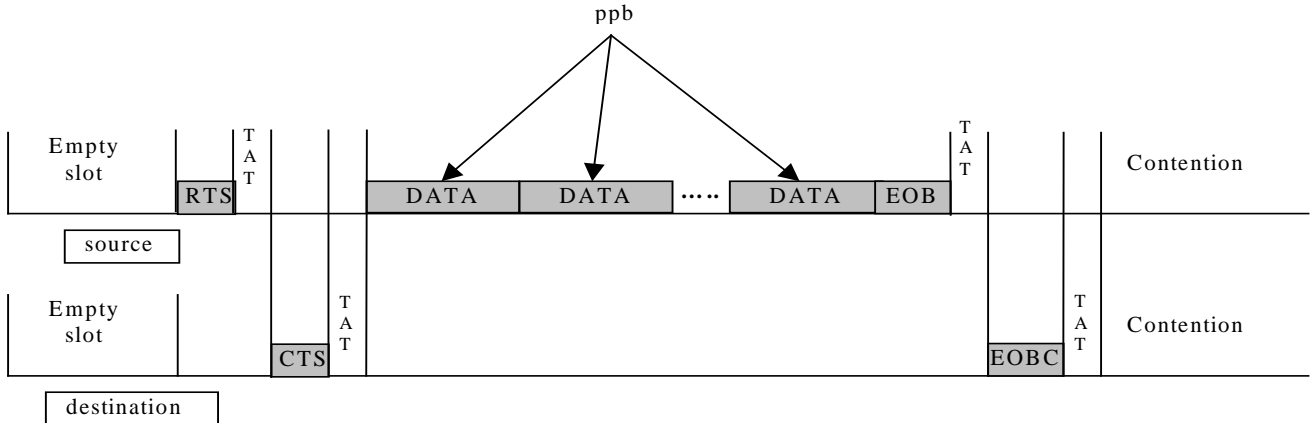
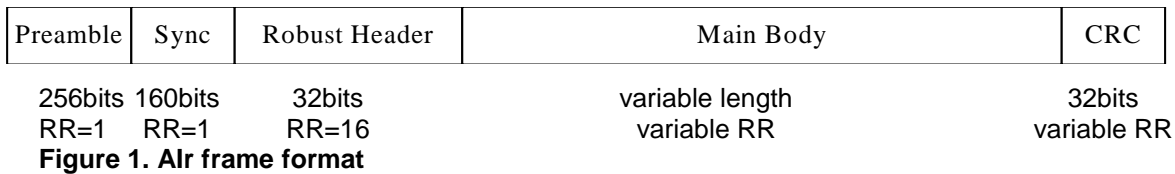
The recently published Air specifications are still in draft state. The specifications present protocol finite state transition diagrams. Based on these state transition diagrams, we have developed a simulator for the Air protocol using C/C++ emulating Air station behaviour. We use the simulator to evaluate protocol behaviour under saturation conditions in contrast to the OPNET™ Air simulator presented in [7] used to examine protocol behaviour for different load conditions. Simulation results allow protocol evaluation and comparison with similar CSMA/CA protocols such as the IEEE 802.11 protocol [8][9].

## 2. The Air-MAC Protocol

The Air MAC sub-layer is a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol [5]. It provides, among others, reliable and

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**Fig.2 Reserved Access scheme**

unreliable modes of data exchange, sequencing of data, adaptive rate scheme and reservation based media access control through Request To Send / Clear To Send (RTS/CTS) packet exchange. The RTS/CTS exchange is implemented to address the hidden station problem [10].

| Repetition Rate | Data rate |
|-----------------|-----------|
| RR=1            | 4 Mbps    |
| RR=2            | 2 Mbps    |
| RR=4            | 1 Mbps    |
| RR=8            | 500 Kbps  |
| RR=16           | 250 Kbps  |

**Table 1. Alr RR enumeration**

The Alr frame format is presented in Fig. 1. The Robust Header (RH) is always transmitted using the maximum allowable Repetition Rate (RR=16) to provide maximum detection sensitivity. Main Body may be transmitted at various RR shown in Table 1.

The transmitter decides the suitable RR for a specific transmission according to its evaluation of the link quality to the receiving station. A receiving station also recommends RR values to the transmitter based on its evaluation of link quality.

### 3. Simulation model

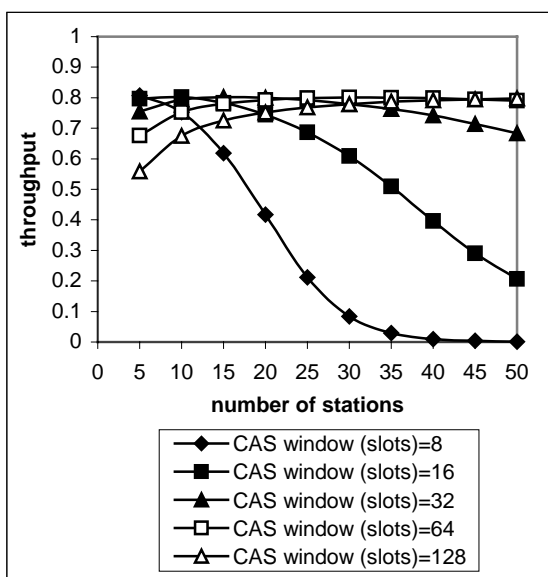
In this work, an Alr wireless LAN of  $n$  stations is examined. We consider a saturation case, meaning that all stations always have a packet ready for transmission. All stations employ the AIR reserved mode access control scheme, which is presented in Fig. 2.

In the current simulation model, an Alr frame body is always transmitted with RR=1 at 4Mbps. DATA frames always carry 16Kbps of user data and the number of DATA packets transmitted in every successful reservation is determined by the packets

|                         | Restriction                    | Suggested<br>Usec | Implemented<br>Usec |
|-------------------------|--------------------------------|-------------------|---------------------|
| $T_{RTS}(RR=16)$        |                                | 244               | 244                 |
| $T_{PA}$                |                                | 64                | 64                  |
| $T_{SYNC}$              |                                | 40                | 40                  |
| $T_{RH}$                |                                | 232               | 232                 |
| Turn Around Timer (TAT) |                                | 200               | 200                 |
| CAS                     | $>T_{RTS}+TAT+T_{PA}+T_{SYNC}$ | 800               | 800                 |
| WFCTS Timer             | $\geq TAT+T_{RH}$              | 632               | 556                 |
| EXIT2 Timer             | $=TAT$                         | 200               | 200                 |

**Table 2. Alr timers and packet element transmission times.**

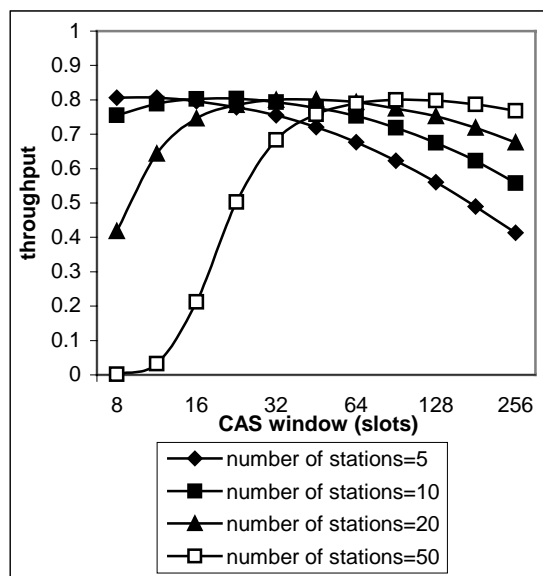
per burst (ppb) parameter. After the last DATA packet, the transmitter sends an EOB (End Of Block) packet requesting termination of current reservation. The destination station responds with an EOBC (End Of Block Confirm) packet, indicating the end of the current reservation. Whenever the direction of packet flow is reversed, the transmitter awaits a Turn Around Time (TAT) to cope with hardware latency. The model assumes that all packets are transmitted error free to all stations except from packets that experience collisions. Time required for transmitting the packet elements is presented in Table 2. The table also presents timer values suggested by the draft standard and the corresponding values used in our simulation model. All protocol suggested values are closely followed with an exemption of the Wait For CTS (WFCTS) Timer value. This timer value expresses the amount of time a station that has transmitted an RTS frame will wait for the corresponding CTS frame. If a valid CTS has not been received within the WFCTS period, the transmitter assumes that a collision occurred and contends again for the medium. The only value that synchronises the transmitter with other stations in contending for the medium is equal to  $CAS-T_{RTS}=556\mu\text{sec}$ . This value is used in our model.



**Figure 3**  
 $C=4\text{Mbps}, l=16\text{Kbits}, ppb=4$

## 4. Simulation results

Alr MAC designers addressed the Collision Avoidance protocol issues using a new approach. The IEEE 802.11 protocol, being a similar CSMA/CA protocol, defines *Slot Time* as the time a station needs to detect a packet transmission from another station. In particular, the IEEE 802.11 specification defines that *Slot Time* accounts for the propagation delay, the time needed to switch from the receiving to the transmitting state and for the time needed for the physical layer to signal the channel state to the MAC layer [11]. Alr *Slot Time* is defined as being greater than the transmission time of an RTS frame, plus the time needed for the RTS transmitter to change from transmitting to receiving state, plus the time needed to detect the beginning of a CTS response [5].

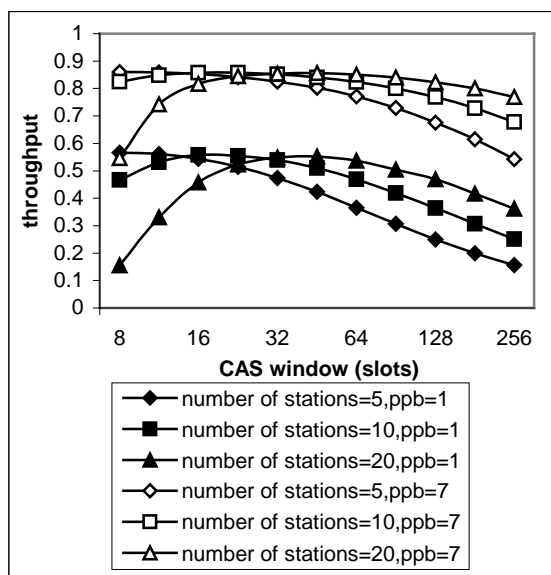


**Figure 4**  
 $C=4\text{Mbps}, l=16\text{Kbits}, ppb=4$

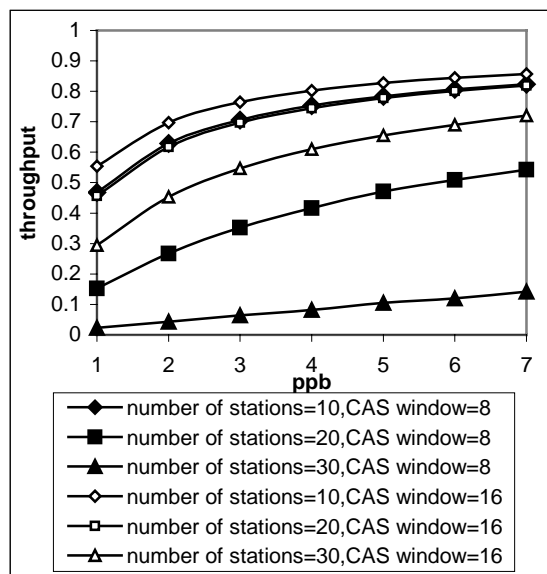
In order to avoid collisions from stations hidden from the transmitter, Alr defines a much greater *Slot Time* to avoid collisions caused by stations not hearing the RTS frame transmission but being able to hear the receiver's CTS frame transmission. This approach provides a much better hidden station approach but, it increases overhead and if an unsuitable CAS window size is selected, idle time wasted on empty slots may seriously limit throughput performance.

Fig. 3 shows throughput performance versus number of stations for various fixed CAS window sizes. If a small CAS window size is selected, throughput seriously degrades when the number of

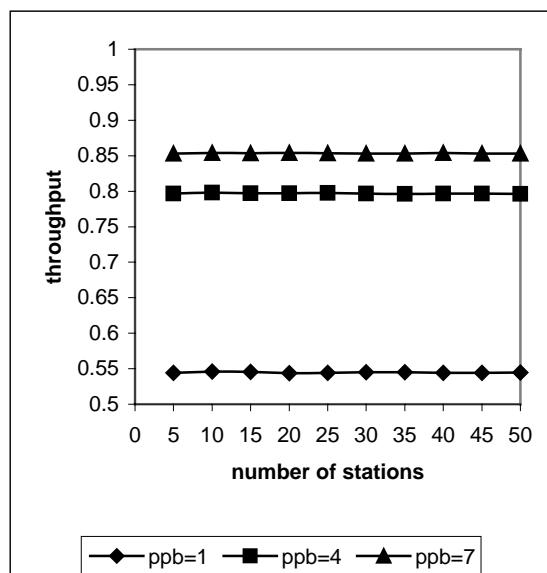
stations increases. Fig.3 also shows that if a large CAS window size is selected, especially for a few contending stations, throughput degradation is caused by the large number of empty CAS slots. Thus, optimum CAS window size selection becomes of key importance if maximum throughput is to be achieved. Fig. 4 plots throughput performance versus CAS window size for different number of contending stations and ppb=4. It shows that a small CAS window size is unsuitable for large networks due to the increased number of collisions while a large window size is unsuitable for small networks due to the increased number of CAS empty slots with large *Slot Time*. Fig. 5 also plots throughput performance versus CAS window size for ppb=1 and ppb=7. It shows that if a large amount of useful data is transmitted at each reservation attempt (ppb=7), throughput efficiency is significantly increased and that if a small amount of information is transmitted at each RTS/CTS reservation, throughput efficiency degrades seriously. Thus, employment of Air reserved mode for small data transmissions becomes questionable. Fig. 6 plots throughput efficiency versus ppb for various CAS window sizes and number of stations. A throughput increase with the increase of ppb is always observed. However, ppb is not always a controllable parameter as it depends on application's communication needs.



**Figure 5**  
C=4Mbps, l=16Kbits



**Figure 6**  
C=4Mbps, l=16Kbits



**Figure 7**  
C=4Mbps, l=16Kbits, adaptive CAS window (increase/decrease by 4).

A close observation of Fig. 3, 4 and 5 reveals that for any network size, there is an optimum CAS window size that maximises throughput. It also reveals the surprising result that maximum throughput achievement is practically independent of network size. To address the proper CAS window size selection problem, Air specification [6] suggests rules for incrementing and decrementing window

size after one or more collisions and one or more successful transmission attempts respectively. AIr specification also defines that CAS window size value should be  $\geq 8$  and  $\leq 255$ .

The simulator developed was used to employ a fixed CAS window size increase in every collision and the same CAS window size decrease in every successful reservation attempt. Throughput achieved is presented in Fig. 7 for a fixed increase/decrease size of 4 for different ppb values. Comparison of Fig. 7 with Fig.4 and 5 reveals that even this simple increase/decrease method achieves the highest throughput performance obtainable by selecting the optimum CAS window size value.

## 5.Conclusions

A simulation model for the proposed Advanced Infrared (AIr) protocol specification is developed. Simulation results for throughput performance of AIr's Reserved mode scheme for different network values is presented. It is shown that the proposed CAS window size employment is very effective in achieving optimum performance for different network scenarios. The proposed large *Slot Time* value is effective in hidden node conditions but Reserved mode employment becomes questionable if small amount of information needs to be transmitted.

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