LINK LAYER PROTOCOL PERFORMANCE OF INDOOR INFRARED WIRELESS COMMUNICATIONS

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ABSTRACT

The increasing deployment of portable computers and mobile devices leads to an increasing demand for wireless connections. Infrared presents several advantages over radio for indoor wireless connectivity but infrared link quality is affected by ambient infrared noise and by low power transmission levels due to eye safety limitations. The Infrared Data Association (IrDA) has developed the widely used IrDA 1.x protocol standard for short range, narrow beam, point to point connections. IrDA addressed the requirement for indoor multipoint connectivity with the development of the Advanced Infrared (AIr) protocol stack.

This work analyses infrared link layer design based on IrDA proposals for addressing link layer topics and suggests implementation issues and protocol modifications that improve the operation of short range infrared connections. The performance of optical wireless links is measured by the utilization, which can be drawn at the data link layer. A new mathematical model is developed that reaches a simple equation that calculates IrDA 1.x utilization. The model is validated by comparing its outcome with simulation results obtained using the OPNET modeler. The mathematical model is employed to study the effectiveness on utilization of physical and link layer parameters. The simple equation gives insights for the optimum control of the infrared link for maximum utilization. By differentiating the utilization equation, simple formulas are derived for optimum values of the window and frame size parameters. Analytical results indicate that significant utilization increase is observed if the optimum values are implemented, especially for high error rate links. A protocol improvement that utilizes special Supervisory frames (S-frames) to pass transmission control is proposed to deal with delays introduced by F-timer expiration. Results indicate that employing the special S-frame highly improves utilization when optimum window and frame size values are implemented. The achieved practical utilization increase for optimum parameter implementation is confirmed by means of simulation.

AIr protocol trades speed for range by employing Repetition Rate (RR) coding to achieve the increased transmission range required for wireless LAN connectivity. AIr employs the RTS/CTS medium reservation scheme to cope with hidden stations and CSMA/CA techniques with linear contention window (CW) adjustment for medium access. A mathematical model is developed for the AIr collision avoidance (CA) procedures and validated by comparing analysis with simulation results. The model is employed to examine the effectiveness of the CA parameters on utilization. By differentiating the utilization equation, the optimum CW size that maximises utilization as a function of the number of the transmitting stations is derived. The proposed linear CW adjustment is very effective in implementing CW values close to optimum and thus minimizing CA delays. AIr implements a Go-Back-N retransmission scheme at high or low level to cope with transmission errors. AIr optionally implements a Stop-and-Wait retransmission scheme to efficiently implement RR coding. Analytical models for the AIr retransmission schemes are developed and employed to compare protocol utilization for different link parameter values. Finally, the effectiveness of the proposed RR coding on utilization for different retransmission schemes is explored.

DEDICATION

Αφιερώνεται στην μητέρα μου Αννα
και στον πατέρα μου Κωνσταντίνο

PUBLICATIONS RESULTING FROM THESIS

I. Awards

[1] V. Vitsas and A. C. Boucouvalas, 'IrDA IrLAP Protocol Throughput Performance Analysis for Optical Wireless Links', Proc. of 2^{nd} International Workshop on Networked Appliances (IWNA 2000), Nov. 30- Dec. 1, 2000, Rutgers Univ., New Jersey, USA **(Best paper award).**

II. Journal publications

[2] V. Vitsas and A. C. Boucouvalas, 'Optimisation of IrDA IrLAP Link Access Protocol', IEEE Journal on Selected Areas in Communications, accepted for publication.

[3] V. Vitsas and A. C. Boucouvalas, 'Performance Analysis of the Advanced Infrared (AIr) CSMA/CA MAC Protocol for Wireless LANs', Wireless Networks, accepted for publication.

[4] V. Vitsas and A.C. Boucouvalas, 'Automatic repeat request schemes for infrared wireless communications', IEE Electronics Letters, vol. 38, no. 5, pp. 244-246, 28th February 2002.

[5] V. Vitsas and A.C. Boucouvalas, 'Simultaneous optimisation of window and frame size for maximum throughput IrDA links', IEE Electronics Letters, vol. 37, no. 16, pp. 1042-1043, 2nd August 2001.

[6] A. C. Boucouvalas and V. Vitsas, 'Optimum window and frame size for IrDA links', IEE Electronics Letters, vol. 37, no. 3, pp. 194-196, 1st February 2001.

[7] P. Barker, A.C. Boucouvalas and V. Vitsas, 'Performance modelling of the IrDA infrared wireless communications protocol', International Journal of Communication Systems, vol. 13, pp. 589-604, 2000.

[8] P. Barker, V. Vitsas and Boucouvalas A.C., 'Simulation analysis of the Advanced Infrared (AIr) MAC wireless communications protocol', accepted for publication in IEE Proceedings Circuits and Systems.

III. International conference refereed publications

[9] V. Vitsas and A. C. Boucouvalas, 'Effectiveness of packet level acknowledgement in infrared wireless LANs', IEEE 55^{th} Vehicular

Technology Conference 2002, VTC Spring 2002, vol. 4, pp. 1814-1818, Birmingham, AL, May 6-9, 2002.

[10] V. Vitsas and A. C. Boucouvalas, 'Performance analysis of the collision avoidance procedure of the Advanced Infrared (AIr) CSMA/CA protocol for wireless LANs', IEEE 55th Vehicular Technology Conference 2002, VTC Spring 2002, vol. 3, pp. 1502-1506, Birmingham, AL, May 6-9, 2002.

[11] V. Vitsas and A. C. Boucouvalas, 'Effectiveness of Selective Reject (SREJ) Automatic Repeat Request (ARQ) scheme with RR-coding in infrared wireless LANs', accepted for publication in CSNDSP 2002, July 15-17, 2002, Staffordshire, UK.

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[13] V. Vitsas and A. C. Boucouvalas, 'Performance evaluation of IrDA Advanced Infrared AIr-MAC Protocol', Proc. of the 5th Multi-Conference on Systemics, Cybernetics, and Informatics, vol. IV, pp. 347-352, Orlando, USA, 2001.

[14] V. Vitsas and A.C. Boucouvalas, 'Performance Analysis of the AIr-MAC optical wireless protocol', International Conference on System Engineering, Communications and Information Technologies, (ICSECIT 2001), Department of Electrical Engineering, University of Magallanes, Punta Arenas, Chile, April 16-19, 2001.

[15] V. Vitsas and A.C. Boucouvalas, 'Throughput analysis of the IrDA IrLAP optical wireless link access protocol', Proc. of the 3rd Conference on Telecommunications (ConfTele 2001), pp. 225-229, April 23-24, 2001, Figueira da Foz, Portugal.

[16] A. C. Boucouvalas and V. Vitsas, '100 Mb/s IrDA protocol performance evaluation', IASTED International Conference on Wireless and Optical Communications, (WOC 2001), June 27-29, 2001 Banff, Canada, pp. 49-57.

NOTE: Most of these publications are available at:

http://dec.bournemouth.ac.uk/staff/tboucouvalas/acbpub.htm

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ABBREVIATIONS

4PPM/VR	4-slot Pulse Position Modulation with Variable Repetition Rate encoding
ACK	Acknowledgement
AIr	Advanced Infrared
AIr MAC	AIr Medium Access Control
AIr LC	AIr Link Control
AIr LM	AIr Link Manager
AP	Access Point
ARQ	Automatic Repeat reQuest
BER	Bit Error Rate
CA	Collision Avoidance
CAS	Collision Avoidance Slot
CDMA	Code Division Multiple Access
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CT	CAS Timer
CTS	Clear To Send
CW	Contention Window
DA	Destination Address
DCF	Distributed Coordination Function
DD	Direct Detection
DSSS	Direct Sequence Spread Spectrum
EOB	End Of Burst
EOBC	End Of Burst Confirm
ETSI	European Telecommunication Standards Institute
F-bit	Final bit
FCS	Frame Check Sequence
FER	Frame Error Rate
FH	Frequency Hopping
FHSS	Frequency Hopping Spread Spectrum
FIR	Fast Infrared
FLACK	Frame Level Acknowledgment
FLACK-M	Frame Level Acknowledgment MAC
FOV	Field Of View
GBN	Go-Back-N
HiperLAN	High Performance Radio LAN
I-frame	Information frame
IrDA	Infrared Data Association
IrLAP	IrDA Link Access Protocol
IM	Intensity Modulation
IR	Infrared
ISM	Industrial / Scientific / Medical
L-PPM	L-slot Pulse Position Modulation
LAN	Local Area Network
LOS	Line Of Sight
MAC	Medium Access Control

MACA	Multiple Access with Collision Avoidance
MBR	Main Body
MT	Mobile Terminal
NoFLACK	No Frame Level Acknowledgment
NoFLACK-ACK	No Frame Level Acknowledgment utilizing LC ACK frames
NDM	Normal Disconnect Mode
NRM	Normal Response Mode
OFDM	Orthogonal Frequency Division Multiplexing
P-bit	Poll bit
P/F bit	Poll/Final bit
PA	Preamble
PAN	Personal Area Network
PCF	Point Coordination Function
PDA	Personal Digital Assistant
PSAP	Physical layer Service Access Point
QoS	Quality of Service
RH	Robust Header
RR	Repetition Rate
RR S-frame	Receive Ready Supervisory frame
RT	Reservation Time
RTS	Request To Send
S-frame	Supervisory frame
SA	Source Address
SEQ-NoFLACK	Sequential No Frame Level Acknowledgment
SIR	Serial Infrared
SNR	Signal-to-Noise Ratio
SREJ	Selective Reject
SYNC	Synchronisation
SW	Stop-and-Wait
TAT	Turn Around Time
TDMA	Time Division Multiple Access
U-frame	Unnumbered frame
VFIR	Very Fast Infrared
VTT	Virtual Transmission Time
WFCTS	Wait For CTS
WLAN	Wireless LAN
WPAN	Wireless Personal Area Network
WTT	Window Transmission Time