An Event Driven MACA Optical Wireless MAC Protocol Simulator

C Vijay and J M H Elmirghani
School Of Engineering, University of Wales, Swansea UK

Abstract

There has been a huge demand for wireless communications in recent years. Though radio is the most popularly used medium, Infrared (IR) has been receiving wide attention. Various MAC protocols are available but mostly for radio communications. The performance of these protocols in optical wireless environment needs to be analysed. A generic simulator was designed to serve this purpose. This simulator includes the features of medium access control layer, packet structure and determination of the system performance. As the simulator is generic, it can be used for a wide range of protocols by making a few changes. This paper discusses Multiple Access with Collision Avoidance (MACA) protocol and analyses its performance in optical wireless environment.

Introduction

Over recent years there has been rapid progress in communication networks driven by the need for information gathering, processing, and distribution. There are two main telecommunications infrastructures: the wide infrastructure using optical fibres and the mobile infrastructures based on wireless communications. Over the recent years mobile communications have taken giant leaps; the increase in availability, production and low cost of mobile phones and PDAs are evidence of this. Wireless technology now reaches or is capable of reaching virtually every location on the face of the earth. Hundreds of millions of people exchange information every day using pagers, cellular telephones, and other wireless communication products [1-2].

There has been extensive research done in the field of IR to augment its performance and considerable amount of work has been carried out at the physical layer level. But to support multimedia services for indoor optical wireless communications, there is a need for more detailed research in the higher layers [3]. There is a requirement for a MAC protocol specifically designed for IR transmission for the control of the wireless bandwidth to mobile nodes, for dealing with the several impairments due to the noisy IR environment, multi-path propagation and user mobility and changes incurred when a node move from one cell to another. There are several MAC protocols already specified for radio communications like MACA, MACAW, CSMA/CA to name a few. As said above, there is a need for a protocol specific to optical wireless communications. There is a necessity to analyse the performance for the different MAC protocols in an optical wireless environment. It is the objective of this paper to report the design and development of a simulator exclusively for optical wireless communications. This simulator provides features of packet structure, design of medium access control layer and performance analysis of different MAC protocols in an optical wireless environment.

Overview of the Simulator

The simulator designed analyses the performance of various MAC (medium access control) protocols in an optical wireless environment. The novel characteristics of the simulator are

- It is dedicated to optical wireless environment with base stations and nodes
- The simulator is not protocol specific. It can be extended to any MAC protocol and extending its features is relatively simple.
- Extensive performance analysis of the protocols in an optical wireless environment in terms of (for example) throughput and average access delay.
- Generic building blocks constructed in C++ and Microsoft Foundation Class (MFC).

The layout of the paper is as follows: an overview of proposed network scenario is presented. This is followed by a description of the general properties of the simulator. The architecture of the wireless MAC simulator is then given with respect to MACA (medium access with collision avoidance) protocol and performance analysis is provided followed by conclusions.

Optical Wireless Network architecture

The proposed architecture of the network is shown in Figure 1.It consists of a cellular network structure. Consider a building for example, where there are many rooms. The entire building consists of a number of cells; smaller rooms may only consist of one or two cells.

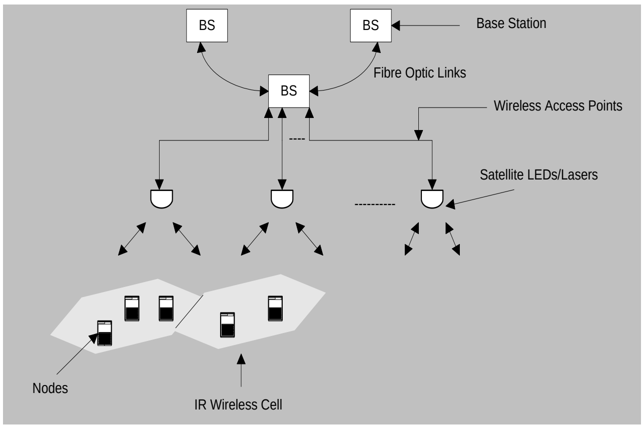

Figure 1. Proposed Network Architecture

In the proposed architecture, we consider an open plan office where there are several nodes moving around. Each cell has a satellite point similar to the optical telepoint discussed in [4] fixed to the ceiling. Every node then transmits to this satellite point using the infrared medium making use of the transceivers fitted to mobile devices. The satellite points in turn transmit to the base station, and the base station corresponds with the nodes regarding the collision avoidance, hidden terminals and detection for the respective protocol. Each of the base stations is connected to a wired optical fibre link, which serves as the backbone of the network and thus allows the entire building to be interlinked..

Medium Access With Collision Avoidance (MACA) Protocol

The simulator is designed for various MAC protocols but this paper emphasises MACA. This protocol was proposed by Karn [6] for use in packet radio as an alternative to CSMA scheme. MACA uses two types of short, fixed – size signaling packets [7]. When station A wants to transmit to station B it sends a Request To Send packet (RTS) to B; the RTS packet contains the length of the proposed data transmission. On hearing the RTS station B replies immediately with a Clear To Send (CTS) packet, provided station B is not currently in a different state. The CTS packet contains the length of proposed DATA transmission. On receiving the CTS, station A sends its DATA immediately. Any station over hearing an RTS will defer all transmissions until sometime after the associated CTS packet would have finished. Similarly any station over hearing a CTS packet defers transmission for the length of expected DATA transmission. In MACA collision between RTS packets can still occur, but they are minimised with a randomised exponential back off strategy. Since there is no carrier sensing in MACA, each station simply adds a random amount to the minimum interval each station is required to wait after over hearing an RTS or CTS packet. The extra random interval would be an integer multiple of the slot time and in MACA the slot time is the duration of RTS packet. Although collisions occur between RTS packet, MACA has an advantage over CSMA as long as RTS packets are smaller than the data packets. It has been found that the collisions occurring between the RTS packets are less expensive than the collisions that would otherwise occur between data packets.

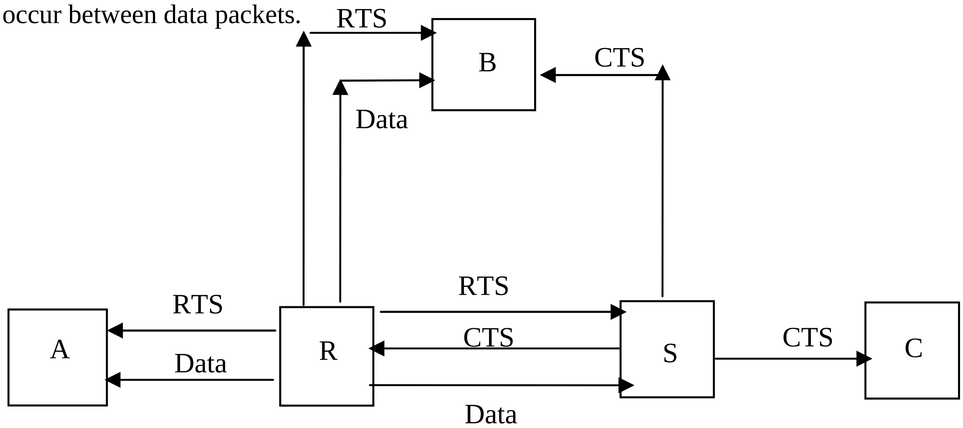

Figure 2: Mechanism of MACA protocol

Design of the Simulator

In this section, a general design description of the simulator is given, the architecture of the simulator is described and finally the system parameters in terms throughput and delay are determined.

General Design Description of the Simulator

There are certain features, which are essential in the simulator for efficiency, ease of use and accuracy. First and foremost, the design of the simulator should be such that it is user-friendly. It should be easy for the user to interface. This led to the development of the simulator in C++ and Microsoft Foundation Class in Visual C++ editor. In visual C++, dialog windows appear and the node motion and the results can be displayed in the respective text boxes.

As the simulation is considered only at the MAC level, the physical events taking place at lower layers [8] usually are not simulated, as it is time consuming. In this simulator, lower-level events are modelled such that the effect of the event appears at the MAC layer. For example, the collision between nodes results in a corrupted message and this can be seen in the message bits.

The design of the simulator is made generic so that the simulator can be extended to be used for various medium access control protocols. The different MAC protocols are designed as separate classes, which inherit the basic features of the simulator using object-oriented concepts. This is one of the main reasons for use of C++ to design the simulator.

Architecture of the Simulator

The simulator employs event driven simulation and is programmed in Visual C++ using object-oriented concepts. The simulator uses Poisson process to generate traffic for each node. A class diagram is designed, as it is the backbone of the simulator. The first step is to identify the classes and objects that will be required and related to each other.

By generalizing the classes, the simulator has an advantage in that it is not protocol specific. It can be used for different protocols (DBTMA, CSMA, MACA, MACAW, PRMA etc) as specified by the user. This paper considers MACA protocol.

CNode is the basic class for the node. This gives a brief description of the node structure. It decides the source and destination nodes. It also generates two short signal packet RTS (Request To Send) and CTS (Clear To Send). It is responsible for generating the packet and converting the packet in terms of 0's and 1's and sending the packet to the CMac class

CMac class is the main and the base class for the entire simulator. Various other MAC classes inherit the basic features from this class. This is the starting point for the simulation and it starts the simulation with nodes being placed randomly in the room. This class checks for the collision and corrects the corrupted message by resending the packet.

Performance Analysis

The performance of the protocol was analysed using the system parameters such as throughput and access delay. The terminals are transmitted at 10Mbit/s and can support a number of different media including speech, data and compressed video. The throughput increases with number of nodes and it reaches a maximum of 22%-25% and saturates after some time as shown in figure 3. The reason for the throughput being low can be attributed to the protocol design, wherein at a time only two nodes can transmit data. These low throughput figures are in line with those published in the literature [6]. Extensions to the protocol are currently being considered where sub carrier multiplexing or wavelength based multiple access are used. As seen in figure 4, the average access delay increases with increase in the number of nodes. The maximum delay predicted (20ms) is suitable for speech and multimedia services where packets delayed more than 20ms are usually dropped.

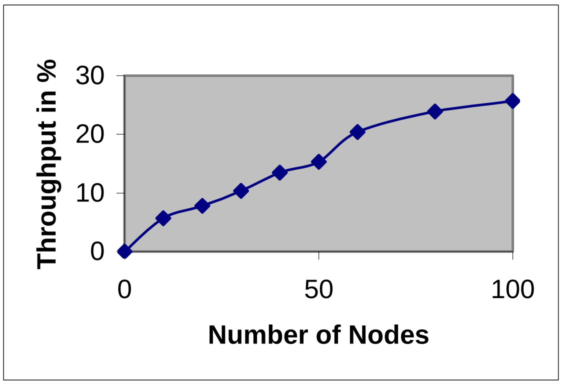

Figure 3: Throughput Vs Number of Nodes

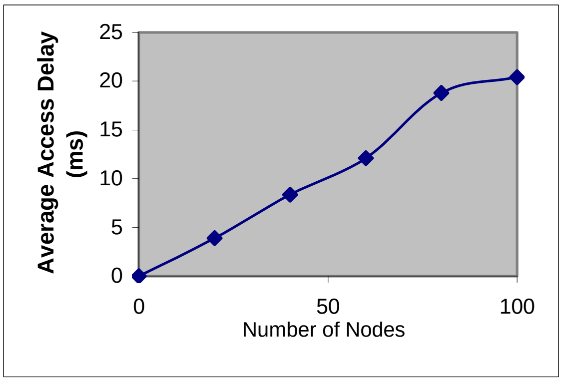

Figure 4: Average Access Delay Vs Number of Nodes

Conclusions

A simulator has been designed and developed to simulate medium access control protocols in optical wireless environment. This simulator is extensible and can be used to test the performance of various MAC protocols in optical wireless environment. The simulator also gives a good indication of the performance of the protocol by determining system parameters like throughput and average access delay.

References

1. www.comsoc.org/pubs/pcm
2. J.Mark, W.Z Hung, "*Wireless Communications and Networking*", Prentice Hall 2003.
3. A.Tanenbaum ,"*Computer Networks*" , Prentice Hall
4. David J.T. Heatley, David R.Wisely, Ian Neild and Peter Cochrane *"Optical Wireless: The Story so far"*, IEEE Communications Magazine, December 1998.
5. Int. Electrotech Commission (IEC), "Safety of laser Products" CEI/IEC 1993 825-1.
6. Phil Karn "MACA – A New Channel Access Method For Packet Radio", ARRL/CRRL Amateur Radio 9th Computer Networking Conference, September 22, 1990.
7. Vaduvur Bharghavan, *"MACAW: A Media Access Protocol for Wireless LANs"*, SIGCOMM 94-8/94 London.
8. Al Ghamdi and JMH Elmirghani, "*Performance Evaluation of a Triangular Pyramidal Fly-Eye Diversity Dectector for Optical Wireless Communications*", IEEE Communications Magazine March 2003 Vol 41. No.3.