Design of a MAC protocol with Call Admission Control procedures

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Abstract
An indoor optical wireless environment with mobile nodes is considered. An eight directional random walk model with consideration of physical barriers is proposed. Using this model, the call arrival and departure rates are determined. The design of medium access control (MAC) protocol with mobility management features is discussed. The handover priority schemes, guard slots and queuing concept is used in the MAC protocol and the call blocking probability, forced termination probability and throughput are determined.

Introduction

There has been extensive work carried out in optical fibre technology over the past twenty years, which has led to many advances in the industry, allowing optical networks to benefit from low attenuation, low cost and high bandwidth. The next evolutionary step was to merge the advantages of optical networks with wireless communication. The emergence of Optical Wireless Communication (OWC) and more specifically infrared (IR) technology is a move towards that goal [1]. Infrared technology offers major performance advantages over traditional cable or radio systems with huge available bandwidths in excess of 1.5 Gbs[2]. Unlike radio and microwave technologies, infrared offers complete freedom from interference or radio licensing regulations. IR provides a degree of security at physical level, as it cannot penetrate opaque objects and thus reducing the problems of interference.

The IR diffused channel is subject to several impairments due to noisy environments, multipath propagation, inherent user mobility and changes incurred due to the movement of the surrounding environment, there is a requirement for a MAC protocol specifically designed for IR transmission for controlling the above mentioned impairments. This MAC layer should incorporate the features of mobility management, as it is one of the most important and challenging issues.

The layout of this paper is as follows: a network architecture scenario is proposed and explained, an innovative mobility model using eight directional Brownian motion is considered as opposed to the four and six directional walks usually studied. The effect of physical barriers on the node motion is included in this model. Using these models, a new set of node arrival and departure rates are determined. A brief description about the handover priority MAC protocol is given incorporating the features of the mobility model. The call blocking probability, forced termination probability and throughput for the system are calculated.

Proposed Network Scenario

The network structure envisaged for the proposed protocol is as shown in Figure 1.

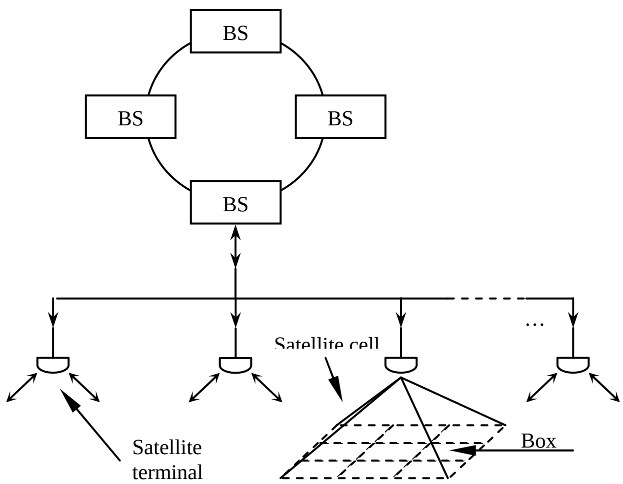

Figure. 1 Optical Wireless Network Architecture

Consider an open plan office, where every room contains many cells. Each user has a mobile unit whose communication medium is infrared. The mobile units acts as transceivers and communicate to the satellite terminals embedded in the ceiling. These satellite terminals provide full ground coverage and are analogous to the telepoint systems described in [3]. As users move around the building, the units switch automatically from one satellite cell to another satellite cell. The satellite terminals are interlinked and connected to the base station. The base stations are in turn interconnected by a high speed ring, which may be a WDM ring for example. The optical wireless links between the user and the satellite terminal could be at least capable of 155 Mb/s, since such systems have already beeen demonstrated [4].

Real World Model

A big open room of size 15m by 15m is considered. The room is divided into 9 cells each of size 5m by 5m. A node can move in any one of the eight compass directions; N, NE,E,SE,S,SW,W and NW and is guaranteed to move every *T* seconds. This constitutes a random walk very similar to two-dimensional Brownian motion. Figure 2 shows the direction of motion the node may take.

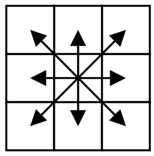

Figure 2: Ilustration of node directions

The node moves a fixed distance before it changes direction and each step is considered to be 0.5 m. The fixed distance considered here is 2m and it can be extended up to 5m. The other key difference between the radio model and this model is the presence of barriers imposed by the walls of the building. As infrared cannot penetrate opaque objects, this factor plays a crucial role in analysing the random walks of the node. The possible combinations of the barriers are considered and results are developed both theoretically and through simulation, for each of the five cells as shown in the Figure 3 as well as for various sizes of the cell [5].

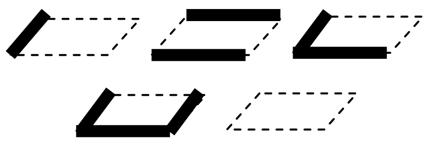

Figure 3: Possible combinations of barriers

Based on these factors, arrival and departure rates of the nodes are determined by simulating the node motion. The simulation setup conformed precisely to the model outlined above. A run of the simulation begins by placing the nodes at random positions all over the room. A particular cell is chosen among the 9 cells and the arrival and the departures rates for that cell is considered. (Since we assume a homogenous mobile network, every cell in the network is statistically identical and independent to each other. Hence analysis of the performance of the single cell can characterise the performance of the whole network.) At the start of the simulation, the node selects a direction and moves along the same direction for a fixed random of distance before it changes direction. The node continues to move and on entering the cell in consideration, the time is noted and similarly when it departs from the cell the time is noted. Also, nodes coming in with active calls, leaving the cell with active calls, calls originating within the cell and calls terminating inside the cell are determined. On further analysis, it is found that the arrival and departure rates follow a binomial distribution.

Design of handover priority MAC protocol

The MAC Protocol is based on Packet Reservation Multiple Access (PRMA) [6], a terminal-to-terminal transmission protocol through base station for wireless local area networks which acts as a statistical multiplexer to improve the capacity of Time Division Multiple Access (TDMA). It can be used to transmit data, video and/or speech. Speech can be separated into two parts, talk spurt and silence by using a voice activity detector (VAD). For efficient use of transmission links, only talk spurts are put into packets for transmission. PRMA is a TDM based protocol, and uses CSMA/CA [7] techniques to avoid collisions when users try to reserve a slot.

The time organisation of Uplink and Downlink frame of the MAC protocol can be seen in Figure 4. Each frame is divided in to J channel frames. The uplink frame consists of a reservation (R) slot and N information slots. The downlink frame consists of an acknowledgement (ACK) slot and N information slots.

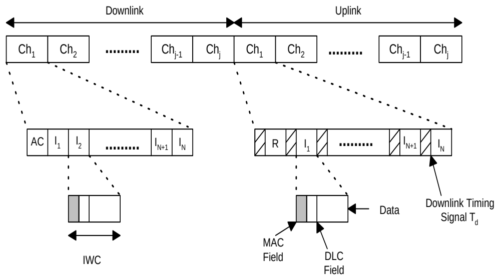

Figure 4: Timing organisation of the MAC protocol

The nodes request the reservation by transmitting their source and destination addresses through the R slot. The duration of the I slot is the transmission time of an IR wireless cell. The base station uses the ACK slot to broadcast messages relating to each downlink slot as well as reservation messages for each node, which requested a slot. Nodes start to transmit in their own time slots by means of short downlink timing signals (T_d).When an acknowledgement is received, the transmitting node will know which slot (in the uplink frame) is allocated to it. The receiving node will continue to read data from this slot until it encounters an end of transmission (EOT) value, upon which the slot is released for contention. The system parameters such as channel bit rate, speech bit rate are mentioned in [6].

For a good quality of speech service, network parameters such as new call blocking probability and forced termination probability should be minimal. The parameter "forced termination probability" is considered to be more important than the new call blocking probability, the reason being that an active call should be given a slot rather than terminating the call and giving the slot to a new call originating from the cell. By giving priority to handover calls, there is an increase in the new call blocking probability. This trade-off is quite inevitable in handover priority-based schemes and has been observed by many studies in the literature[8].

There are three basic schemes for handover priority: 1) the guard slot concept , where certain number of slots are reserved for handover calls exclusively. 2) the queuing of handover requests where a handover call is queued till a slot is available to be served and 3) the subrating scheme where certain slots are temporarily divided into two slots to accommodate handover calls. This paper employs a hybrid guard slot concept and queuing concept as it can offer efficient spectrum utilization when dynamic channel strategies are used.

To give priority for handover calls, the uplink frame is divided into two groups :- the common group and the guard group. The common group is used for both new calls and handover calls. The guard group is used exclusively for the handover calls. When there is a handover request coming in, the base station looks for and allocates a place in the common group else it looks for a slot in guard group and assigns it.

In case of a new call or handover call request, when there is no slot available the call is not blocked instantly. It is put in a queue and waits up to a certain tolerable time (Dmax=20 ms) for an available slot. Once it exceeds Dmax the call is blocked completely. As it can be seen, the handover mechanism is a hybrid of both guard slot concept and the queuing concept.

The call blocking probability for new calls arising within the cell is determined and is shown in Figure 5

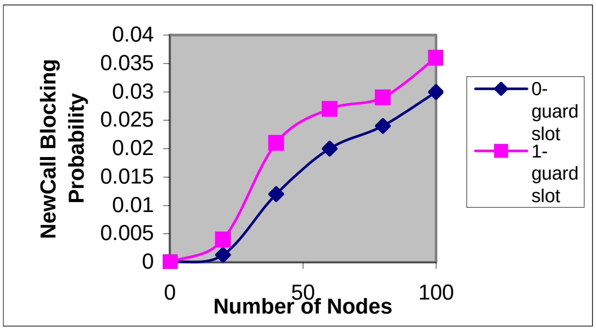

Figure 5: New Call Blocking Probability Vs Number of Nodes

As mentioned before, there is trade-off present when guard slot is introduced. It can be seen that new calls are blocked more when there is a guard slot introduced and increases with number of nodes

When a node with "an active call" and a "talk packet" requests a handover, priority should be given to the call and a slot should be allocated. It is better to block a new call rather than terminate an existing call. The forced termination probability for handover calls is shown in Figure 6 and the throughput for the system is shown in Figure 7.

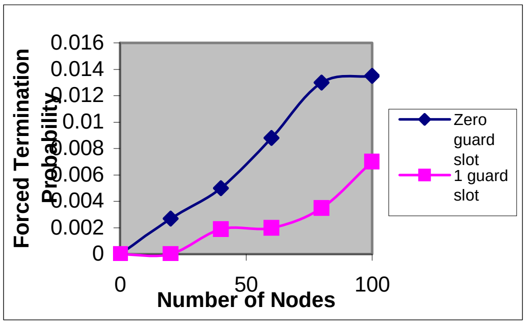

Figure 6: Forced Termination Probability Vs No. of Nodes

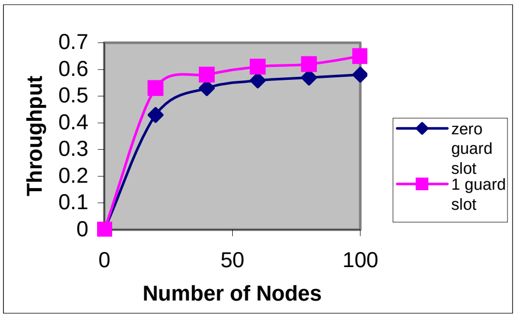

Figure 7: Throughput Vs Number of Nodes

As can be seen, the forced termination decreases as soon a guard slot is introduced. One would expect the throughput of the system to be lower on introduction of a guard slot. However this does not happen (see Figure 7) as many more calls are forced terminated in zero guard slot scheme, thereby reducing the throughput of the system. As the forced terminations are lower for 1-guard slot, the throughput increases with the channel being utilized efficiently.

Conclusions

This paper proposes a MAC protocol design and reports a simulator for the protocol used for indoor optical wireless LANs employing IR technology and with a wire line fibre optic network backbone. A proposed scenario for such a LAN is presented. A new model for the node motion within the confines of the indoor environment is developed. Using these results, the call arrival and departures rates are modelled. The MAC protocol is simulated with these features incorporated and the performance is analysed in terms of new call blocking probability, forced termination probability and throughput.

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