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Energy Efficient MAC Protocol for Directional Sensor Networks

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Abstract: Sensor networks have consistently relied on Radio Frequency (RF) to provide connectivity between various sensor nodes and Cluster Head (CH). This paper provides potential role of Free Space Optical (FSO) communication within the wireless sensor networks. The requirements for Medium Access Control (MAC) protocol in directional sensor networks are different than traditional sensor networks. The protocol must be fast in providing access to the node and energy consumption must be least. In this paper, we propose an additional receiver at the CH which will give provide access to the urgent node. This new architecture will reduce the access energy consumption due to various collisions occurring at CH. The simulation results shows that energy consumed in the network is decreases with new state of art although energy consumed by additional receiver is added.

Keywords: FSO, MAC protocol, Optical wireless communication, Receiver diversity, Sensor networks.

Introduction

Present communication links requires high bandwidth, good channel capacity, and minimum errors with physical security. Free space optical (FSO) communication is the way by which we can achieve these characteristics simultaneously. A FSO is the communication system where air is used as a medium to transmit light wave signals to another location. These links are mainly characterized by geometric or atmospheric attenuation. The geometric attenuation can be controlled by changing the parameters like transmitter diameter, divergence angle and link distance. The atmospheric attenuation depends on weather conditions like fog and rain [1]. The main advantage of optical communication is that optical signals do not leak through walls nor interfere with delicate wireless equipment. Thus providing security from intruders. Optical wireless networks can be used in many network applications including structural health monitoring within a fixed infrastructure; real-time performance feedback from sensors placed inside airplanes; and rapid upload/ download links within various terminals in settings, such as indoor offices, houses, airplane cabins, connection of avionic systems [2] and shallow-water sensor networks [3].

Furthermore, communication through wireless medium such as air or vaccum requires certain protocols that will define rules for each user to orderly access the channel. These protocols are called MAC protocols which are discussed later in section III.

FSO Design

In Block diagram [4] Figure 1 shows Basic design of FSO system. FSO system consist source, transmitter, receiver and atmospheric channel. The message signal is originated from source that fed the modulator and produce output that is transmitted towards an end point. Modulator modulates input signal into optical signal. The modulation scheme can be: amplitude modulation (AM), frequency modulation (FM), or phase modulation (PM), Intensity Modulation (IM), On-Off Keying (OOK). There are three types of wavelength that are commonly used for transmitting data in FSO communication which are 850nm, 1310nm, 1550nm. But 1550nm wavelength laser generally preferred because it provides large range, long life, and eye safety, high data rate [5]. On other ways 850nm and 1310nm laser not preferred due to low power, less range and data rate 2.5 Gbps only [6].750nm is another wavelength that have low data rates and consume less energy.

The transmitter is the arrangement of Driver circuit, Optical source and Transmit Optics. The link between transmitter and receiver is called atmospheric channel. It is affected by factors such as turbulence, scattering, beam divergence etc. The misalignment between transmitter and receiver can also affect the channel as it causes pointing error [7] of several micro radians resulting in a huge energy loss [8].

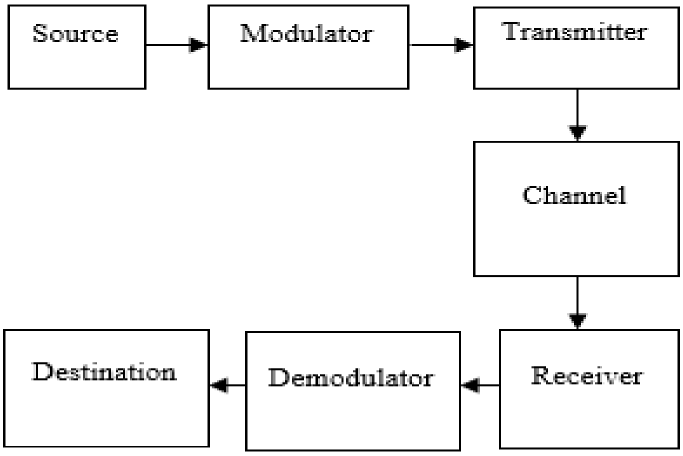

Figure 1. **Block diagram of FSO link**

Avalanche Photo Diodes (APD) or P- I -N diodes are generally used at receiver side. APD works in reverse biased. It can detect visible and near IR wavelengths if we uses silicon material for APD manufacturing. PIN diodes are less expensive and have faster switching speeds but for shorter distances. These are generally used for longer wavelengths. These diodes can detect diverse wavelengths like PIN manufactured from InGaAs material can detect 1550nm and Si material can detect up to 1.1µm.

Existing MAC Protocols

OSI model has seven layers structure for computing networks. The second layer of OSI model is data link layer. The main function of data link layer is to transfer the data to neighbor network nodes. The data link layer is concerned with delivery of frames between devices on the same network. The sublayer of data link layer is MAC. The MAC layer provide mechanism that address and control channel access. This make it possible to communicate within a shared medium, e.g. a wireless sensor network. The hardware that implements the MAC is referred to as a media access controller. MAC layer is responsible for Generating and managing beacons, manages network coordinators, Channel access, Guaranteed Time Slot management, Frame validation and Acknowledged frame delivery. The MAC protocols are broadly classified as scheduled based protocols and contention based protocols.

A. Scheduled Based Protocols

The scheduled MAC protocols are based on Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Frequency Division Multiple Access (FDMA). In TDMA, one time slot is assign to each node. Nodes have to transmit in the slot number given to them. CH is responsible for channel time division and timing synchronization of the nodes. It is collision free protocol. The problem with the TDMA MAC protocol is that it requires timing synchronization so only using TDMA MAC protocol is not sufficient.

B. Contention Based Protocols

The approach of Contention based MAC protocols are Carrier Sense Multiple Access (CSMA) and Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA). The problem of contend among all the nodes to get wireless channel for sending data is resolved by MAC protocol. The channel is accessed randomly by each node so there is no need for coordination. The performance of any network increases if the chances of collision decreases. Chance of collisions are decreased if a station senses the medium before trying to use it. If the channel is free we can send data on the channel but if channel is not free it will wait for random amount of time. The principle of CSMA is "sense before transmission". The collision can be avoided by CSMA/CA using three strategies: the interface space, the contention window and Acknowledgement (ACK). CSMA have low latency and higher throughput. However it still suffers from collisions.

In the past few years, various media access control protocols were designed to reduce the energy consumption. K.J Wong et.al [9] proposed a low power distributed, random access MAC protocol for specks called specknets. Speck MAC-B sends wakeup packets in place of the preambles while speck MAC-D sends the actual data packet repetitively. Kwan-Wu Chin et.al [10] worked on a new technique for reducing MAC address overhead in sensor networks. The scheme scaled down the MAC addresses by $\log_2 N$ according to number of sensor nodes used.

In RF technology, there are considerable interest in 60 GHz networks. This is allocated worldwide for high data rate wireless communication. At 60 GHz frequency, the communication system uses narrow beam of antenna systems to efficiently transmit power from node to node. Thus, these systems have similarities with directional beam optical systems and have similar challenges such as LOS. Xueli An et.al [11] presented a directional MAC protocol for millimeter wave based Wireless Personal Area Network (WPAN). In this paper, they had propose a rate adaptation scheme to coordinate the directional and omni-directional transmission in WPANs. Also a new channel allocation algorithm was introduced which enables spatial reuse TDMA.

The use of directional antennas in ad hoc networks imposes new challenges for MAC protocol such as deafness and collision problems. Emad Shihab et.al [12] worked on a distributed asynchronous Directional to Directional (DtD) MAC protocol for wireless ad hoc networks. Most of existing MAC protocols with directional antennas required node to be able to operate in both directional and omnidirectional modes. The use of two antennas resulted in asymmetry-in-gain problem. Man-Han Yuen et.al [13] had proposed Aloha and Slotted Aloha schemes for home private optical fiber bus network. By keeping the collision probability below threshold probability, a reliable quality of service was provided. Packet delay was also low.

G Kalfas et.al [14] demonstrated an analytical model of medium transparent MAC (MT_MAC) protocol in 60GHz radio over fibre networks. Contention both at optical as well as wireless layer was taken into account. The saturation throughput obtained for different optical capacity factor. It was observed that all wireless clients effectively resolved within seven frames even when number of users greatly exceeds. Shuguo Zhuo et.al [15] proposed a new hybrid CSMA/TDMA MAC protocol called Queue MAC (QMAC). This protocol dynamically adapts the duty-cycle according to current network traffic. When traffic increases, the CSMA period was accordingly extended by adding dynamic TDMA slots. G. M. Shafiullah et.al [16] presented an efficient bit map assisted protocol which achieves better energy efficiency for low and medium traffic by minimizing the idle time during the contention period.

Navik Agarwal et.al [17] had presented the design and performance of a directional media access control (DMAC) protocol for optical wireless sensor networks. To control the flow of communication, RA protocols were required. The network performance was shown in energy consumption with respect to transmission probability and in synchronization frames required to solve the sensor node contention for different network traffic.

Table 1 summarizes the literature by specifying different methods of accessing unguided medium, parameters used by authors and corresponding comments.

Table 1: Comparison of Various Protocols

AUTHORS	YEAR	METHOD	PARAMETERS	COMMENTS
Kwan-Wu Chin [10]	2005	Reducing MAC address overhead	Energy Consumption	Less Energy Consumption
Xueli An [11]	2006	Rate Adaptation Scheme for Directional MAC	Spatial Reuse Capability and Link Utilization	Improved Capacity and link utilization with decreased beamwidth
Emad Shihab [12]	2009	Asynchronous Directional to Directional MAC	Saturation Throughput and Fairness	Throughput and Fairness Improved but Deafness problem exist.
Man-Han Yuen [13]	2010	Aloha and Slotted Aloha	Threshold ,collision probability and Packet delay	Reliable quality of service is obtained
G Kalfas [14]	2011	Medium Transparent MAC Protocol	Saturation Throughput , Synchronization Frames and Channel Contention	Contention resolved within up to 7 frames
Shuguo Zhuo [15]	2012	Hybrid CSMA/TDMA Protocol	Throughput, Latency and Energy Consumption	Higher Throughput during heavy burst load
G. M. Shafiullah [16]	2013	TDMA MAC Protocol	Energy Dissipation and Transmission Latency	Nearly Constant Energy Consumption
Navik Agarwal [17]	2014	Directional MAC Protocol	Energy Consumption, Window Size , Transmission Probability	Better Network Performance for Varied Load

Directional MAC Protocol with Receiver Diversity

The challenge in implementing MAC protocol in FSO sensor networks is that most of the nodes are unknown to the transmission of other nodes because of their narrow directional link. If multiple nodes transmit information to the same cluster head at same time, it will leads to collision of data packets. The collision of data packets requires retransmission of data packet which results in wastage of energy and Random Access (RA) time will increases. RA time should be minimum for MAC protocol to be effective. So an improved RA protocol is required to formulate for better handling of contention.

The network architecture which we have considered is point to multipoint architecture. CH uses five transmitter with narrower FOV and one wide FOV photodiode in [15]. Sensor node uses one transmitter with narrow FOV and one receiver only. To improve number of successful transmission and to decrease contention at CH, we proposed two photodiode for receiving data instead of one photodiode. One photodiode is dedicated only for communicating with an urgent node while other will receive transmission from nodes in RA algorithm.

By increasing the number of photodiodes, the number of independent receiver channels would increase. Because of this multiple pathways can exist between a node and the end destination to ensure link stability in the case of a link obstruction. This will also reduce the random access time. This method is called as receiver diversity. In the proposed technique, we uses TDMA protocol with the combination of FDMA protocol for distinguishing the transmission frequency of urgent nodes.

For communication in directional network, it requires different devices to be in LOS of one another. Communication protocols are needed to be implemented so that devices do not interrupt one another. To minimize the chances of packet collision a directional MAC protocol is used. The DMAC protocol directs nodes to transmit their media access control (MAC) addresses to the CH whenever a nodes needs to transmit data. The cluster head then reads the different MAC addresses and organizes time slots for different nodes to transmit their data. A synchronization signal is send to specific node whose time slot is beginning. This alerts the node to transmit data. The number and length of the time slots can be adjusted in real-time by adding and removing MAC addresses of different nodes that need to transmit data. In this manner, the data throughput can remain near its peak value regardless of how many nodes are transmitting. If channel contention is determined, RA protocol is initiated by CH to resolve contention.

A stop transmission request (STR) signal is broadcasted to all the sensor nodes. The purpose of this signal is to temporarily halt the network traffic to build the D-TDMA queue. When sensor node detect the STR signal, they go into sleep mode if they already have a time slot. The nodes which does not have time slot stop transmitting to CH but they are still awake. In the meantime, the CH waits for a specific time in which it is not expecting any signal from nodes. After the time interval passes it will transmit a RA signal. This signal contains a probability value p. The nodes reply back to the CH according to this value. When only single sensor node replies, then the CH successfully detects its DMAC address and assign back a time slot. This sensor node now enter into sleep mode. When many sensor nodes reply, the CH detects a collision, and if no nodes reply, the CH detects a timeout. In these two cases, no time slot is allotted to nodes. The transmission of RAS continues till all sensor nodes have been given a time slot. After this the network communication resume back.

Simulated Results

A. Simulation Parameters

We implemented directional MAC protocol in MATLAB R2014b. The values of parameters used in simulation are listed in Table 2. The number of nodes, voltage, current, rate, throughput and range of the sensor and cluster head are constant. The number of nodes taken are 10. The input parameters used are the window size, and initial probability value (p_0). Window Size is the value that determines how many Synchronization Frames (SF) are required before the cluster head can potentially adjust the current value of p to a new value of p, based on the number of packet collisions, successful transmissions, and timeouts. Increasing the window (W) size leads to more accurate estimations because more data is aggregated, but in doing so can also increase the overall number of SFs. Initial probability is the value that the algorithm uses before making any sort of adjustment. The value can range from 1 to 0.1.

Table 2: Simulated Parameters

PARAMETER	VALUES
Number of nodes	**10**
Voltage (in v)	5
Current (in mA)	9
Rate (Kbps)	100
Throughput (Kbps)	14
Range (in meter)	1
Initial probability(p_o)	0.1 to 1
Window size	1

B. Energy Consumption

The total amount of energy consumption used in network is calculated by considering the energy used to transmit a packet, energy wasted in collisions and timeouts. Figure 2 shows the graph of energy consumption for window sizes equals to 1. For larger p_0 values, all 3 algorithms consume the most energy because many collisions are occurring. As the

p_0 value decreases, the energy begins to decrease because collisions become less abundant. However, for further decrease in p_0 more timeouts occurs which leads the RA protocol to add more Synchronization Frames to resolve contention, which increases energy consumption at the cluster head. Thus even at smaller values of p_0, energy begins to increase.

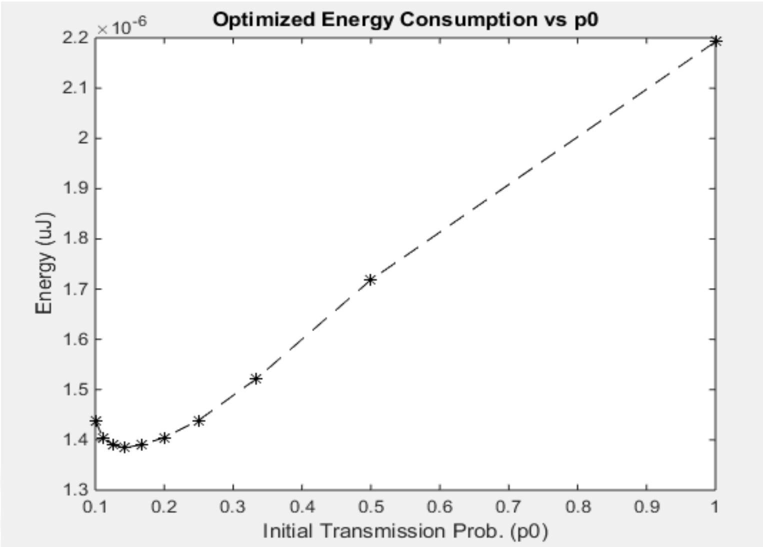

Figure 2. **Energy Consumption**

It is followed from results that for w=1 and p_0 =1/7, the energy consumption obtained is 1.37 µJ and for p_0 =1, the energy consumption obtained is 2.2 µJ.

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Conclusions

In this paper, we have outlined the Directional MAC protocol that supports directional sensor networks. It require to exchange SFs for effective communication between the sensor nodes and CH. The performance of the protocol is verified by simulation using MATLAB. The simulated results shows that proposed directional MAC protocol with receiver diversity can considerably improves the network's energy consumption. The energy consumption is decreased up to 42%.with window size =1.

Research can be further extended by verifying results for different window sizes and dynamically varying the nodes in and out of different network clusters.

References

[1]. C.C. Davis, I.I. Smolyaninov, "Effect of atmospheric turbulence on bit-error rate in an on-off-keyed optical wireless system," In Free-Space Laser. Proc. SPIE 4489, Free-Space Laser Communication and Laser Imaging, vol.126, January, 2002.
[2]. J. Perez-Mato, R. Perez-Jimenez, and J. Tristancho, "Optical wireless interface for the ARINC 429 avionics bus: Design and implementation," IEEE Aerosp. Electron. Syst. Mag., vol. 28, no. 6, pp. 15–21, 2013.
[3]. N. Agrawal, S. D. Milner, and C. C. Davis, "Free space optical sensor networking for underwater sensing application," in 5th Int. Conf. on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), pp. 475–480, 2009.
[4]. Wasiu Oyewole Popoola, "Subcarrier intensity modulated freespace optical communication systems," Journal of Lightwave Technology, vol. 27 Issue: 8, September, 2009.
[5]. Davide M. Forin, G. Incerti, "Free Space Optical Technologies," Trends in Telecommunications Technologies, 2010.
[6]. M. Ijaz, Shan Wu, Zhe Fan, W.O. Popoola and Z. "Ghassemlooy, Study of the Atmospheric Turbulence in Free Space Optical Communications," Liverpool John Moores University journal, May, 2009.
[7]. Sanamdeep Singh and Gaurav Soni, Free space Optics System: Pointing Error Evaluation in FSO Link, September 2013.
[8]. B.S. Naimullah, M. Othman, A.K. Rahman, S.I. Sulaiman, S. Ishak, S. Hitam, S.A. Aljunid, Comparison of wavelength propagation for free space optical communications, in: International Conference of Electronic Design, pp. 1-5, 2008.
[9]. K.J. Wong, and D.K Arvind, "SpeckMAC: low-power decentralised MAC protocols for low data rate transmission in specknets," Proc. of 2nd Int. workshop on Multi-hop ad hoc networks: from theory to reality, pp. 71-78, 2006.

[10]. Kwan-Wu Chin, Darryn Lowe, and Ricardo Gandia S˙anchez, “A new technique for reducing MAC address overheads in sensor network,” IEEE Communications Letters, vol. 10, no. 5, pp. 338-340, 2006

[11]. Xueli An and Ramin Hekmat, “Directional MAC Protocol for Millimeter Wave based Wireless Personal Area Networks,” IEEE Transaction on Mobile Computing, vol. 7, no. 9, pp. 1636-1640, 2008.

[12]. Emad Shihab, Lin Cai, and Jianping Pan, “A distributed asynchronous directional-to-directional mac protocol for wireless ad hoc networks,” IEEE Transactions on Vehicular Technology, vol. 58, no. 9, pp. 5124-5134, 2009.

[13]. Man-Han Yuen, and King Tim Ko, “Home private optical network: bus topology with multi-channel Aloha and Slotted Aloha schemes,” IEEE youth conference on Information, Computing and Telecommunication, vol. 5, pp. 343-346, 2010.

[14]. G Kalfas, N. Pleros, K. Tsagkaris, L. Alonso, C.Verikoukis, “Performance Analysis of a Medium-Transparent MAC protocol for 60GHz Radio-over-Fiber Networks,” IEEE Globecom, vol. 11, no. 7, pp. 456-460, 2011.

[15]. Shuguo Zhuo, Ye-Qiong Song, Zhi Wang, Zhibo Wang,” Queue-MAC: A queue-length aware hybrid CSMA/TDMA MAC protocol for providing dynamic adaptation to traffic and duty-cycle variation in wireless sensor networks,” IEEE Proc., vol. 34, no. 25, pp. 105-114, 2012.

[16]. G. M. Shafiullah, Salahuddin A. Azad, and A. B. M. Shawkat Ali, “Energy-efficient wireless mac protocols for railway monitoring applications,” IEEE Transactions on Intelligent Transportation Systems, vol. 14, no. 2, pp. 649-659, 2013.

[17]. Navik Agarwal, Stuart D. Milner, and Christopher C. Davis, “Design and performance of a directional media access control protocol for optical wireless sensor networks,” IEEE Journal of optical communication and networking, vol. 6, no. 2, pp. 215-224, 2014.