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IMPLEMENTATION OF DIRECTIONAL ROUTING IN FREE SPACE OPTICAL MOBILE AD-HOC NETWORKS

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ABSTRACT

Wireless networking has been realized using RF based technologies. But these days, Free Space Optical (FSO) technology is gaining popularity. Because of its attractive characteristics like dense spatial reuse, low power required to transmit bits, and comparatively high bandwidth and also due to the availability of advanced optical components, the networking domain could be incorporated with optical domain to have a higher transmission capacity, which lead to Free Space Optical Mobile Ad Hoc Networks (FSO-MANET) development. In FSO-MANET, there are only limited literature works on routing methodologies. The aim of the paper is to implement a directional routing (Directional Mobile Orthogonal Routing protocol) protocol in FSO-MANET's which uses directionality at the network layer. This routing protocol uses unique concept called directional routing table (DRT). Here the node movement is traced based on local information of neighboring nodes. In this type of routing table (DRT) the interface directions are mapped to a set-of-IDs to provide probabilistic routing information based on interface direction. We show that DMORRP achieves about 17-18 times more average throughput than AODV routing protocol and also gives best performance than AODV under increasing number of nodes.

Index Terms: AODV, DRT, DMORRP, FS0-MANETS

I. INTRODUCTION

Hese days, the rapid increase in the use of portable hand held devices such as laptops, mobile phones and 802.11 based Wi-Fi networking; indicates the need and importance of mobile ad hoc networking [1]. Mobile Ad Hoc Network (MANETs) is a self-configuring network of mobile nodes with no centralized structure. It is a network in which nodes communicate with each other using RF based wireless channels and as the transmission and reception range of the mobile nodes is limited; the transmission of all types of data takes place through multiple hops. The drawback of such networks was limited unlicensed spectrum available to use at any given time. To overcome this drawback free space optical technology is incorporated with MANETs which lead to FSO-MANETS.

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Free Space Optics (FSO)

Free Space Optics is a fiber-less, laser driven technology. FSO has higher bandwidth when compared to RF technology [2]. FSO uses low powered lasers or LED's to generate light pulses (modulated IR signal) which are transmitted in a small conical shaped beam through atmosphere [3]. To set up a networking link between source and destination, the optical transceiver is positioned on each side of transmission path.

1.1 *FSO- MANET's*

1.2 FSO MANET is a self-organizing infrastructure network formed by group of mobile nodes which are connected through fiber less infra red rays. These types of networks are laser driven and have higher bandwidth. FSO-MANETs can be achieved using "optical antennas". FSO structure can be designed in MANET's using two principles:

1. Spherical node surface achieves spatial reuse and angular diversity by using optical transceivers inlaid on it.
2. Self-alignment circuitry sets up the alignment of two transceivers after a predefined misalignment period.

Figure 1 shows the FSO spherical structure. In FSO spherical structures (i) angular diversity is achieved through spherical surface, (ii) spatial reuse is achieved through directionality of FSO signals, and (iii) are multi-element (each element is a transceivers (e.g., LED and photo-detector pair)).

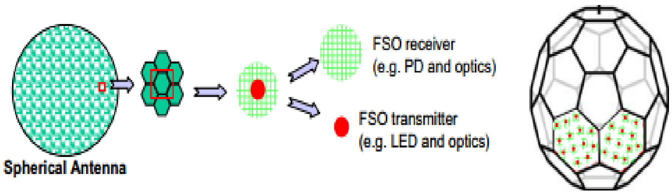

Figure 1: Spherical structure with inlaid transceivers

1.3 *Problem Statement*

As networks become larger and denser,

1. Capacity issues arise from the inherent broadcast nature of the wireless medium.
2. Limited unlicensed spectrum available to use at any given time.
3. Initial protocols were often flooding -based and focused on deliverability rather than scalability.

As networks began to grow in size and complexity, however, new approaches to limit flooding were necessary. The primary goals of this work have been to use directionality at network layer to provide best routing in FSO-MANET's.

II. PRIOR WORK

A recent trend in wireless communications has been the need to use directional forms of communications (e.g. directional smart antennas [4], Free-Space-Optical transceivers [6], and sector antennas) for more efficient medium reprocessing, increased scalability, improved security and high bandwidth. Prior work in directional antennas focused mainly on estimating network capacity and medium reuse [4][8]. In these works, capacity improvement of about 50X (gain) was shown using directional antennas over omnidirectional antennas. These increased capacity and higher bandwidth benefits of directional antennas, raised interesting question on how directionality can be used at all layers of the network stack to enhance wireless networking.

Researchers have work on using directionality at the network layer. Kalyanaraman [5] has developed orthogonal rendezvous routing protocol for wireless mesh network where the nodes using directional antennas not only depend on range but also considers the neighbor's direction and map it to a specific interface in that direction. In this there was a problem with mobility even small movement in the node would dramatically affect the perceived direction. B.Cheng developed MORRP to address the issue of mobility in ORRP.

Additionally, there was a persistent demand on use of FSO as a compliment to RF methods. Even though FSO had several appealing characteristics, it suffered from line of sight issue, and degrading performance under adverse weather conditions. Yuksel et al. [6] developed several ways to address these issues by tessellating low cost FSO transceivers in a spherical fashion. antennas.

III. BACKGROUND WORK

As there are limited researches done on routing in FSO-MANETS, we have implemented directional MORRP in FSO-MANETS which uses optical antennas. DMORRP is based on two basic principles (a) local directionality is enough to sustain transmission of packets along a straight line, and (b) two sets of perpendicular lines in a plane intercross each other with high probability even in poor networks. Directional morrp resolves the issue of mobility in ORRP by introduction the concept of rendezvous regions. Like every other protocol, DMORRP is based on some assumptions,

1. Any given node must know its 1-hop neighboring node, and
2. Select an interface(direction) to transmit data to this neighboring node
3. Every node should select a transceiver as local north and align other transceivers along perpendicular directions.

A. DMORRP BASIC CONCEPT:

Figure 2 represents a basic example of DMORRP. In MORRP, every node will transmit along 2 orthogonal lines. The point of intersection of these lines gives the path from source to destination. But due to mobility the nodes move, so the intersection of lines may not be possible. To resolve this issue each node must maintain a region of influence, i.e it must have location information of nodes within its neighborhood. As long as the data packet travels the original path, there is high probability that it touches the region of rendezvous node which will direct it to rendezvous point.

In figure 2, S is the source node and D is the destination node. S node wants to transmit data to D node. Initially, through announcement and request packets, the original path is established between source and destination with R as the meeting rendezvous node. Here every node maintains a region of influence, i.e.., relative direction of neighboring nodes within the regions. After some time, due to mobility the nodes move, suppose R moves to R' and D has moved to D'. Node R wishes to maintain a general direction to node D based on its own mobility pattern and adjusts its direction of sending to D from angle α1 to α2. The data packets S sends to D will divert to the original path, moves toward R' once it hits R's field of influence. Then, it will be sent in the modified direction of D until it hits D's field of influence and moves toward the destination. MORRP routes packets using directionality in highly mobile environments by 1)shifting destination node directions based on a node's local velocity and 2) increasing probability of finding nodes by introducing “fields of influence". All of this is done using the directional routing table (DRT).

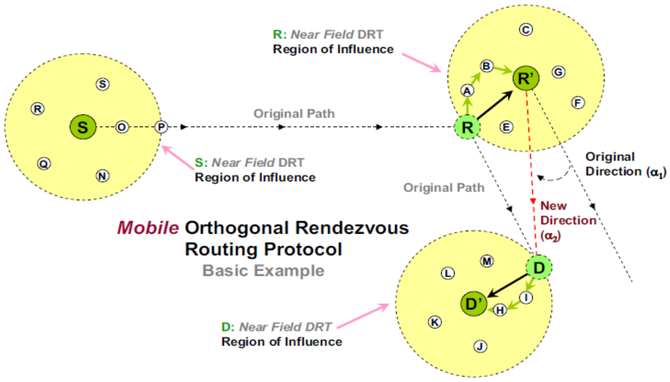

Figure 2: Basic concept of DMORRP

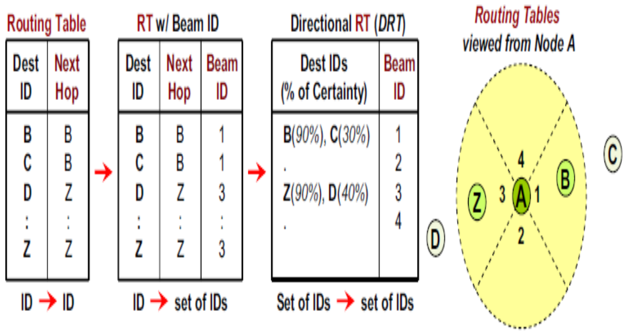

Figure 3: illustrating directional routing table

The concept of DRT is simple, instead of recording destination IDs to next hop, we map probabilistic IDs with sets of interfaces. Bloom filters [9] are used to store the set of IDs; These IDs are aggregated and sent to neighboring nodes. Then the neighboring nodes merge these aggregated IDs with the interface of the direction of reception.

DESIGN METHODOLOGY:

To create FSO-MANET’s scenario we download FSO package for NS-2 [7] and installed it in NS-2. And then the DMORRP was developed. The following are the steps taken and Figure 4 shows the ASM of design methodology.

Define the protocol in C/C+: the files to be created are dmorrp_packet.h, dmorrp_table.h, dmorrp_table.cc, dmorrp_rqueue.h, dmorrp_rqueue.cc, dmorrp.cc, dmorrp.h.

We should register packet header both in C/C++ domain and Otcl domain. By registering packet header in C/C++ domain, the simulator will recognize the new protocol. To register packet header in Otcl domain, we need to modify the file “tcl/lib/ns-packet.tcl”. This is because when the simulator starts to initializes the packet format, all registered packet header should be assembled together. If we do not add “dmorrp”, the simulator’s packet headers will not contain it.

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1. Next, we need to add trace procedures to make ns2 record trace information in trace file.
2. After that, we need to add the procedure to create DMORRP routing agent, and we should modify the file "tcl/lib/nslib.tcl". In a particular branch, the specified routing agents will be created and assigned to the current node.
3. In next step, the code to initialize parameters in DMORRP agent should be implemented in "tcl/lib/ns-agent.tcl" final step in post layout simulation of design to fabricate the chip.
4. Next two steps are connecting the interface queue and routing agent to each other.
5. Last but not least, add new compile options to the "Makefile" and re-build the ns2 software

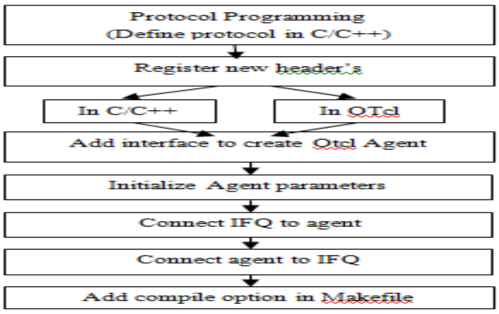

Figure 4: Design methodology

Parameter	Values
Trans. Radius / # Interfaces	250m / 8
Topology Boundaries	1300m x 1300m
Queue Length / Simulation Time	250 / 70s
Announcement Interval /Mobility (m/s)	4.0s / RWP 0m/s - 30m/s
DRT Update Interval	2.0s
Distance Decay Factor (Dd)	0.7
Time Decay Factor (Dt)	0.3
Time Decay Interval (Di)	0.5s
# of BF Hash Funcs / BF Size	30 / 16000 bits
NF Threshold / FF Threshold	6 bits / 6 bits
Spread Decay Ratio (sratio)	0.5
CBR Packet Size / Send Rate	512 bytes / 2Kbps

Table 1: Default simulation parameter

IV. RESULTS

The simulations are performed using NS-2 [10]. Table 1 shows the default simulation parameters used for evaluation. Average throughput, packet delivery fraction as the quantitative metric used for performance analysis of DMORRP in FSO-MANETs.

Average Throughput:

It is the ratio of total number of packets received to the difference in the received and sent time. This metrics measures the efficient usage of the channel for packet transmission.

AverageThroughput=(∑rcvd_pkts)/(rcvd_time-sent_time)   (1)

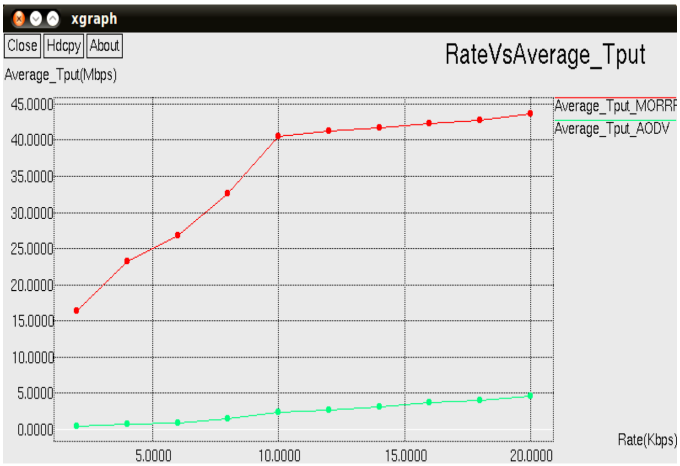

Figure 5: comparison of DMORRP versus AODV (varying rate)

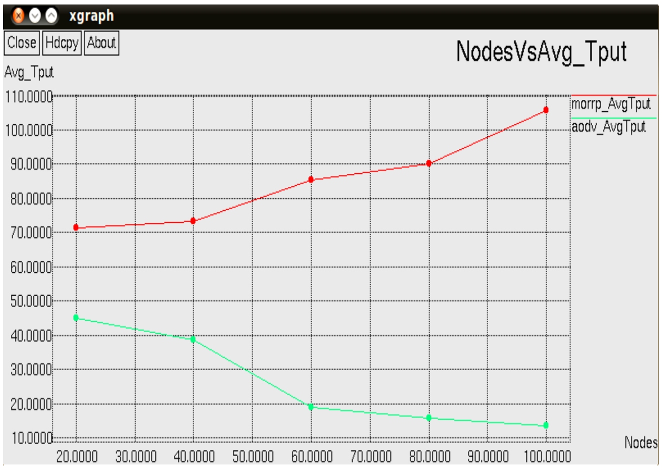

Figure 6: comparison of DMORRP versus AODV (varying node)

Figure 5 shows that DMORRP with 8 interfaces achieves much higher average throughput than AODV [10] protocol (roughly 17-18X more than AODV). DMORRP utilizes local directionality to disseminate packets along lines to limit flooding and also send out less control packets which frees up the network for data transmission. And also with MORRP, RREQ packets stop being forwarded once it intersects with a destination's “field". And hence there is medium usage in case of DMORRP in FSO-MANET’s which leads to higher throughput (aggregate goodput).

Figure 6 shows that DMORRP gives better performance than AODV under varying nodes. It can be seen that as the number of nodes increases, AODV’s average throughput start dropping because with the high mobility, AODV will struggle to send more control packets to keep link information up-to-date. With increased density, more nodes are expected to share the medium and take turns transmitting which results in greater network congestion (network saturation. This implies that DMORRP improves scalability in FSO-MANETs.

Packet Delivery Fraction:

It is the ratio of total number of data packets delivered successfully to the total number of packets generated by the CBR source agent. This metric shows the efficiency of the routing protocols in successful delivery of packets.

PDF=(∑total_pkts_rcvd/∑total_pkts_sent)*100 (2)

Figure 7 shows the performance analysis of DMORRP with AODV routing protocol in terms of Packet Delivery

Fraction. As maximum velocity increases, AODV which is an on-demand protocol fail because of stale routes and need to perform limited flood to find new paths leading to medium saturation. As MORRP in FSO-MANET's uses transceivers with directional form of communication which by default frees the medium up for multiple simultaneous transmissions which lead to higher packet delivery success under the presence of high load and high mobility.

Figure 8 shows the performance analysis of DMORRP with AODV routing protocol in terms of Packet Delivery Fraction (under varying nodes). DMORRP shows better PDF than AODV because it uses directional form of communication which leads to medium reuse and as DMORRP uses the concept of "region of influence", RREQ packets stop being forwarded once it intersects with a destination's "Field". Because these "Fields" are two or three hops large, DMORRP RREQ packets traverse less hops than AODV RREQ packets. In short, DMORRP sends less control packets which give more space to send data packets.

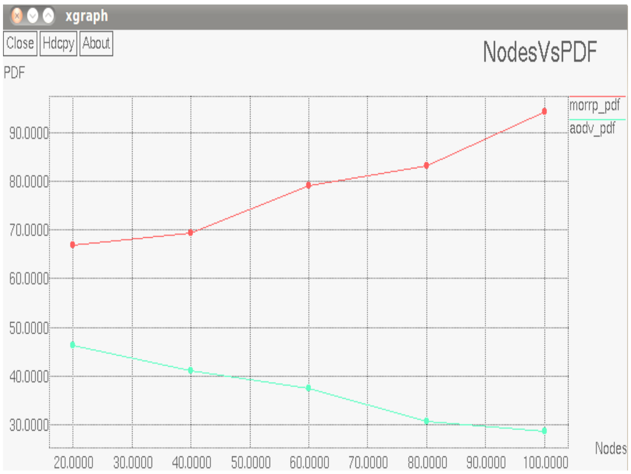

Figure 7: DMORRP V/S AODV in terms of PDF

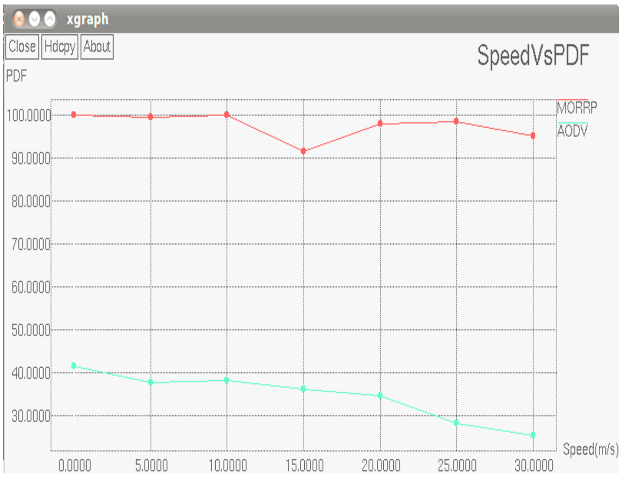

Figure 8: DMORRP V/S AODV in terms of PDF (varying nodes)

V. CONCLUSION

A directionality based MORRP routing protocol is implemented in FSO-MANETs. All the simulation results are done using NS-2 software. We achieved about 17-18x higher throughput than AODV in FSO-MANETs. DMORRP also improves scalability in FSO-MANETs.

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