ROUTING IN OPTICAL MESH NETWORKS-A QOS PERSPECTIVE

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ABSTRACT

*Wireless Ad-Hoc Mesh Networks are characterized by static nodes connected in a mesh topology. A routing protocol discovers and maintains the route for successful transmission of data in a network. The routing protocol should also provide load balancing and fault tolerance for improved network performance. In Free Space Optical networks (FSO) line of sight (LOS) should be maintained between the two communicating nodes. In a multihop scenario maintaining LOS during routing is a challenge. In this paper we propose a routing protocol Quality of Service-Directional Routing Protocol (QDRP) - which assures a certain level of performance to a data flow in terms of delay and implemented on FSO MANET. Through simulations it is observed that QDRP chooses the path with the least delay and performs satisfactorily under varying node densities and transmission rates achieving end to end delay of .14 s and packet delivery percentage of 96% when simulated for an area of 1300 m *1300 m for 100 nodes. This work explores the potential of the proposed routing protocol for free space optical mesh networks. QDRP is compared with ORRP (Orthogonal Rendezvous Routing Protocol) and AODV (Ad-Hoc on Demand Distance Vector), a reactive protocol which is also implemented in free space optical environment. We support our conclusions that QDRP gains in terms of packet delivery percentage, end to end delay and goodput.*

KEYWORDS

Free Space Optics, Line of Sight, AODV, nodes, delay.

1. INTRODUCTION

The radio frequency part of the electromagnetic spectrum is classified into licensed and unlicensed bands, the existing unlicensed bands are already saturated thus the research is shifting towards using the optical part of the spectrum. This technology is referred to as "optical communication without the fiber" and also defined as "optical communication at the speed of light"[1].Environmental conditions such as fog, scattering, absorption affect FSO communication. An optical mesh network is equipped with optical transceiver nodes. A mesh network is very robust to link failure. For dense networks finding out the connectivity and best path in terms of QoS is a very cumbersome task. Destination Sequenced Distance Vector (DSDV) [2] is a proactive routing approach whereas Dynamic Source Routing (DSR) [3] and Ad-Hoc on Demand Distance Vector (AODV) [4], protocols explored reactive routing methods which used the flooding technique during the course of finding the path from source to destination. Flooding causes additional overhead on the network and thus reducing the throughput. Directional form of data communication can be very promising because of directional nature of the FSO transceivers. In this work a routing protocol with directional perspective is proposed for the optical mesh networks to satisfy QoS requirements. Out of multiple paths between source to a destination, the path with the least delay is selected for data transmission. Through comparative evaluation we provide conclusions for the "metrics" packet delivery percentage, delay, number of hops and

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goodput. Section 2 presents the literature related to free space optical networks. Section 3 discusses the methodology of existing work Orthogonal Rendezvous Routing Protocol (ORRP).Section 4 discusses proposed routing protocol QDRP. Section 5 presents NS-2.34 implementation of the protocol. Section 6 provides details of the results obtained after implementation. Conclusion and future scope is presented in section 7.

2. LITERATURE SURVEY

Recent studies have indicated to be locum to traditional RF networks [5] for small areas. To cover large distances, free space optics communication technologies use high-powered lasers and expensive components often to offer redundancy to RF networks and some limited spatial reuse of the optical spectrum. Study was restricted to a single primary beam (and some backup beams) or use expensive multi-laser systems [6, 7]. The chief intended application of these FSO technologies has been to serve profitable point-to-point links [8, 9] in infrared indoor LANs and terrestrial last mile applications [11, 6]. Any obstruction like walls, trees, automobiles, etc can absorb these frequencies and thus a clear line-of-sight (LOS) between the transmitter and receiver is a significant requirement. Low cost components can be organized in a multi-hop network to tackle LOS related issues. Akella et al. [10] showed that error characteristics of FSO over multiple hops are very promising.

Sensor networks are power scarce and FSO is a very attractive option for such applications [11].The majority of FSO research in higher layers has been on topology construction and maintenance for optical wireless backbone networks [12, 13]. Authors considered dynamic configuration [14], node discovery [15], and hierarchical secure routing [16] in FSO sensor networks. However, the challenges that FSO will enforce on MANETs has not been studied in depth. The contribution of previous work focused on directionality in communication and showed how it can be effectively used in localization [19], multi-access control [20], and routing [21, 22, 23].

A key FSO characteristic that can be leveraged at higher layers is its directionality in communication. Murat *et.al* worked on packet-based simulation tools for free space optical (FSO) communication. They implemented the propagation models for free space optical communication as a set of modules in NS-2[17]. Orthogonal Rendezvous Routing Protocol (ORRP) was proposed for wireless mesh networks. ORRP is a scalable routing protocol utilizing directional communications such as directional or free-space-optical transceivers to relax information requirements such as coordinate space embedding and node localization. The ORRP source and ORRP destination send route discovery and route dissemination packets respectively in locally-chosen orthogonal directions [18] and do not resort to flooding during the discovery of a route. The protocol did not consider the QoS metrics. C. Zhu and M. Corson [24] implemented AODV with QoS. It was used to establish QoS routes with bandwidth estimation in a network employing TDMA. The protocol was not implemented for optical MANETs. Devi S., Sarje A. presented a geographical routing protocol for FSO MANET and compared it with DREAM protocol implemented in RF MANET. It did not present any QoS metrics implementation [27].

3. BASIC METHODOLOGY OF ORRP

The working principle of ORRP can be divided into proactive and reactive approach. It is based on the assumption that two pairs of orthogonal lines intersects at two places. These are called as rendezvous points. The nodes at these points can be used to forward data and are called as rendezvous nodes. Announcement packets are sent periodically in orthogonal directions. The path from destination to rendezvous is found using the reactive approach and the path from source to rendezvous is done proactively. Announcement packets are sent at regular intervals of time by the nodes to reflect their interest in finding a path to a destination node. The intermediary nodes which forward the announcement packets, stores a reverse path to the node which generated ORRP and the information of the previous hop. If the path to destination is to be requested, then the source node sends a route request RREQ, in orthogonal directions. A node which has path to the destination will send a reply RREP to the source node and data transmission begins.

4. QDRP –PROPOSED METHODOLOGY

We base our protocol QDRP on ORRP [18].QDRP is designed for FSO MANETs and is a modified approach to ORRP to accommodate QoS.

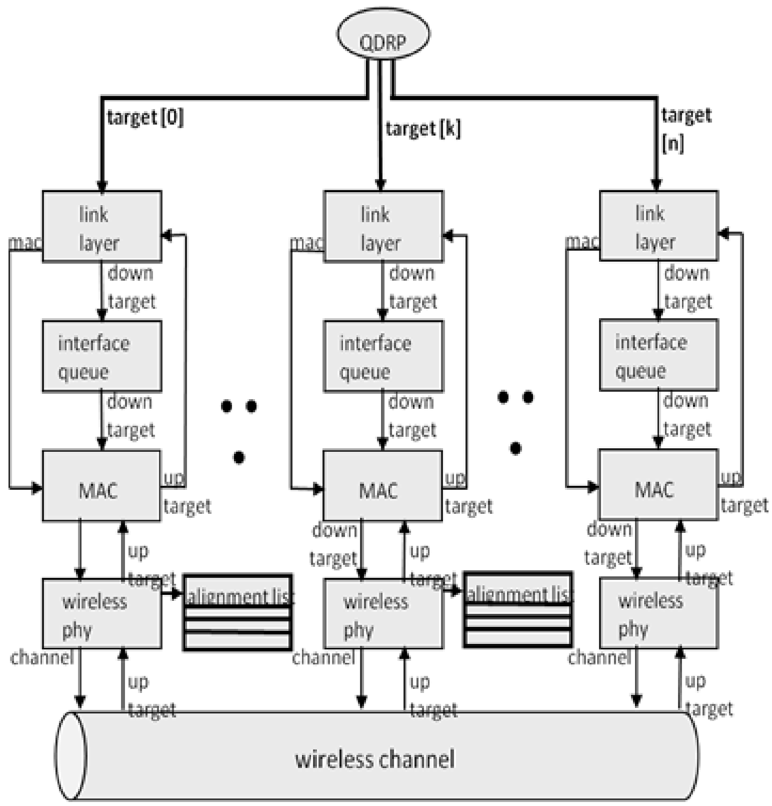


Figure 1. QDRP for multiple interfaces [26]

We include QoS requirements i.e delay that a route to a destination must satisfy as a part of a request packet [28]. In particular, a request packet has a QoS object extension that includes delay parameters. We accordingly modified the routing table, which will accommodate maximum allowable delay and sources requesting delay guarantees. The cumulative delay that has been experienced by the nodes, along the path from the originating node to the node currently processing the request packet is present in a field in RREQ (request packet). The nodes receiving the request packet, but not satisfying the maximum delay upper limit will not forward the RREQ.

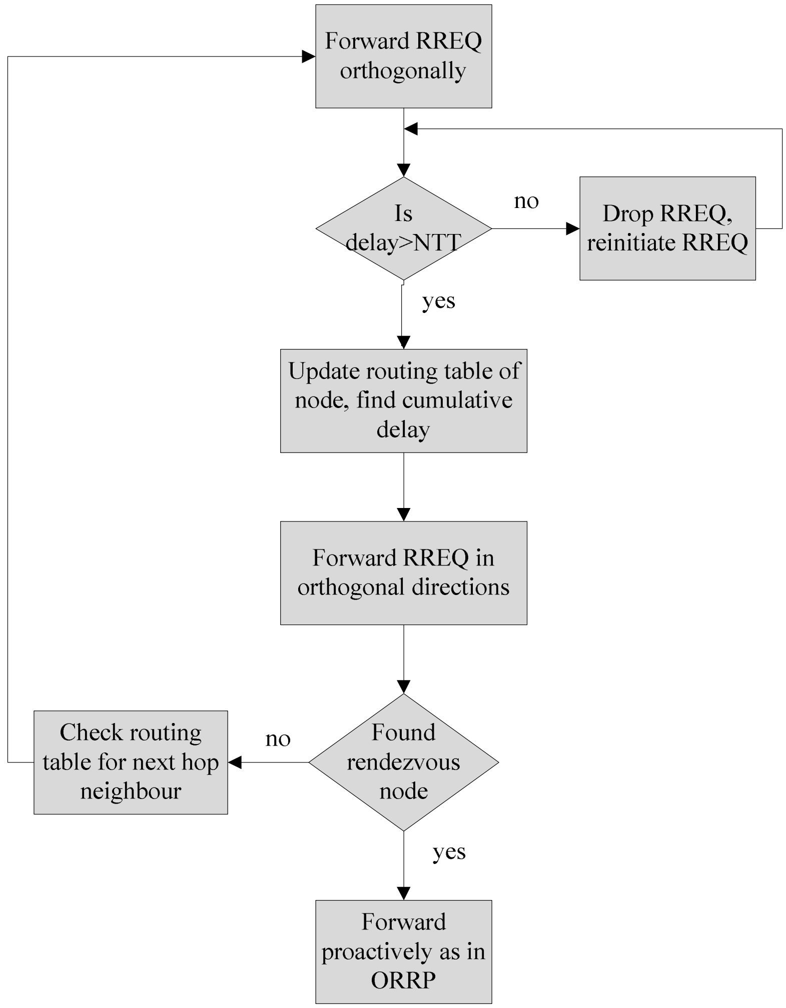


Figure 2. Route reply propagation

The route reply is generated as discussed in [18], We select the least delay path as a metric of QoS. When proclamation packets (announcement packets [18]) are received by nodes, the routing table is updated for the source address, hop count, previous hop and sent out in the interface opposite from which packet is received. The next hop node checks for the delay specified in request packet with the node traversal time (NTT).If the value is positive, the request is forwarded as depicted in Figure 2. Source node after receiving multiple route reply packets, compares the delay and selects the path with the least delay as in Figure 3.QDRP uses MAM i.e multiplier angle method for deviation correction as in [18].This value is stored in the packet header of RREQ and proclamation packet.

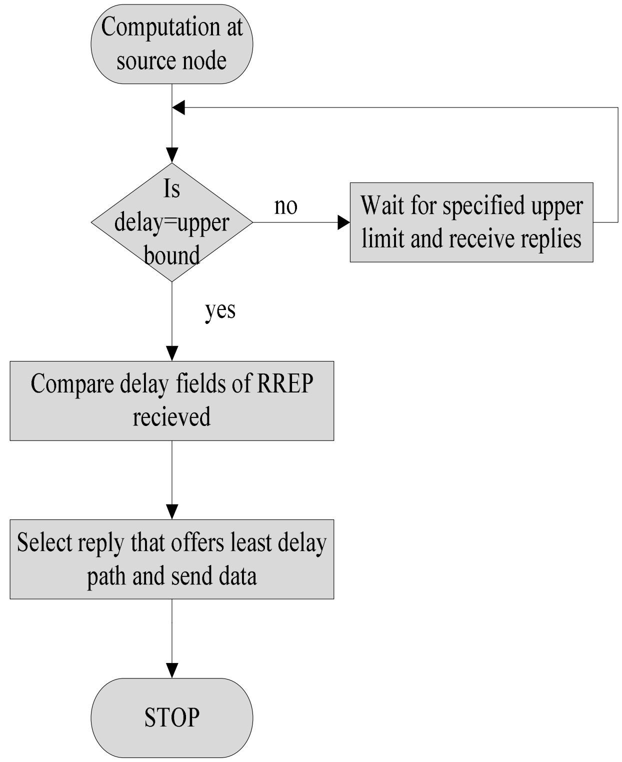


Figure 3. Computation at source node

The node has now "learnt" the paths and uses if for sending data packets to the assignation node. If new nodes are added to the network, the source node again compares the estimated delay from different nodes which have returned the route replies and chooses the path based on the interface and delay. To avoid indefinite comparisons of estimated delays, we specified a 1s upper limit.

5. PROTOCOL IMPLEMENTATION ON NS 2.34

For illustration, we consider a random network of seven nodes which can connect wirelessly in a mesh topology. The nodes are denoted as N1, N2 and so on. The (…..) represents the imaginary orthogonal lines through the nodes. All the source nodes send proclamation packets at a fixed time interval, for example, source N1 sends out the proclamation packets orthogonally. To find the best possible route from the source to destination, the assignation node (rendezvous node) and destination paths should be in place [18].To find the routes from the source to the assignation node, request packets are sent through the network. This is a reactive or on demand approach of the protocol. For example N1 sends request messages. The assignation node here is N3 and the destination node is N6.Nodes N2,N4,N6,N7 have a path to the assignation node and hence the reply is propagated through the network to the source node N1.The various paths are depicted as P1(N3-N2-N1),P2(N3-N6-N7-N1),P3(N3-N4-N6-N7-N1),P4(N3-N1)P5(N3-N4-N1).The source node compares the delay from the reply packets of different nodes and selects the path with the least delay. The probability of reaching out to a node from a particular interface is done by mapping beam ID to node ID [18].

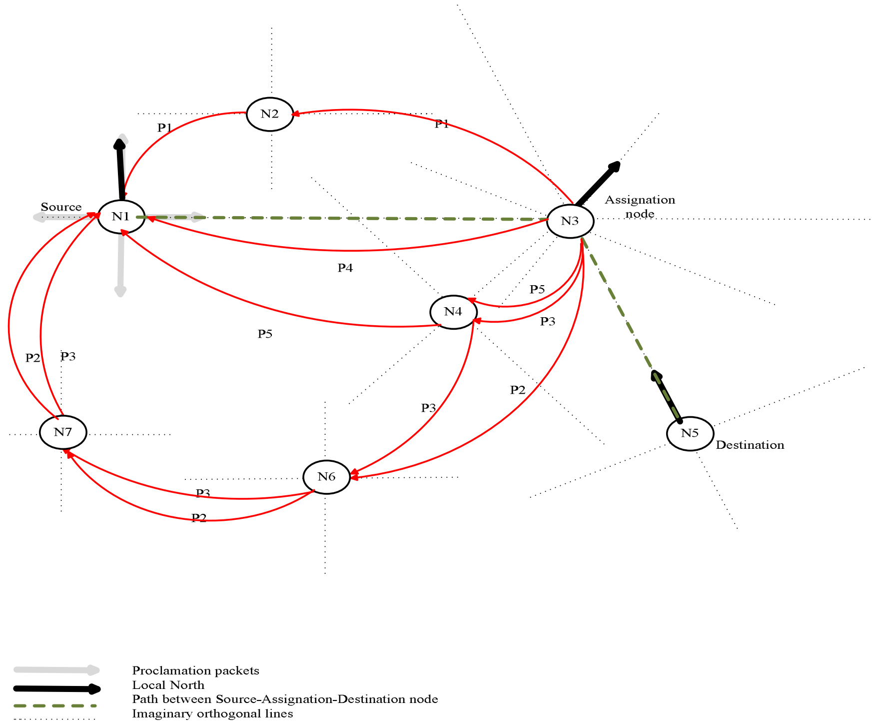
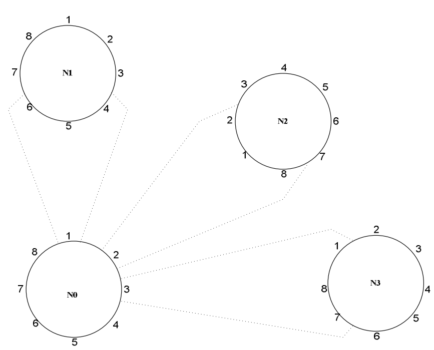


Figure 4. Illustration of QDRP routing protocol



Interface of node N0	Next hop node	Interface with which aligned
1	N1	6, 5, 4
2	N2	2, 1, 8
3	N3	1, 8, 7

Figure 5. Illustration of alignment w.r.t interfaces and alignment list [26]

We use AlingmentTimer [26] for interface alignment as shown in Figure 5. The interface alignment is done at regular intervals of time. The interface on which the transmission can be done is interface 5, 1, 8 for node N1, N2, N3 respectively. Figure 6. shows the important files used in NS-2.34 [25] in implementing QDRP. The actual dynamics of protocol is implemented in qdrp.cc. Route repair is taken care of in qdrp.h. It is also responsible for taking feedback from the link layer to know whether the links are still valid or not.

Route timeout, ARP timeout, waiting time for route replies, routing table management, transmission and reception of packets, entry of values into the routing table is all taken care of in qdrp.h. Packets that are sent, dropped, received by interface queues, routers and agents is taken care by cmu-trace.h. [25]. Queue management is done by priqueue.h. The working of QDRP is dependent on the following files.

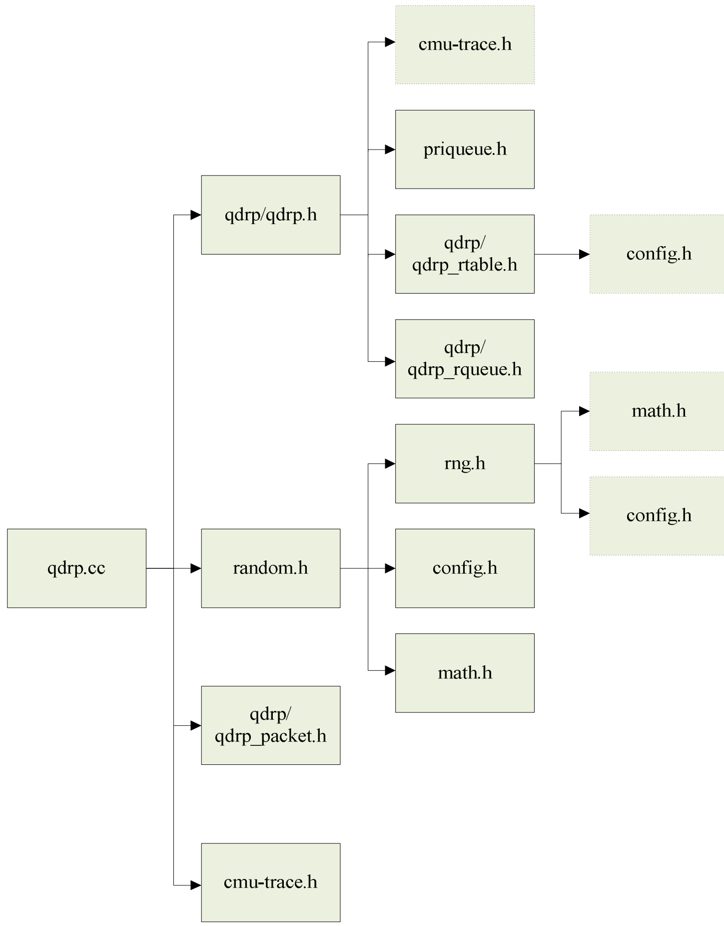


Figure 6. File structure of QDRP routing protocol

The various timers used in implementation of routing protocol are Hello timer, Broadcast timer, Neighbor Timer Routecache, Local repair timer along with ProTimer which sends out proclamation packets at fixed time intervals. The function QDRP::minDel(Packet*P) is called to identify the minimum delay. Figure 7 shows the scheduling and reception of packets and the functions used.

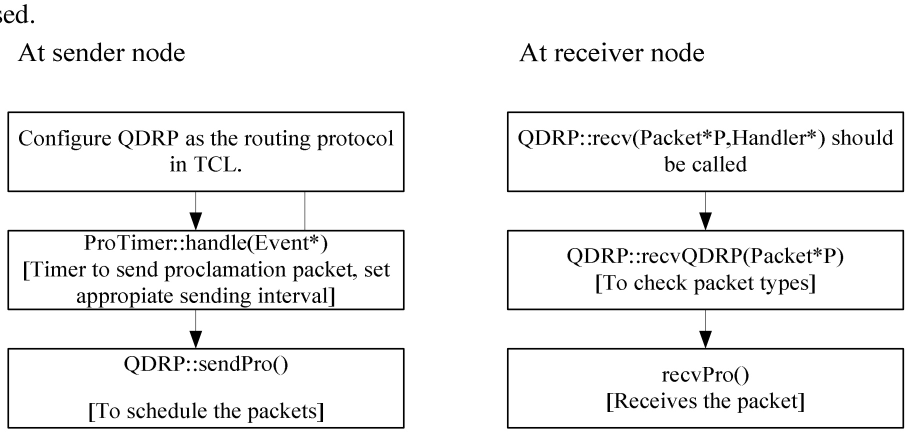


Figure 7. Flow of the proposed QDRP

6. RESULTS AND DISCUSSION

This section presents the simulation results of the proposed routing protocol QDRP and its comparison with ORRP and AODV, which is implemented for optical mesh network. Initially a mesh network spread over an area of 1300 m*1300 m, was simulated. Constant bit rate traffic was used with a rate of 2 Kbps (unless specified). QDRP routing protocol was used in simulations.

Table 1.Simulation Parameters

Parameter	Values
Simulator	NS 2.34, FSO extension package
Topology	Mesh,1300 m*1300 m
Radius of transmission	30.0 m (NS-2 Default)
Interfaces/angle	8/.5 rad
Proclamation interval	4.0 sec
Route timeout	5.0 sec
Traffic type	CBR,512 bytes
Send Rate	2 Kbps
Simulation time	90 sec

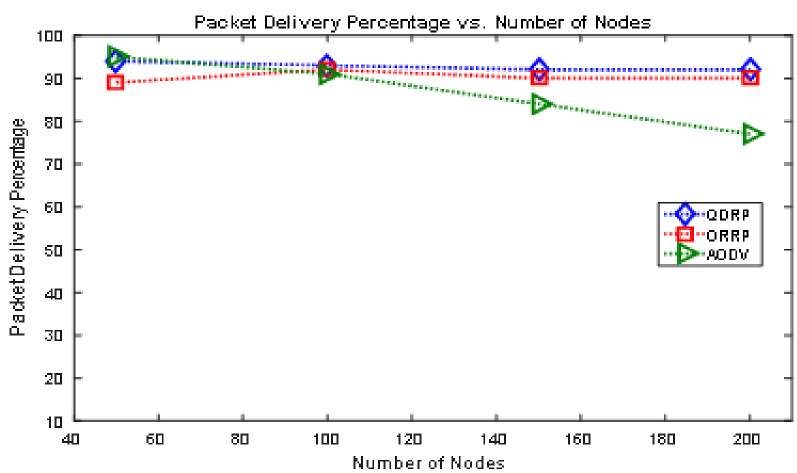


Figure 8 . Packet delivery percentage vs. Nodes

The packet delivery percentage increased for QDRP when the number of nodes is increased as observed in Figure 8. The packet delivery percentage for both the protocols is comparable when the number of nodes is 50. The packet delivery percentage of AODV decreases with an increase in number of nodes but QDRP performs better compared to ORRP and AODV. As QDRP selects the path based on delay, once the node “learns” the path, the same path is used for data transmission, providing better packet delivery percentage than ORRP and AODV. Nodes that satisfy the QoS- delay constraint participate in routing, resulting in increased deliverability which is the not the case with ORRP. Figure 9. shows packet delivery percentage deteriorates for QDRP,ORRP and AODV when the transmission rate is increased. The packets delivered in QDRP decreased to 68% and this is attributed to failure in finding a QoS satisfying path. The gradual decline in the packet delivery percentage for AODV is because of dispersion of the medium due to request and reply packets.

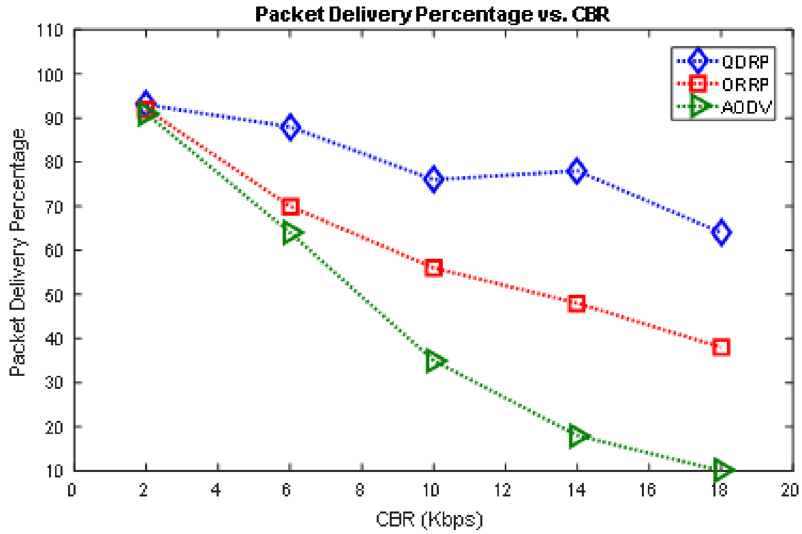


Figure 9. Packet delivery percentage vs. CBR

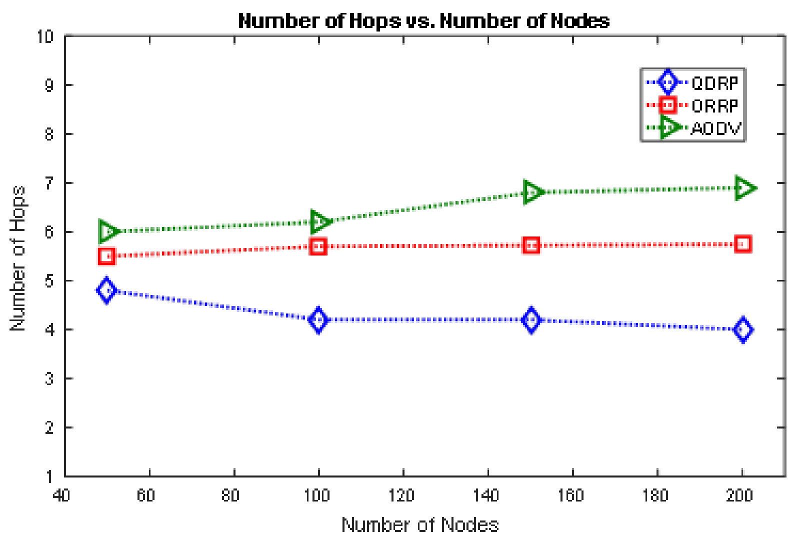


Figure 10. Plot of Number of Hops vs. Nodes

The average number of hops in QDRP is less compared to ORRP and AODV as shown in Figure 10. for all densities of nodes. QDRP optimizes itself to find the path with less delay. In AODV, with the increase in nodes the emphasis is more on forwarding to a next hop neighbor without considering the delays involved. This results in choosing inefficient paths involving more number of hops which may or may not have the least delay.

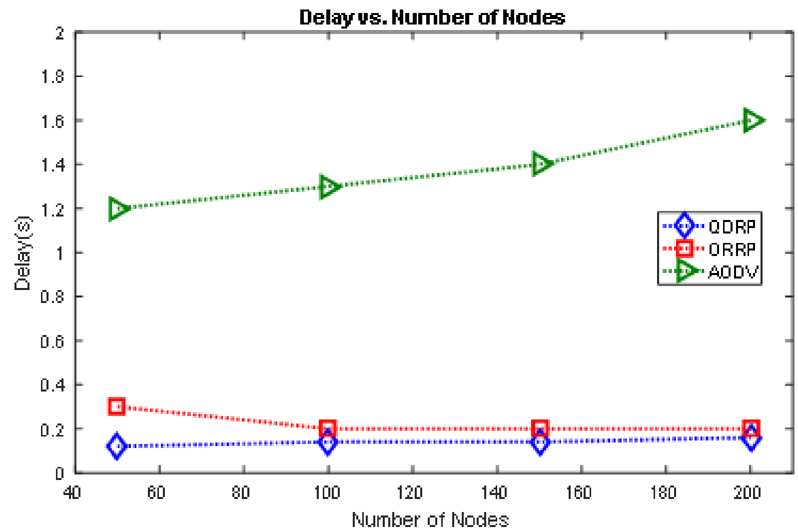


Figure 11 . Plot of delay vs. Nodes

Figure 11. illustrates the effect of increasing number of nodes on delay. In QDRP, the selection of data for forwarding to the next node is based on delay.Thus even when the nodes are increased, the delays are less for varying number of nodes with a transmission rate of 2 Kbps.In ORRP the delay is slightly more as it sends data on the path from where it receives the reply which may or may not be QoS path. In AODV the delay is comparatively more because of its inherent mechanism of operation that is based on route request and route reply query cycle.The data transfer will not take place till reply packets reach the source. Figure 12. shows that the delay increases with increase in transmission rates for both QDRP and ORRP when simulated for 100 nodes.AODV presents an entirely different profile.The delay decreses with increasing transmission rates.

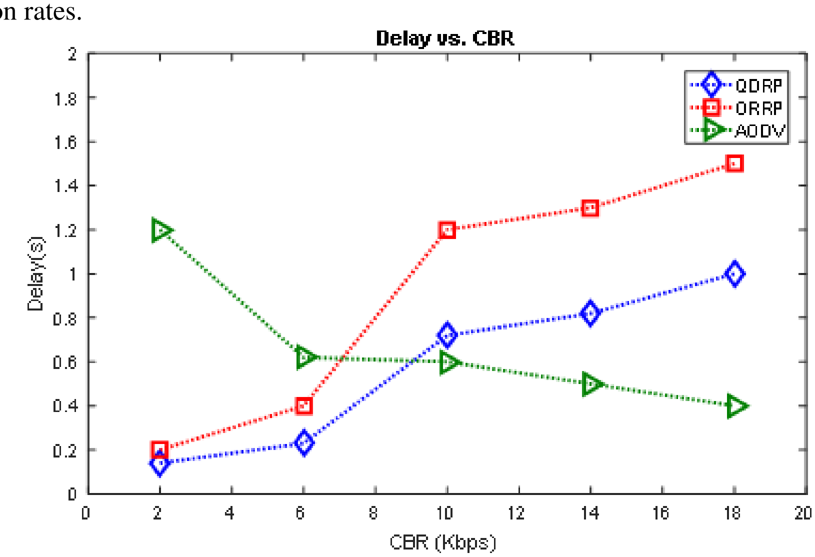


Figure 12. Plot of Delay vs. Nodes

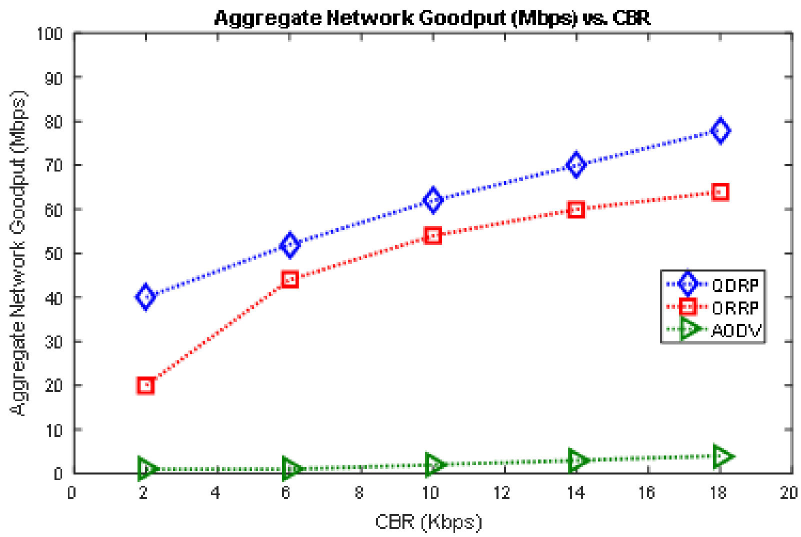


Figure 13. Plot of Delay vs. Nodes

The goodput of QDRP and ORRP is shown in Figure 13, the advantage of QDRP is availability of QoS path for QDRP.With increasing CBR the goodput of AODV decreases because of increased transmissions and interference.

7. Conclusion and Future Scope

The proposed routing protocol QDRP-Quality of service-Directional Routing Protocol is investigated in static, mesh connected networks. The end to end delays obtained are well within the maximum allowable upper limit for delay i.e. 1s as specified by us. The packet delivery percentage with increasing number of nodes reaches 96%, though the same does not hold good for increasing rate of CBR which is 68%. We look forward to improve this in our future studies. We considered only delay as a parameter for path selection. QoS study is more challenging when tradeoff between two parameters like bandwidth and delay is considered. It would be rather riveting to implement a similar method in free space optical mobile environment. QoS path reservation can also be studied in this context. Destination based routing can be considered as a research problem for optical ad hoc networks.

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