Bandwidth Constrained Routing of Multimedia Traffic over Hybrid MANETs using Ant Colony Optimization

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***Abstract*—As the world is moving towards wireless devices, the support for more and more multimedia based applications over communication network is the need of the day. The bandwidth for data transfer, comes with a price, and we need to support a large number of bandwidth hungry applications. Hence, Quality of Service(QoS) is a key word for the overall optimize usage of the available network resources. Mobile Adhoc networks are known for their self organizing, autonomous nature. QoS based routing over MANET requires an adaptive and fast solution to path search problems. Swarm Intelligence, is a machine learning technique, where we derive intelligence from the collective behavior of natural agents. This scheme has been reflected in the Ant based algorithm, which are specialized in optimization of routing solution. Hence, in this paper we propose the implementation of protocol HMQAnt(Hybrid Multipath QoS Ant), ACO based solution with hybrid adhoc routing strategy for a hierarchical MANET architecture, so as to give optimum solution for adaptive and dynamically changing networks. We have mainly concentrated on bandwidth optimization as a key to provide effective paths for multimedia networks. This algorithm would eventually decrease the overhead and route according the bandwidth requirement. The proposed routing solution also takes queuing theory into consideration. In MANETs, whenever there is a connection loss, routing is carried out again, and it is drastically affected by queuing.**

***Index Terms*—Multimedia routing, Quality of Service (QoS), Proactive, Reactive, Hybrid routing, Ant Colony Optimization(ACO), Mobile Adhoc Network (MANET)**.

I. Introduction

Multimedia has long achieved acceptance for the conveyance of information. The wireless multimedia network has gained tremendous importance in recent years due to its wide applications.Examples of the wide spectrum of applications are advertisement, product presentations, tourist information, e-learning units, and virtual museums. Due to the availability of large bandwidth of wireless communication, it can be used for multimedia applications. It is unreliable because of network parameter constraints such as bandwidth, buffer, delay, jitter, routing etc. Also, the Bit error rate for wireless network is 10^{-3} to 10^{-5}, which is quite high compared to that of wired network, that ranges from 10^{-9} to 10^{-12} [4]. Hence, QoS based multimedia routing is very important requirement in Adhoc network. In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users.section that you want to designate with a certain style, then select the appropriate name on the style menu. establishing survivable, efficient, dynamic communication for emergency/rescue operations, disaster relief efforts, and military networks [13].

The basic characteristics of MANET lies in its dynamic topologies, bandwidth and capacity link, since the capacities are lower due to wireless connections. There is also a energy constraint, due to limited battery power. The security is limited because of peer-to-peer communication, messages may be sent to unknown intermediate node. There is also a higher security threats due to open transmission medium. Hence, the routing protocol for MANET should be efficient, scalable and distributed with simple implementation. The existing protocols in MANET can be divided into three basic categories. This includes reactive, proactive and hybrid protocols. In the reactive protocols, the routes are discovered on demand. This includes source routing (eg DSR) and table driven (eg AODV, ABR, TORA)[15]. The proactive protocols that maintains updated routes. This includes variation of distant vector (eg. DSDV) and a variation of link state routing (eg OLSR). The proactive routing protocols have problems of higher overhead, low convergence rate, waste in maintaining routes that are not going to be used. Protocols like RIP, OSPF, DSDV fail to converge in highly dynamic MANET. The reactive routing protocols have prohibitive flooding traffic during route discovery. Also there is a large route acquisition delay due to new route discovery initiated for every route breakage.[4]

TABLE I: COMPARISON BETWEEN REACTIVE AND PROACTIVE PROTOCOLS

Parameters	Reactive Protocols	Proactive Protocols
Routing Information Availability	Available only when needed	Always Available
Traffic Overhead	Low	High
Average Packet Delay	High	Low

Rest of the paper is organized as follows. Section II explains Ant Colony Optimization. Section III explains the previous works in routing using ACO. Section IV describes proposed scheme for multimedia routing. Section V explains how queueing affects routing process in adhoc network. Section VI shows the simulation results and Section VII concludes and summarizes the paper.

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II. Ant Colony Optimization

A. Introduction

Ant Colony Optimization (ACO) is a technique under Swarm Intelligence, that derives intelligent way of managing complex tasks, based upon the collective behavior of ants in nature. The basic idea of the ant colony optimization is taken from the food searching behavior of real ants. When ants are on the way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit a pheromone, which ants are able to smell, which marks the route taken. The concentration of pheromone on a certain path is an indication of its usage. With time, the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamics into the path searching process[17].

B. Using ACO for Multimedia Routing Networks

ACO algorithms have shown to be a very effective approach for routing problems in multimedia networks where the properties of the system, such as the cost of using links or the availability of nodes, vary over time. ACO algorithms were first applied to routing problems in circuit switched networks (such as telephone networks) and then in packet-switched networks (such as local area networks or the Internet).

The ant colony optimization meta-heuristic is based on agent systems and works with individual ants. This allows a high adaptation to the current topology of the network, leading to a high adaptation to the dynamic topology of the network. In contrast to other routing approaches, the ant colony optimization meta-heuristic is based only on local information. It is possible to integrate the connection or link quality into the computation of the pheromone concentration, especially into the evaporation process. This will improve the decision process with respect to the link quality.Ant-based routing algorithms are suitable for MANETs due to their decentralized nature, high robustness to node failures, load balancing and adaptability to highly dynamic environment.

C. Multipath Routing

Each node has a routing table with entries for all its neighbors, which contains also the pheromone concentration. The decision rule, to select the next node, is based on the pheromone concentration on the current node, which is provided for each possible link. So, quantitative and stochastic procedure of finding the best path, has the availability of the next best path also. This confirms the support of multipath routing support with ACO based algorithms. The feature is highly useful for managing multimedia traffic over IP networks. [17].

III. Related Work

The different Ant Colony Optimization based Routing algorithm used in Adhoc networks are AntHocNet, ARMAN (Ant Routing for MANET), ADSR (Ant Dynamic Source Routing). The rest of the section includes a short description of the above techniques.

A. AntHocNet[5]

AntHocNet is a hybrid algorithm based on the framework of ACO. It does not maintain paths to all destinations at all times, but sets up paths when they are needed at the start of a session. This is done in a reactive path setup phase, where ant agents called reactive forward ants are used. While a data session is going on, the paths are probed, maintained and improved proactively using different ant agents called proactive forward ants. AntHocNet reacts to link failures with either local repair or by warning preceding nodes on the paths. To gather routing information, the AntHocNet algorithm uses two complementary processes. One is the repetitive end-to-end path sampling using artificial ant agents. The other is what we call pheromone diffusion, an information bootstrapping process that allows to spread routing information over the network in an efficient way.AntHocNet combines both processes in order to obtain an information gathering process that is at the same time efficient, adaptive and robust.The reactive ant packet is broadcast, hence, all nodes within wireless broadcast range, that is, the node's neighbors, receive it and if their routing tables contain the destination, they forward the reactive ant packet to the next hop with a probability proportional to its pheromone value.

TABLE II: COMPARISON OF ANTHOCNET AND AODV

Parameter	AntHocNet	AODV
Delivery	Very High	High
Multiple Paths	Yes	No
Average Delay(Simple Scenarios)	High	Low
Average Delay(Complex Scenarios)	Low	High
Adaptivity	High	Low

B. ARMAN[7]

ARMAN stands for Ant Routing for Mobile Adhoc Networks.This algorithm is highly adaptive, efficient and scalable and mainly reduces end-to-end delay in high mobility cases.It has two main phases namely route discovery phase and route maintenance phase.When a source node has to pass data to a destination node with QoS requirements its starts with the route discovery phase.Once the route is passed, the data transfer will take place.While data transmission is going on,it is also required to maintain the path to the destination. The Hello ants are used for neighbor detection. Ant is broadcasted for every second by every node `i' in the network. Upon receiving a Hello Ant, a neighbor `j' will react by replying a Hello Acknowledgement containing i and j's IP addresses. Now node i receives this acknowledgement and finds the delay between two nodes as the time difference between sending hello and receiving ack. Immediately the node j is entered into the neighbor table and a initial pheromone amount is deposited on the link. Route-Request-Ant is broadcasted upon receiving real time data from the upper layer at source. Initially the value for Hop count will be 1, starting time is current time and bandwidth is the available bandwidth of outgoing link. Upon the receipt of Route-Request-Ant, the destination will convert this to a Route_Reply_Ant.The Route_Reply_Ant will be unicasted to the original source. While forwarding Route_Reply_Ant, the intermediate nodes will not alter hop count and Request starting time as well as Reply Starting time.At each node the stack is also popped to see the next node to which this reply has to be forwarded.food searching behavior of real ants.

C. ADSR[14]

ADSR takes into consideration of three QoS parameters delay, jitter and energy. Dynamic Source Routing (DSR) protocol is an on-demand routing protocol that is based on the idea of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware. Entries in the route cache are continually updated as new routes are learnt. The protocol consists of two major phases: route discovery and route maintenance. In route discovery, to send packet, it checks the route cache to determine whether there in an entry to the destination or not.If the node does not have such a route, it initiates route discovery by broadcasting a route request packet. A route reply is generated when the route request either reaches the destination itself, or reaches an intermediate node which contains in its route cache an unexpired route to the destination. By the time, the packet reaches either the destination or such an intermediate node, it contains a route record yielding the sequence of hops taken. If the node generating the route reply is the destination, it places the route record contained in the route request into the route reply. If the responding node is an intermediate node, it will append its cached route to the route record and then generate the route reply.Route maintenance is accomplished through the use of route error packets and acknowledgments. Acknowledgments are used to verify the correct operation of the route links. In Ant DSR (ADSR) the Forward ant (FANT) and backward ant (BANT) packets are added in the route request and route reply of DSR respectively. FANT and BANT packets are used in the route discovery process.

IV. PROPOSED ALGORITHMS

A. Bandwidth Utilization

QoS routing requires not only finding a route from a source to a destination, but a route that satisfies the end-to-end QoS requirement, often given in terms of bandwidth or delay.QoS is more difficult to guarantee in Ad hoc networks than in most other type of networks, because the wireless bandwidth is shared among adjacent nodes and the network topology changes as the nodes move. This process is used to get the details of the minimum bandwidth that is available for the data transmission.

When the source sends forward ants, it would also pass the bandwidth information required for the data transmission. When this forward ants reaches the intermediate node, it compares the bandwidth available at its own node with the forward ants bandwidth. The node would replace the minimum of bandwidth in the forward ant packet. This continues at each intermediate node, until it reaches destination. Finally, at the destination, we will be able to gather the minimum of all the minimum available bandwidth. This is the global minima, selected out of the local minimas at the internediate nodes. Destination node would puts this information in the backward ants. At the source side, it would compare whether the bandwidth is within some range, for the packet transmission to be carried out. If yes, then the transmission would take place or else the new route discovery process will be started. Such an evaluation would, however, be a good asset for bandwidth-constrained applications.

For bandwidth metric each arc (i,j) in a network is assigned a real number BW_{ij}.

$$BW(p) = min(BW_{ij}, BW_{jk}, ..., BW_{qr}) \quad (1)$$

The routing problem is to find a path from i to r that maximizes BW(p). The aim of the proposed algorithm is to guarantee the QoS requirements. Thus, the following condition must be satisfied.

$$BW(p) \geq B_{req} \quad (2)$$

where B_{req} is the original required Bandwidth for the transmission of multimedia data rom the food searching behavior of real ants.

B. HMQAnt Protocol

This protocol is an optimization of the classical AntHocNet algorithm tailored to the requirements of a mobile wireless LAN. The key concept used in the protocol is that of Master Nodes. Master Nodes are selected nodes which forward messages during the flooding process. A node selects Masters from among its one hop neighbors with "symmetric", i.e., bi-directional, linkages. Master nodes forward the ants to Multipoint Relays(MPR). The key concept used in the protocol is that of multipoint relays (MPRs). MPRs are selected nodes which forward broadcast messages during the flooding process. MPR's are selected on the basis of required QoS parameter.The better the QoS parameter, the more chances of getting the neighbor selected as the MPR.Whatever the bandwidth requirement is provided, number of MPR are selected. This MPR will further flood the network.This technique substantially will reduce the message overhead as compared to a classical flooding mechanism, where every node retransmits each message when it receives the first copy of the message. It minimizes the number of control messages flooded in the network. The protocol is particularly suitable for large and dense networks. It operates as a table driven, proactive protocol, i.e., exchanges topology information with other nodes of the network regularly.

At each intermediate node, the ant at node *i* chooses its next hop *j* for destination *d* with probability P_{ijd}. This probability depends upon the pheromone value, the heuristic function and the average delay of *i*'s neighbors.

$$P_{ijd} = \frac{(\tau_{ijd})^{\alpha}(\eta_{ijd})^{\beta}(D(e)_{ij})^{\gamma 1}(B(e)_{ij})^{\gamma 2}}{\sum_{e \in H_i}(\tau_{ied})^{\alpha}(\eta_{ied})^{\beta}(D(e)_{ie})^{\gamma 1}(B(e)_{ie})^{\gamma 2}} \quad (3)$$

TABLE III: NOTATIONS

τ	Pheromone trail
α, β, $\gamma 1$, $\gamma 2$	Weight functions that control τ, η, *D(e)* and *B(e)* respectively.
D(e)	Link delay at node *e*
B(e)	Bandwidth at node *e*
H_i	The neighbours at node *i*
q_{ij}	Queue length from node *i* to node *j*

The heuristic value η_{ij} depends on the queue length at node *i*.

$$\eta_{ij} = 1 - \frac{q_{ij}}{\sum_{e \in H_i} q_{ie}} \tag{4}$$

Also the packet loss at a node is dependent on queue length.The queue length is proportional to the arrival rate and service rate at a node, whereby the service rate is governed by QoS factors.The arrival rate is assumed to be as per the Gaussian Distribution [22] and the service rate follows Exponential Distribution. Since initially the system will be in a transient state, so as to adapt to the route discovery and stability of path maintenance. But gradually the maintenance overhead may be stable due to the above mentioned implementation of HMQAnt Algorithm.

Thus this algorithm has the advantage of having routes immediately available when needed due to its proactive nature. It minimizes the overhead from flooding of control traffic by using only selected nodes, called MPR, to retransmit control messages. This technique significantly reduces the number of retransmissions required to flood a message to all nodes in the network. It is designed to work in a completely distributed manner and does not depend on any central entity. The protocol does not require reliable transmission of control messages: each node sends control messages periodically, and can therefore sustain a reasonable loss of some such messages. Such losses occur frequently in radio networks due to collisions or other transmission problems. Link Sensing is accomplished through periodic emission of HELLO messages over the interfaces through which connectivity is checked. A separate HELLO message is generated for each interface.

V. Queuing Analysis for Effective Routing

Queueing theory is important to computer networking because it can precisely predict the length of time a computer will need to wait for the data it requests. In Adhoc network, often there is a link breakage due to problems in radio transmission or mobility of nodes. The routing for this, need to be carried out again. Thus Routing process is dependent not only on transmission of data traffic but also on the size of transmission queues. Low bandwidth of wireless links makes efficient queueing paradigms critical for the performance of routing protocols. This has been displayed in Fig1.

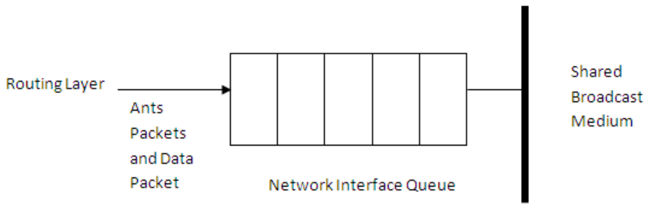

Fig. 1. Queuing at Radio Interface.

If the incoming bandwidth at a node is 'm' and outgoing bandwidth of the same node is 'n', then the queueing delay for that node would n/m. For multimedia transmission, we would always require to achieve 100% of this bandwidth utilization.

VI. Simulation

For testing and comparing the performance of Bandwidth Utilization, we used Network Simulator (Ns2). For this we, prepared two programs, one with bandwidth utilization concept and other without bandwidth utilization. Number of Nodes were varied from 3 to 50. Different links between nodes were set with different bandwidth. Using Ants the required bandwidth for data transmission was sent.The path with higher bandwidth was selected as per requirement.As shown in Fig2, the number of drop packets are more in method using bandwidth utilization compared to the one in which bandwidth utilization is not used

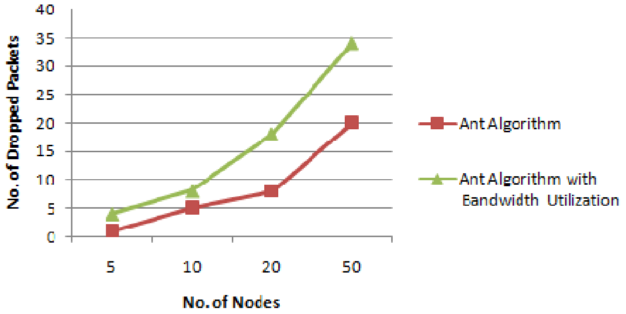

Fig. 2. No. of Nodes v/s Drop Packets.

This is to show that, the path in the network, that does not satisfy bandwidth requirements are filtered. Hence, due to the lack of fewer path selection, the packet drop ratio has increased. However, this result is only symbolic to our implementation supporting the selection of best path based on bottleneck bandwidth. If, the bottleneck bandwidth is selected to be optimal to a particular network, then down the line, the end-to-end delay in the network improves. The next graph shown in Fig3, displays that the delay component in the normal ACO based implementation and the Bandwidth Utilization based implementation improves gradually after some time for an optimal bandwidth selection in a MANET environment.

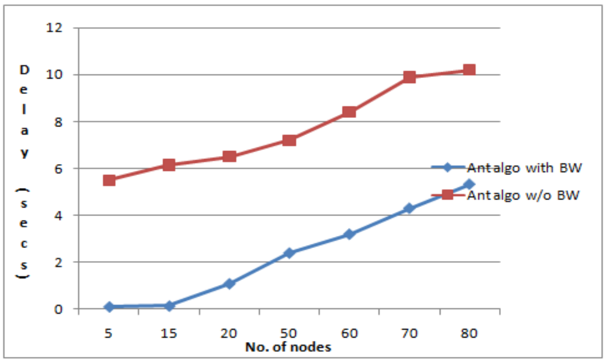

Fig. 3. No. of Nodes v/s Delays.

VII. Conclusion

The optimized usage of bandwidth in MANETS, when it comes to multimedia traffic is the need of today's growing demand of high-end hand held devices. ACO based algorithms have specialized to provide adaptive and efficient solutions to network routing. AntHocNet provides multiple paths with comparatively less overhead in the network. However, the bandwidth utilization method covered in this paper, selects path with required bandwidth parameter sent through ants. In this scheme, we can send multimedia data without incurring higher delay and jitter in communication. The solution can be highly beneficial to loss sensitive applications with stringent Bottleneck Bandwidth requirements. Further, the selection of MultiPoint Relay

Nodes(MPR) helps in reducing the generation of Ants, causing less traffic in the network. At the same time it helps to get multipath property for routing multimedia data. Queueing Policy has been considered as an important property for multimedia transmission as it effects the end-to-end delay in the highly volative Adhoc Networks.

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