ISSN : 2229-4333(Print) | ISSN : 0976-8491(Online)

Optimization in Stagnation Avoidance of ACO based routing of Multimedia Traffic over Hybrid MANETs

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Abstract

As the world is moving towards wireless devices, the demand for more and more IP based multimedia services is growing. Network routing refers to the activities necessary to guide IP based packets in its travel from source to destination nodes. Routing becomes more complicated for MANET architecture, due to the changing topology and the dynamic behavior of the nodes. The delivery of multimedia requires QoS provisioning at various layers of OSI. Routing in general is a NP problem, and when it for multimedia traffic over MANETS, it is all the more a complicated optimization problem. Hence, a hybrid architecture for a more conditioned routing over MANET is proposed in this paper. The protocol needs to be adaptive, flexible, and intelligent for efficient network management. Ant Colony Optimization (ACO) is a characterization of Swarm Intelligence (SI) that is highly suitable for adaptive routing solutions to such volatile network. In this paper, we propose Hybrid architecture for routing with more than one QoS parameters. ACO algorithm may suffer from stagnation, due to which, the exploration probability for new paths is reduced. Hence, the proposed work also minimizes the stagnation issue. The Multimedia traffic prioritization algorithms sets the priority to minimize playback delay and jitter by giving the highest priority to I-frames since its losses leads to multiplicative effect on the Video Quality.

Keywords

MANET, ACO, SI, QoS, OSI

I. Introduction

The characteristics of multimedia make heavy demands on storage and transmission systems. Multimedia network includes a packet switched architectures for the delivery of audio, video and text in a controlled manner. The control requires the networking entities like the routing protocols to provision or condition the traffic at various layers of OSI. Routing in general is an optimization problem that can be solved by computations complexities theory. In this theory, the NP problems [1,2,8] consists of all those decision problems whose positive solutions can be verified in polynomial time given the right information, or equivalently, whose solution can be found in polynomial time on a non-deterministic machine. In fact, although in some simplified solutions it is possible, in realistic settings the dynamics of the traffic, and therefore of the costs associated with network links, is such that it might even be impossible to give a formal definition of what an optimal solution is. Adaptive routing can adapt the routing policy to time and spatially varying traffic conditions. Optimal routing has a network wide perspective and its goal is to optimize a function of all individual link flows(usually this function is a sum of link costs assigned on the basis of average packet delays).

In the current networks performance and costs are usually measured by metrics like routing delay, maximum link utilization, packet loss rate, stability of the system, and convergence time after failures. However, the routing protocols are not ideally optimal. For instance, most of the routing protocols use hop-counts, or artificial weights assigned to the links in order to derive the routing tables which (due to the artificial nature of these techniques) obviously cannot optimize any of the metrics mentioned above. Also, some routing protocols are sensitive to link failures and it might take them several minutes to converge. Considering all these facts we are trying to develop new methods for routing which can optimize one or preferably a number of the parameters mentioned above

The real time multimedia application places new demands on the service that a network must provide. The most important of these are the bit error rate, the packet or cell loss, delay and delay variation. Network resources need to be committed to multimedia data streams to accommodate the peak bit rate, mean bit rate and burstiness of the data stream. Wireless networks are more prone to attenuation due to interference, scattering, reflection, refraction etc. 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 [12,29].Hence, multimedia transported over those networks are more prone to bit error rate, delay and delay variation.

For effective transportation of real-time multimedia traffic, the network must support Quality of Service(QoS) guarantees based on various metrics like loss rate, throughput, security, and delay. QoS routing is the key to support QoS. The task of QoS routing is to find a path in the network that satisfies certain constraints on metrics such as bandwidth, delay, and delay jitter and cost. Most recent QoS routing algorithms consider only a single metric, such as hop-count, delay, cost etc. to characterize routes in a network. However, the use of multiple metrics is needed to better characterize a network and to support a wide range of QoS requirements. However, finding a path subject to multiple constraints is inherently a NP-hard problem[1,2,12]. Solutions to such problems are possible by approximations in polynomial time if the weights and lengths have a small range of values.

II. QoS and Multimedia Communication

MPEG-1 provides near-VCR quality with typical rates between 1.5 to 3 Mbps and MPEG-2 achieves broadcast-TV and higher qualities at rates 5-30Mbps (or higher). However, cost of hardware (codecs, cameras and microphones) is considerably high. MPEG-4 is a new standard providing a wide range of quality and data transfer rates. Its initial commercial focus is video-on-demand streaming at a quality higher than that of MPEG-1 but at only 300-400 Kbps. However, multimedia being compressed is not always a good solution for providing better utilization of the available bandwidth. If higher compression is needed to accommodate for more bandwidth limited networks, then encoding delay may interfere with interactivity.

The main goal of transmission of video in lossy environments (ie packets should be self contained in real-time transmission), following are some of the open issues of multimedia research[14]:

- Providing QoS in packet switching multimedia network without completely sacrificing the gain of statistical multiplexing is

the major challenge of multimedia network.
- Adaptive, flexible and intelligent solution using routing devices
- Continuity of service during handoff for wireless networks.
- Selection of the required TCP variants as per various Multimedia Services and forwarding the traffic accordingly.
- Performance enhancement for circumventing the issues with Wireless TCP
- Heuristics in Admission Control mechanisms for QoS provisioning, using bandwidth and delay bounds for all types of traffic class.
- Heuristics in Multipath routing algorithms for congestion minimization while QoS Provisioning using multiple QoS parameters.

The QoS metrics can be classified as additive metrics, concave metrics, and multiplicative metrics [4]. Bandwidth and energy are concave metrics, while cost, delay, and jitter are additive metrics. Bandwidth and energy are concave in the sense that end-to-end bandwidth and energy are the minimum among all the links along the path. The end-to-end delay is an additive constraint because it is the accumulation of all delays of the links along the path. The reliability or availability of a link based on some criteria such as link break probability is a multiplicative metric. For example: the effect of video due to loss of I-frame of multimedia. Finding the best path subject to two or more additive/concave metrics is a complex problem. A possible solution to route dealing with additive and non-additive metrics is to use an optimization technique. In this paper, we propose a new globally distributed optimizing routing algorithm based on ant algorithm, and we consider the multiple metrics, such as bandwidth, loss rate, delay and delay jitter. The approach can be extended for larger number of metrics also.

A. MPEG streams

In MPEG-2 standard[12,13], three 'picture types' are defined. The picture type[13] defines the prediction modes that may be used to code each block. The characteristic importance of these picture types are mentioned as below:

'Intra' pictures (I-pictures) are coded without reference to other pictures. 'Predictive' pictures (P-pictures) can use the previous I- or P-picture for motion compensation and may be used as a reference for further prediction. Each block in a P-picture can either be predicted or intra-coded. By reducing spatial and temporal redundancy, P-pictures offer increased compression compared to I-pictures. 'Bidirectionally-predictive' pictures (B-pictures) can use the previous and next I- or P-pictures for motion-compensation, and play ordering. For a given decoded picture quality, coding using each picture type produces a different number of bits. In a typical example sequence, a coded I-picture was three times larger than a coded P-picture, which was itself 50% larger than a coded B-picture. Hence, the loss of I-frame should be strictly avoided while the multimedia is in transit, by giving premium quality handling to these frames.

The QoS based protocol for multimedia traffic should take into consideration the differentiation of the MPEG streams with respect to its importance in decoding a stream. e.g I-frames should be routed on a path with highest suitability, followed by P-frames and then B-frames.

III. MANET Routing

Mobile wireless networks have two basic variations. The first category is for infrastructure (fixed) network and the second is for infrastructureless network [12]. Factors such as variable wireless link quality, propagation path loss, fading, multiuser interference, power expended, and topological changes, become relevant issues. The network should be able to adaptively alter the routing paths to alleviate any of these effects. The Adhoc routing protocols can be classified into three categories:

Table-driven (Proactive Protocols): The Table-driven protocols attempt to maintain consistent, up-to-date routing information among all nodes in the network, through periodic route-update messages to propagate throughout the network. However this can cause a large amount of overhead. eg DSDV[15], FSR[28], OLSR[RFC3626]

Source initiated on-demand (Reactive Protocols): In on-demand routing, the source must wait until a route has been discovered, but the traffic overhead is less than Table-driven algorithms, where many of the updates are for unused paths. Thus, there is a tradeoff between the overhead for maintaining paths and the time for establishing and mending of paths.[11] eg. AODV[20, RFC3561], TORA[27], DSR[RFC4728]

Hybrid Protocols: .Hybrid protocols combines the advantages of proactive and of reactive routing. eg. ZRP[29], ZHLS[25], DDR[30], CBRP[22], CEDAR[24]

In this paper, we have proposed a hybrid architecture to improve the stability aspects and routing scenario of multimedia networks. However, efficiency in routing solution also needs to deal with the problems of stagnation/congestions. Hence, we have also worked on a scheme for stagnation avoidance

IV. Ant Colony Optimization

Ant Colony Optimization (ACO) [2-4] is a technique under Swarm Intelligence[5], where the main idea is taken from the food searching behavior of real ants. Recently, attempts are being made to solve combinatorial optimization problems using Ant Colony Optimization (ACO) algorithms. ACO is a metaheuristic that allows to find the best solution of NP Hard optimization problems (Dorigo and Caro, 1999; Ramos et al., 2002). The aim of ACO algorithms is to find a path of minimal cost while respecting the constraints (Dorigo and Caro, 1999). Advantages of such systems are high parallelism and can exhibit high level of robustness, scalability, fault tolerance and effectiveness on unquantifiable data along with simplicity of individual agent. Several characteristics make ACO a unique approach: it is constructive, population-based metaheuristic which exploits an indirect form of memory of previous performance. These combinations of characteristics are not found in any of the other metaheuristic (Dorigo and Stutzle, 2004). Depending on the species, ants may lay pheromone trails when travelling from the nest to food, or from food to the nest, or when travelling in either direction. They also follow these trails with a fidelity which is a function of the trail strength, among other variables. Ants drop pheromones as they walk by stopping briefly. Since pheromones evaporate and diffuse away, the strength of the trail when it is encountered by another ant is a function of the original strength, and the time since the trail was laid. Most trails consist of several superimposed trails from many different ants, which may have been laid at different times; it is the composite trail strength which is sensed by the ants.

V. ACO based routing for MANET

The ACO algorithms are specialized to solve routing solutions for MANETs, which are self organizing in nature. The Table 1 contains list of various proactive, reactive and hybrid ACO based protocols for MANETs.

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Table 1: Characterization of ACO based routing protocols

Type	Protocol Name	Description
Proactive	AntNet [12,10,20]	For Ant based packet routing in communication networks
	ABC [2]	Ant Based Control mechanism for telecommunication network
	ARAMA [9,19]	Ant based routing algorithm for MANET using proactive approach. The protocol looks into the energy efficiency of self organizing networks
Reactive	ARA [31, 32]	ACO based routing algorithm using reactive approach
	ADSR[10]	DSR based routing is done using number of hops, batter power and delay as parameters
	ARMAN [25,26]	Ant routing for MANET using reactive routing approach
Hybrid	AntHocNet [14]	Combines AntNet and ARA, but less scalable
	POSANT[23]	Position based ACO based routing algorithm for MANET
	AntHocNetM[6]	Extension of AnthocNet for Multimedia Communication in Adhoc Wireless Network

VI. Proposed approach

Multimedia routing over MANET is challenging due to the self organizing, autonomous and infrastructure-less architecture. We propose the following architecture in order to add a partial stability aspect, as represented in the Figure 1 below:

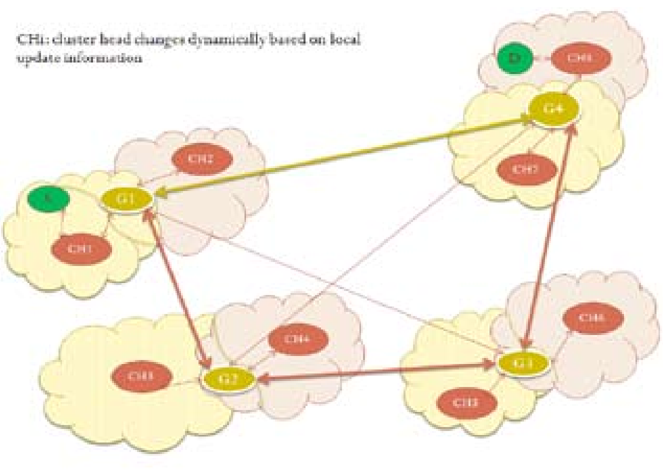

Fig. 1: Hybrid MANET Architecture [16,21]

In this architecture the Gateway routers G1,G2..Gn are added as fixed nodes. The core routers C1, C2..Cm are selected at random based on Cluster head election technique. The cluster head changes dynamically, based on the local mobility of the nearby nodes. Various techniques [17, 18] mentioned below have been studied for the cluster head election:

- Highest-Degree Clustering Algorithm (HDCA)[34,35]: This algorithm uses the degree of a node [number of neighbours] as a metric for the selection of clusterheads ordinary nodes in a cluster is increased, the throughput drops and system performance degrades
- The Lowest-ID Algorithm (LID[34]: Distributed Clustering Algorithm (DCA) and Distributed Mobility Adaptive clustering algorithm (DMAC) node is chosen to be a cluster-head if its weight is higher than any of its neighbor's weight; otherwise, it joins a neighboring cluster-head.
- Weighted Clustering Algorithm (WCA)[35]: This technique is based on the use of a combined weight metric that takes into account several parameters like the node-degree, distances with all its neighbors, node speed and the time spent as a cluster-head
- Least Cluster-head Change Algorithm (LCC)[18] allows minimizing cluster-head changes that occur when two CHs come into direct contact.
- Mobility-based d-hop Algorithm (MBCA)[36] allows most stable node to be selected [received signal strength taken from periodic beaconing

Out of the above mentioned techniques, we have used the LCC technique, since it is used in Cluster Based Routing Protocol [22]. In LCC scheme, the nodes with least number of neighbor is selected, since it will result in lesser overhead during the proactive path maintenance phase [14].

A. ACO based Routing of Multimedia Traffic

Let us assume that Ng1 represents a generation of Forward Ants(FA), released from source node. The contents of the Forward Ants are mentioned in Table 2:

Table 2: Forward Ant Fields

Fields	Description
Source address	Address of the source
Destination address	Address of the destination
Generation Number	It is used to limit the number of acceptable same generation ants
Trip time	It is used to compare the time of same generation ants
List of hops	It is used to guarantee that the paths are loop free
Hop count	It is used to decide if the intermediate node is suitable to generate backward ant or it is close to destination
Flag	It is used to show the generation of reactive backward ant at an intermediate node.
QoSVector Expected	A vector of allowable QoS parameters specific to the multimedia application
QoSVector Available	A vector of allowable QoS parameters specific to the multimedia application

Ant timer is the time interval after which the subsequent ant of the same generation ie Ng1 of Ant is to be released. The FA may take different paths to reach the destination. The selection of the path is based as per Equation 1 :

$$P_{ijd} = \frac{(\tau_{ijd})^{\alpha}(\eta_{ijd})^{\beta}(D(e)_{ij})^{\gamma1}(B(e)_{ij})^{\gamma2}}{\sum_{e\in H_i}(\tau_{ied})^{\alpha}(\eta_{ied})^{\beta}(D(e)_{ie})^{\gamma1}(B(e)_{ie})^{\gamma2}} \quad (1)$$

Table 3: Notations used in Equation 1

τ	Pheromone trail
α, β,$\gamma1$,$\gamma2$	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

B. The Pheromone updation Rules

In the ACO based approach the routing tables in the network nodes are replaced by table of probabilities called pheromone table. Every node has a pheromone table for every possible destination in the network and each table has an entry for evey neighbor. The pheromone laying procedure is represented by updating probabilities. When an arrives at a node, the entry in the pheromone table corresponds to the node from which the ant has just come is increased according to the formula

$P_{new} = (P_{old} + \Delta p) / (1 + \Delta p)$ …. (2)

Here, Pnew is the new value of pheromone after updation, Pold is the previous pheromone value before updation and Δp is the probability increase.

Other entries will be decreased by

$P_{new} = P_{old} / (1+ \Delta p)$ ……. (3)

C. Avoiding stagnation

The biggest challenge is to explore for new paths based on Qos requirement outlined by the multimedia traffic flows, and at the same time avoid nodes that are heavily congested. Hence, the value of Δp for a path should be progressively decreasing with the age of the ants. The age of the ants increases corresponding to the path length it has traced so far. Particular generations of ants Ng which have trailed on longer paths are not considered for updating the pheromone value at a node. They are marked for destruction. The other approach suggested is to initialize the ant's age with the time at which the experiment started. Hence, as the time elapses the ants are known to age and beyond a threshold value, they are not considered for changes in the pheromone value.

D. Multipath Routing

ACO algorithms lend themselves to be parallelized due to its dynamic behavior. The path selection at a time is based on the values in pheromone table. Multipath routing approach refers to parallel routing different types of frame types of multimedia data. A mentioned above, the path with the highest pheromone value is selected for delivery of I-frames. This is followed by the selection of next best path for p frames and the other available path for the delivery of B frames.

VII. Experiment and Results

The simulation for MANET environments requires the following parameters:

- Network size--measured by the number of nodes
- Network connectivity--the average degree of a node (i.e. the average number of neighbors of a node)
- Topological rate of change--the speed with which a network's topology is changing
- Link capacity--effective link speed measured in bits/second, after accounting for losses due to multiple access, coding, framing, etc.
- Mobility- mobility models selected so as to describe the movement patterns of nodes

The simulation was conducted on NS2 with parameters configured as mentioned in the Table 4:

Table 4: Simulation parameters

Parameter Name	Values
N/W size	Vary the number of nodes to measure delay ratio: [900m x 900m with 50 nodes 1500m x 1500m with 100 nodes 2000m x 2000m with 150 nodes]
Area	2000m x 2000m
Transmission range	300 m
Link bandwidth	1 Mbps
Arrival Rate	150 kbps
Frame Rate	CBR
MAC	DCF
Packet Size	512 bytes
Control packet size	64 bytes/sec
Send buffer size	64 packets
Mobility Model	Random Waypoint Model (pause time: 0-360 msec, 150 msec was selected)
Speed	15 m/sec
Simulation time	300 sec

In the algorithm AntNetM, the ant timer is the time interval after which the subsequent ant of the same generation of Ant is to be released. This value was also modified from 0.03 to 0.3, and it was noted that, if ants release should be optimal, so that a large number of diagnostic control packets are not released in the network. The value of Δp as mentioned above is modified gradually by a parameter known as the reinforcement factor r. The relation between Δp and r is given by :

$\Delta p = r (1 - \Delta p)$, where r □ {0,1} ……. (4)

The QoS parameters identified for measurement for performance testing of Multimedia data transmission in MANET are efficiency measured as packet drop ratio(PDR). The other parameter is cumulative delay that includes queuing delay as well as propagation delay of packet transmission. The queuing delay is proportional to the efficiency of the system. These two parameters are have shown considerable improvement in the results mentioned below:

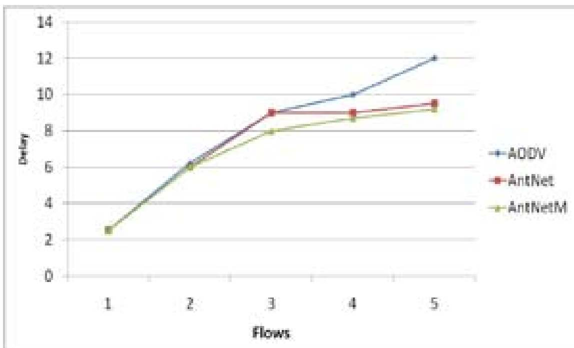

Fig. 2: Flow/Delay

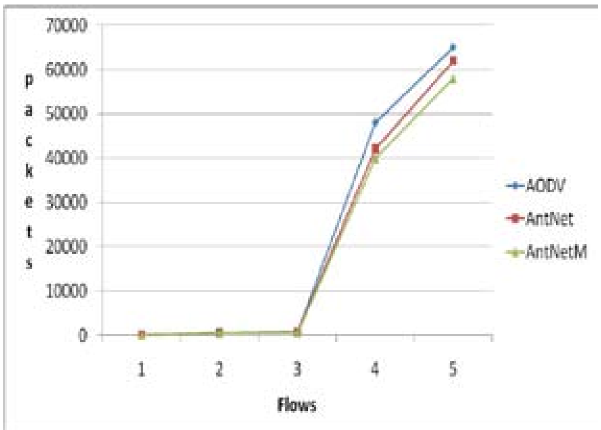

Fig. 3: Flow/Drop

As per the results shown above the packet drop ratio and end to end delay components are better in AntNetM as compared to AODV and AntNet.

VIII. Conclusion and future work

QoS based routing in multimedia communication applications, has been proved to be NP-Complete. In this paper, we have proposed a hybrid architecture for ACO based routing of multimedia traffic over MANETS. The architecture uses a hybrid routing approach of reactive route discovery and proactive path maintenance phase. The ACO based approaches, though known for a very adaptive and fast solution to QoS based routing, is known to suffer from stagnation problems, since most multimedia packets may rush towards the shortest path, gradually increasing overhead over those paths. Hence, we have also improvised on the stagnation avoidance mechanisms.

After changing the value of ant timer, the pheromone value of all the links is relatively close to each other. Hence, there is a uniform distribution of traffic throughout the network and there is also stagnation avoidance of best links. The route discovery and maintenance overheads are also reduced. This research does not claim that the approach will entirely remove stagnation, but it offers a new approach for differentiated multimedia data routing mechanism using Ant based Optimization techniques for QoS based routing of multimedia networks.

The simulation results indicate a better throughput and less end to end delay of the improved proposals. However, the present work also be extended for heuristic based stagnation avoidance.

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