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Minimum Routing and Congestion Avoidance in Mobile Ad Hoc Networks Using M/M/m Queuing Models

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Abstract: Mobile ad hoc networks are composed of mobile nodes communicating through wireless medium without any fixed backbone infrastructure. In these networks, broadcast and congestion are major issues. In MANET route discovery, conventional on demand route discovery methods employ flooding method where a mobile node blindly rebroadcasts Received Route Request (RREQ) packets until a route to a particular destination is established, it is costly and results in serious redundancy and collisions in the network. The problems of congestion it occurs in any intermediate node when data packets travel from source to destination and they incur high packet loss and long delay which cause the performance degradations of a network. This study proposes, a avoidance of congestion and minimum path routing in MANET. Initially, minimum routing is d-hop connecting and d-hop dominating sets method of cluster based routing is used in high dense region by using mean of neighbours. After segregation of networks, it initiates a minimum routing route discovery process to find a route to destination. This minimum routing is to reduce RREQ overhead during the route discovery operation. All the primary path nodes periodically calculate nearest neighbourhood node, it calculates the minimum path among all the path, the message is send from the path to the neighbour minimum path when the acknowledgment is received then a route is discovered to the destination. The congestion avoidance is performed by queuing models to avoid congestion in a routing path.

Key words: MANET, congestion, RREQ, avoidance, node

INTRODUCTION

A distributed algorithm for producing a variety of sets of nodes that can be used to form the backbone of an ad hoc wireless network. The backbone produced is a d-hop dominating set and in special cases is also d-hop connected and has a desirable "shortest path property". In this study, we enhanced the d-hop connected and d-hop Dominating Set algorithm with new properties. Which is called Enhanced d-hop dominating and enhanced d-hop connected (EdhopC and EdhopD). EdhopC means that every node is within a graph distance d of some node in the set. Routing via the backbone created is also discussed. The algorithm has a constant time complexity in the sense that it is un-affected by the size of the network as long as the node degrees aren't growing. The performances of this algorithm for various parameters are compared and also compared with other algorithms.

One of the important problems in ad hoc wireless networks is to find efficient routing algorithms. There are several approaches to do this. A common method is cluster-based hierarchical routing (Bannerjee and Khuller, 2001; Perkins, 2001; Ramanathan and Streenstrup, 1998; Toh, 2002). The network is divided into several clusters and from each cluster; certain nodes are elected to be cluster heads. These cluster heads are responsible for maintaining the routing information (Amis and Prakash, 2000; Chatterjee *et al*., 2002). Each cluster can have one or more gateway nodes to connect to other clusters in the network. These gateway nodes ensure connectivity between all the clusters in the network another approach; called backbone-based routing selects certain nodes from the ad hoc network which are similar to gateway nodes. These nodes form connected dominating set and are responsible for routing within the network (Das and Bharghavan, 1997). However, this backbone tends to be rather large. The approach blends features of these two approaches with the intention of gaining the advantages of each. The set produced by the algorithm is not connected and does not produce a traditional backbone. It is a Enhanced d-hop connected and Enhanced D-hop dominating (EDhopC and EDhopD) set with certain properties.

Let us recall that a connected dominating set is a set of vertices in a graph such that every vertex not in the set

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is adjacent to some vertex in the set and the sub-graph induced by the vertices in that set is connected (Guha and Khuller, 1998). Construction of a connected dominating set in an ad hoc net-work is desirable because the routing process needs to only consider the sub-network induced by this set. In this study, we propose a distributed algorithm which can be used to produce a variety of sets of vertices which could serve as the network backbone. The sets produced are DhopC and DhopD, small in size and in special cases are also EDhopC and EDhopD have a certain shortest path property.

In this study, G will denote a connected graph, representing ad hoc network. V denotes the set of all vertices in the graph G. The distance function in G will be denoted by δ. A vertex u in G is said to have eccentricity e(u) if G has a vertex v such that $\delta(u, v) = e(u)$ and for all vertices w in G, $\delta(u, w) \leq e(u)$. The radius of G, r(G) is the minimum of the eccentricities of its vertices. Gd will denote the d-closure of G by which we mean the graph whose vertices are the same as those of G but which has an edge between two vertices u and v if and only if $0<\delta(u, v)\leq d$. We call a subset D of the set of vertices of G a EDhopD set of G if it is a dominating set for Gd that is if every vertex of G is within a distance d of some vertex in D. We further say EDhopC if it is connected in Gd. We say a distributed algorithm is constant-time when the algorithm is unaffected by the size of the network as long as the vertex degrees aren't changing. That is the network can get bigger but not more dense. In this case, each node will have the same amount of work to do and will do it in the same time, assuming synchronicity.

LITERATURE REVIEW

Minimum connected dominating sets have been used to do routing in wireless ad hoc networks. Das and Bharghavan (1997) use the connected dominating set on a graph to do shortest path based routing. The dominating set induces a virtual backbone of connected vertices in the graph. Since, it is 1-hop connected and 1-hop dominating, the set is likely to be very big for a network with a large number of nodes. Moreover, if some node in the backbone were to fail, it may partition the induced sub-graph. The max-min scheme for clustering nodes in a wireless ad hoc network is described by Amis *et al*. (2000) which introduces the concept of d-hop dominating sets and proves that finding a minimum d-hop dominating set is NP-complete. They use the nodes selected in this set to divide the graph into a set of clusters. They assume unique IDs for each node and select a node for inclusion in the set if it has the highest ID in some d-hop neighbourhood. They describe a distributed way of finding the dominating nodes by flooding the node ID information for d rounds to all the neighbours of the node. Further, they do other d rounds of flooding to determine the clusters dominated by each node in the dominating set. This algorithm is constant-time. d-hop connected and d-hop dominating is a basic algorithm (Wu and Li, 2000; Eckberg Jr., 1979) for constructing a connected dominating set in a connected graph of radius at least two. This algorithm is distributed in the sense that each node processes local information that it receives from its neighbours in order to decide whether or not it should join the dominating set and it is constant time. They then consider some ways to refine the basic algorithm in order to produce smaller connected dominating sets.

The basic EDhopC and EDhopD algorithm (Eckberg Jr., 1979) can be characterized as follows. For each node z, the following question is asked: does z have neighbours x and y such that x and y are not adjacent? The vertex z is then admitted to a set which we will call d-hop connected and d-hop dominating (G) if and only if the answer to this question is yes. It is then possible to show that d-hop connected and d-hop dominating (G) is a connected dominating set, unless G is complete (i.e. has radius one). d-hop connected and d-hop dominating then consider refining the above technique by assuming that each vertex has a unique (perhaps randomly assigned) integer identifier. Their Rule 1" amounts to asking a further question for each vertex z in dhopD(G) as follows: Does z have a neighbour z' in dhopD(G) whose ID is higher than that of z and which is such that all of the neighbours of z are also neighbours of z1? If so, z is deemed to be superiors. The set dhopD1(G) consists of all the vertices from DhopD0(G) for which the answer to the question is no". It too is a connected dominating set. To further reduce the size of the set, d-hop connected and d-hop dominating also introduce Rule 2". For each vertex z in dhopD(G), the following question is asked: does z have two neighbours from dhopD(G) which are themselves adjacent and which have IDs larger than that of z and which are such that their combined neighbours include all of the neighbours of z? The set dhopD2(G) consists of all the vertices from dhopD(G) for which the answer is no". This too can be shown to be a connected dominating set.

d-hop connected and d-hop dominating: Let us consider the possibility of replacing Rule 1" with a stronger condition. The resulting set of vertices will be denoted by D(G). Specifically, the algorithm we wish to consider proceeds as follows:

- Consider each pair of vertices x and y which are separated by a distance2 in G
- For such a pair, consider all of the common neighbours of x and y. Let, E(x, y) denote the vertex among these common neighbours whose ID is largest
- Admit a vertex to the set D(G) if and only if it is E(x, y) for some suitable pair x and y

We will say that E(x, y) was elected by the pair x and y to join the set. Notice that vertices elected by d-hop connected and d-hop dominating are also in the set. Moreover, any vertex eliminated by Rule 1 an advantage of this approach over that of ED-hop connected and ED-hop dominating is the shortest path property" described in the following the theorem. This is a special case (d = 1) of Theorem 2 which is stated and proved in the next study. Theorem 1: assume that the connected graph G has radius at least two. Then, the set D(G) constructed by Enhanced d-hop connected and dominating set.

Moreover, any two vertices in G can be connected by a shortest path consisting solely of vertices from D(G) (apart from the endpoints).

Part I

The Enhanced d-hop Connected d-hop Dominating (EDhopC and EDhopD) set algorithm: There is a trivial way to apply d-hop connected and d-hop dominating algorithm in order to produce the EDhopC and EDhopD. To do so, simply apply the d-hop connected d-hop dominating algorithm to Gd instead of G. Then, from the standpoint of G, the resulting set is a EDhopC and EDhopD set. However, because the graph Gd obscures the sense of distance in G, we feel that this is not a desirable approach. By contrast, the d-hop Connected d-hop Dominating Set algorithm (d-CDS) to be proposed next, works directly with the graph G, rather than Gd and results in a set with this desirable shortest path property. Moreover, we will show that this algorithm has a more efficient implementation. It is described as follows:

- For each pair of vertices x and y satisfying $\delta(x, y) = d+1$, consider all of the shortest paths from x to y
- Consider the set of vertices that lie strictly between x and y along such a path. Let, E(x, y) be the vertex in this set with the highest ID. Call this vertex E(x, y)
- Construct the set Dd(G) by including all such E(x, y) and only these vertices. This algorithm also has a shortest path property as described in the following theorem

Theorem: Assume that the connected graph G has radius at least d+1. Then, the set Dd(G) is a d-hop connected d-hop dominating set. Moreover, any two vertices u and v from G can be connected by a shortest path (in G) with the property that the set of vertices which are on this path and also in Dd(G), together with the vertices u and v form a connected path between u and v in the d-closure Gd.

Proof: Consider a vertex x in G. There exists a vertex y at a distance d+1 from x. The vertex E(x, y) is in Dd(G) and is within a distance d of x. Hence, Dd(G) is d-hop dominating. To show the rest, x and y two vertices u and v. Let, p be a shortest path in G from u to v. Let, u_j denote the vertex arrived at after taking j steps along this path ($j = 0, 1, 2, ..., m$ where, $m = \delta(u, v)$). Consider the vertices on p that are also in Dd(G), together with the vertices u and v. Consider the sub-graph of Gd induced by this set. If this is not a path from u to v in Gd, then let i be as large as possible so that u_i is either u or is in Dd(G) and is connected to u in the induced subgraph. So, $i<m-d$. So, u_i+d+1 is a vertex on the path at a distance d+1 from u_i in G. Therefore, there is a path q of length d+1 from u_i to u_i+d+1 which goes through an element of Dd(G), namely $E(u, u_i+d+1)$. Now create another shortest path in G from u to v by replacing the sub-path of p from u_i to u_i+d+1 with the path q. If the resulting path is still not satisfactory to establish the second claim in the theorem, then repeat the procedure. This time i will be larger. Continuing in this way, a suitable path will eventually be produced (Fig. 1).

Part II: There is a widespread increasing use of wireless technologies, Quality of Service (QoS) provisioning in ad hoc networks remains a challenging task. Good scalability of the QoS architecture is necessary as the size of the ad hoc networks is huge. A networked control system traditionally consists of a wired based communication medium, either direct connections

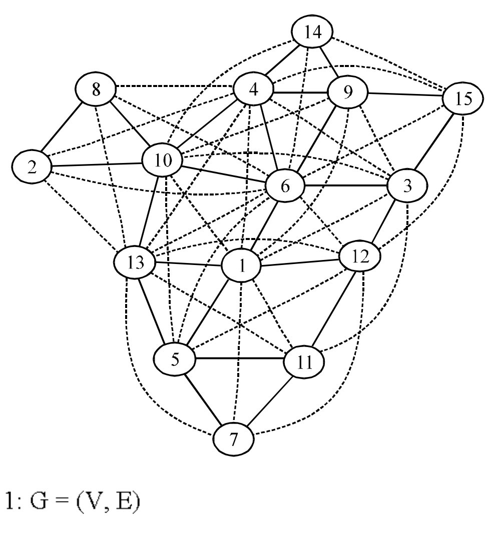

Fig. 1: G = (V, E)

between the plant and controller using dedicated cables or by employing a bus based technology such as token ring or ethernet. Recent research has investigated using wireless networks between the plant and a backbone wired network technology such as ethernet to the controller (Amis and Prakash, 2000; Chatterjee *et al*., 2002). This study investigates using a wireless network that does not rely on any wired infrastructure as the communication medium and for the purpose of controlling congestion which happens due to heavy traffic is overcome by queuing models. Mobile Ad hoc Networks (MANETs) are dynamic infrastructure less wireless networks where each node within the network is required to forward and route packets, nodes can also leave and enter the network in real time due to their mobility. In this research, researchers consider the problem of congestion control in Mobile Ad hoc Networks (MANETs) and overcome the problems by applying queuing models. In most wireless networking environments in productive use today, the users' devices communicate either via some networking infrastructure in the form of base stations and a backbone network, examples are WLANs, GSM/UMTS and 4G networks or directly with their intended communication partner, e.g., using 802.11 in ad hoc mode.

In contrast, a mobile ad hoc network does not have an infrastructure and still the devices do not need to be within each other's communication range to communicate. Instead, the end-users' (mobile) devices also act as routers and data packets are forwarded by intermediate nodes to their final destination (Fig. 2a and b). MANETs are applicable in situations where no infrastructure is available; a common example is a disaster relief scenario. They are also the foundation for vehicular ad hoc networks where communication between cars is used to increase vehicle safety and driving comfort. There are also related multihop wireless networks, e.g., wireless mesh networks or wireless sensor networks. These networks share some of the congestion control related problems with MANETs. Much, research effort has been put into the MANET area.

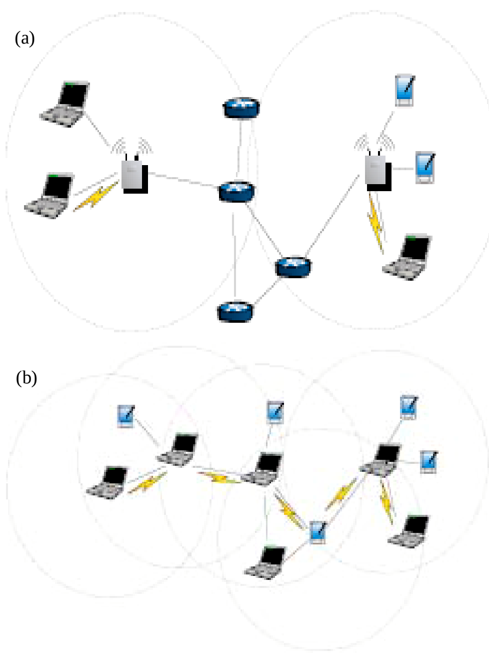

Fig. 2: a) Wireless network and b) wireless ad hoc network

CONGESTION PROBLEM

In a network with shared resources where multiple senders compete for link bandwidth, it is necessary to adjust the data rate used by each sender in order not to overload the network. Packets that arrive at a router and cannot be forwarded are dropped, consequently an excessive amount of packets arriving at a network bottleneck leads to many packet drops. These dropped packets might already have travelled a long way in the network and thus consumed significant resources. Additionally, the lost packets often trigger retransmissions which mean that even more packets are sent into the network. Thus, network congestion can severely deteriorate network throughput. If no appropriate congestion control is performed this can lead to a congestion collapse of the network where almost no data is successfully delivered.

Priority of traffic: Generally, in QoS provisioning, the bandwidth is allocated first to the higher priority traffic in preference and then allocated to the lower priority traffic. The lower priority traffic can utilize the bandwidth only after the utilization of the higher priority traffic. If a high priority flow's traffic pattern satisfies the behaviour described in the service agreement, its packets should be delivered in preference to other packets with lower priorities. On the other hand, flows with lower priorities should use as much bandwidth as possible after the transmission requirements of higher priority flows.

QoS provisioning challenges in MANETs: Due to several problems, QoS provisioning in MANETs is much complicated when compared to wired networks. The following are some of the main QoS provisioning and maintenance problems in MANETs.

It requires knowledge of the available bandwidth which is difficult to be accurately estimated in a dynamic environment.

Bandwidth reservation has to be made through negotiation between neighbours within two to three hops other than only the direct neighbours sharing the same channel and this needs signalling message exchanges between them. Moreover, when the neighbour moves out of the reservation area of the node, the reserved bandwidth in a neighbour should be released through some mechanism. Hence, an extra control overhead will be introduced by these signalling messages and consumes limited bandwidth and energy.

The reserved bandwidth over the entire duration of an active session cannot be guaranteed. Some of the reserved bandwidth might be stolen by the oncoming node, if a communicating node moves towards a node which has reserved some bandwidth for flow(s). The reserved bandwidth over the link between them might be unavailable or the link might be broken, if two nodes on the end of a link move away from each other.

In MANETs, due to the dynamic topology, there is no clear definition of what is core, ingress or egress router. Since, all the nodes in the network cooperate to provide services, there is no clear definition of a Service Level Agreement (SLA). On the other hand, an infrastructure network where the services to the users in the network are provisioned by one or more service providers.

Since, the wireless bandwidth and capacity in MANETs are affected by interference, noise and multi-path fading, it is limited and the channel is not reliable. Moreover, the available bandwidth at a node cannot be estimated exactly because it involves in a large variations based on the mobility of the node and other wireless device transmitting in the vicinity, etc. (Das and Bharghavan, 1997).

Queuing systems: A queuing system consists of one or more servers that provide service of some sort to arriving customers. Customers who arrive to find all servers busy generally join one or more queues (lines) in front of the servers, hence the name queuing systems. There are several everyday examples that can be described as queuing systems (Perkins, 2001) such as bank-teller service, computer systems, manufacturing systems, maintenance systems, communications systems and so on.

Components of a queuing system: A queuing system is characterized by three components:

- Arrival process
- Service mechanism
- Queue discipline

Arrival process: Arrivals may originate from one or several sources referred to as the calling population. The calling population can be limited or ‘unlimited’. An example of a limited calling population may be that of a fixed number of machines that fail randomly. The arrival process consists of describing how customers arrive to the system. If A_i is the inter-arrival time between the arrivals of the (i-1)th and ith customers, we shall denote the mean (or expected) inter-arrival time by E(A) and call it (λ); = 1/(E(A) the arrival frequency.

Service mechanism: The service mechanism of a queuing system is specified by the number of servers (denoted by s) each server having its own queue or a common queue and the probability distribution of customer’s service time. Let S_i be the service time of the ith customer, researchers shall denote the mean service time of a customer by E(S) and μ = 1/(E(S) the service rate of a server.

Queue discipline: Discipline of a queuing system means the rule that a server uses to choose the next customer from the queue (if any) when the server completes the service of the current customer. Commonly, used queue disciplines are:

- FIFO: customers are served on a first-in first-out basis
- LIFO: customers are served in a last-in first-out manner
- Priority: customers are served in order of their importance on the basis of their service requirements

Measures of performance for queuing systems: There are many possible measures of performance for queuing systems. Only some of these will be discussed here.

Let, D_i be the delay in queue of the ith customer W_i be the waiting time in the system of the ith customer = D_i+S_i Q(t) be the number of customers in queue at time t. L(t) be the number of customers in the system at time t = Q(t)+No. of customers being served at t. Then, the measures:

$$d = \lim_{n\to\infty} \frac{\sum_{i=1}^{i=1} D_i}{n}; \; w = \lim_{n\to\infty} \frac{\sum_{i=1}^{i=1} W_i}{n} \tag{1}$$

(if they exist) are called the steady state average delay and the steady state average waiting time in the system. Similarly, the measures:

$$Q = \lim_{T\to\infty} \frac{1}{T}\int_0^T Q(t)dt; \; L = \lim_{T\to\infty} \frac{1}{T}\int_0^T L(t)dt \tag{2}$$

(if they exist) are called the steady state time average number in queue and the steady state time average number in the system. Among the most general and useful results of a queuing system are the conservation equations:

$$Q = (\lambda)d \text{ and } L = (\lambda)w \quad (3)$$

These equations hold for every queuing system for which d and w exist. Another equation of considerable practical value is given by:

$$w = d + E(S) \quad (4)$$

Thus for example, the [M/M/m]: {infinity/infinity/ FCFS} system is one where the arrivals and departures are a Poisson distribution with a single server, infinite queue length, calling population infinite and the queue discipline is FCFS. This is the simplest queue system that can be studied mathematically. This queue system is also simply referred to as the M/M/m queue. The M/M/m-Queue (m>1) has the same inter arrival time and service time distributions as the M/M/1 queue, however, there are m servers in the system and the waiting line is infinitely long. As in the M/M/1 case a complete description of the system state is given by the number of customers in the system (due to the memory less property). The M/M/m system is also a pure birth-death system.

Proposed model: In this study, researchers want to compare three different systems in terms of mean response time (mean delay) vs. offered load: a single M/M/1 server with the service rate mμ, a M/M/m system and a system where m queues of M/M/1 type with service rate ì are in parallel such that every customer enters each system with the same probability. The answer to this question can give some hints on proper decisions in scenarios like the following: given a computer with a processor of type X and given a set of users with long-running number cruncher programs. These users are all angry because they need to wait so long for their results. So, the management decides that the computer should be upgraded. There are three possible options:

- Buy n-1 additional processors of type X and plug these into the single machine, thus, yielding a multiprocessor computer
- Buy a new processor of type Y which is n times stronger than processor X and replacing it and let all users work on that machine
- Provide each user with a separate machine carrying a processor of type X without allowing other users to work on this machine

PERFORMANCE ANALYSIS

We show that the second solution yields the best results (smallest mean delays) followed by the first solution while the last one is the worst solution. The first system corresponds to an M/M/m System where each server has the service rate μ and the arrival rate to the system is λ the second system corresponds to an M/M/1 System with arrival rate λ and service rate m.μ. And from the view of a single user, the last system corresponds to an M/M/1 System with arrival rate λ/k and service rate μ. In this research, we have to visualize variety of queuing models and check the network parameters. Defined queuing models are analyzed and used for reliable communication in MANET's without congestion. Once the congestion is controlled and route overhead is also less we can have a good communication system. The M/M/1 Queuing Model (exponential arrival and service rates) is considered as a base case but due to its specific assumptions regarding the arrival and service processes, it is not useful to describe real-life situations. Relaxing the specifications for the service process, leads to the M/G/1 Queuing Model (generally distributed service rates). Relaxing both assumptions for the arrival and service processes results in the G/G/k Queuing Model. We are designing a system which will speak about three queuing models on different environments. We have considered topologies like static, random and clustered topology where congestion is introduced and checked on these environments. The considered parameters are delay time, network overhead, throughput, etc. The proposed method is been tested on all kinds of networks using queuing models. In this study, random topology has been consider (Fig. 3-5).

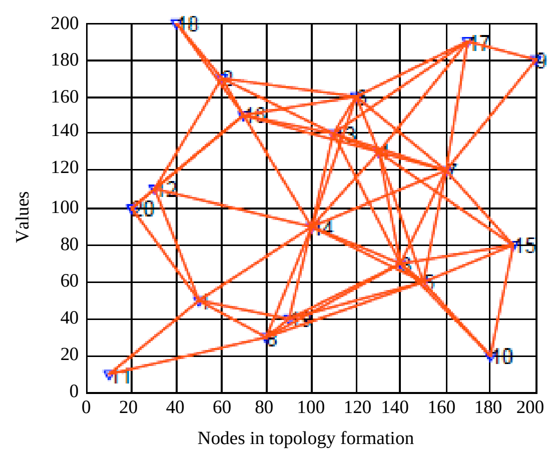

Fig. 3: Nodes in random topology

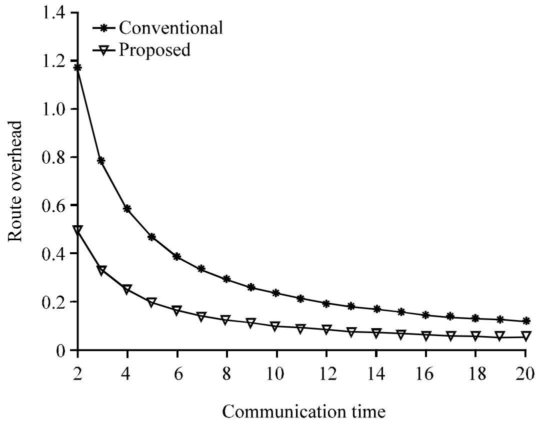

Fig. 4: Route overhead

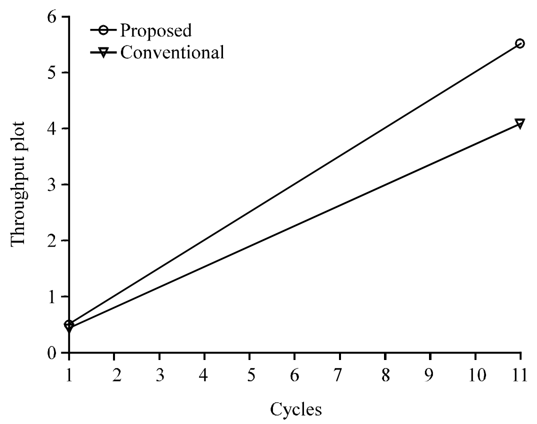

Fig. 5: Throughput

CONCLUSION

Congestion and finite capacity queuing systems are probably one of the most prevalent facts of modern life. Congestion usually leads to a decrease in the systems service rates and finite capacity impedes overall system throughput. Using a wireless network that does not rely on any wired infrastructure as the communication medium and for the purpose of controlling congestion which happens due to heavy traffic is overcome by Queuing Models. The proposed a novel approach of finding a EDhopC and ED-hop dominating set in an ad hoc wireless network that is also ED-hop connected and has a certain shortest path property in some special cases. This is the basis of the routing scheme which is also very efficient from a cost perspective. We evaluated variations of generalized d-CDS algorithm relaxing the "shortest path property" which produces a smaller dominating set size while trading off on computation costs. We are exploring cost efficient alternatives to rule 2 in the d-hop connected and d-hop dominating algorithm. While, we recognize that rule 2 plays a very useful role in controlling the size of the set, it also sacrifices the shortest path property" and is costly to compute. We are also considering the idea of changing the parameters used based on dynamically obtained information about the network, like density (vertex degree).

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