

# Analyzing the Performance of AntHocNet Protocol for MANETs

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## ABSTRACT

Mobile Ad-hoc network (MANET) is an autonomous system of mobile nodes connected by wireless links without a common infrastructure. They move randomly and unpredictably thus making the topology very dynamic in nature. This paper discusses the implementation and performance analysis of the AntHocNet algorithm which is based on the nature-inspired Ant Colony Optimization (ACO) framework for routing in mobile ad hoc networks.

In this work we have implemented and tested the performance of the AntHocNet algorithm for routing in mobile ad hoc networks. AntHocNet is an adaptive hybrid algorithm, which combines reactive path setup with proactive path probing, maintenance and improvement. Using an extensive set of simulation experiments in QualNet, we have compared the performance of AntHocNet algorithm with traditional AODV routing algorithm. It is observed that the bio-inspired algorithm has outperformed AODV on different evaluation criteria such as average end to end delay, throughput, average jitter, packet delivery ratio, queuing delay and convergence time while changing parameters like node density, pause time, terrain size and Random-Waypoint max-speed.

## Keywords

MANET, AntHocNet, AODV, QualNet, Convergence time, Terrain size and RWP max-speed.

## 1. INTRODUCTION

Over the last two decades there has been such tremendous growth in the field of networks that it has paved a way for a wireless era from a wired one. Wireless networks find their applications in many fields such as in military, radio satellites, emergency operations, wireless mesh networks, wireless sensor network among a few. Ad-hoc networks keep changing dynamically, which results in disturbance of the network. Hence a need arises to have seamless communication. Mobile Ad-hoc Network (MANET) is a type of Ad-hoc network with a self-organizing capability. They basically consist of mobile nodes which are connected to each other by wireless links. They do not have any fixed infrastructure or a centralized administration. During communication, nodes within the transmission range can have direct communication, but if that isn't the case they have to communicate through intermediate nodes [1].

The term routing refers to the process of selecting paths in a computer network along which data is sent. This process is carried out by a routing protocol, used to exchange information about topology and link weights, and a routing algorithm, that computes paths between nodes [2]. The routing protocols are divided into three categories [3]. Firstly the proactive protocols like DSDV [4], OLSR [5], reactive protocols like AODV [6] and hybrid protocols like TORA, ZRP [7], and MPOLSR [8]. Another most important type of protocols in recent times are the Bio-inspired protocols. Bio-

inspired protocols are found to be capable of demonstrating self organizing behavior due to their robustness and efficiency; examples of such protocols are AntHocNet, BeeAdHoc [9], and ANSI [10].

This paper discusses the results of the experiments conducted on AntHocNet algorithm, whose design is based on a self-organizing behavior of ants, shortest path discovery and on Ant Colony Optimization. AntHocNet follows hybrid approach unlike other bio-inspired algorithms. While most of the previous bio-inspired algorithms were adopting a proactive scheme by periodically generating ant-like agents for all possible destinations, AntHocNet generates ants according to both proactive and reactive schemes.

The paper is organized as follows: In section II, we discuss the related works carried out in the area. Section III, briefly describes the literature survey relevant to our work. Section IV gives a brief discussion on system design and Implementation followed by Simulation results in Section V. Section VI gives the conclusion and future enhancements possible.

## 2. RELATED WORK

MANETs are networks in which all the nodes are mobile and communicate exclusively via wireless – infrastructure-less topology. Adaptivity is an important factor in MANETs. This is because the nodes move randomly and unpredictably thus making the topology very dynamic in nature. Self-configuring network of mobile routers (and associated hosts) connected by wireless links is also an important requirement of such networks. The inspiration is obtained by nature's self-organizing systems like insect societies which precisely show these desirable properties.

The modeling of social insects by means of Self-Organization forms the concept of swam intelligence. Based on the application of social behavior of insects and other animals, various problems of routing are solved. The term bio-inspired demonstrates the strong relation between an algorithm, which has been proposed to solve a specific problem and a biological system, which follows a similar procedure or has similar capabilities

The Ant Colony Optimization algorithms derive their source of inspiration from the concepts in nature i.e. the behavior of social insects and ant colonies. It is based on the coordinated behavior of the ants which is useful in finding the food and the movement back to the nest from the food source. Based on ACO approach many routing algorithms have been generated for wired and wireless networks. The shortest path finding process is highly distributed and self organized, robust, adaptive and scalable.

Ant-AODV [16] is a hybrid algorithm combining ants with the basic AODV behavior. Fixed number of ants keeps going around the network in a more or less random manner, proactively updating the AODV routing tables in the nodes they visit whenever possible.

Ant-colony-based routing algorithm (ARA) works in an on-demand way, with ants setting up multiple paths between source and destination at the start of a data session [19].

Probabilistic emergent routing algorithm (PERA) works in an on-demand way, with ants being broadcast towards the destination at the start of a data session. Multiple paths are set up, but only the one with the highest pheromone value is used by data (the other paths are available for backup) [20].

Also other ACO routing algorithms have been proposed for MANETs. Most of all these algorithms move quite far away from the original ACO routing ideas trying to obtain the efficiency needed in MANETs, and many of them are not very different from single-path on-demand algorithms.

AntHocNet has been designed after the Ant Colony Optimization (ACO) framework, and its general architecture shares strong similarities with the architectures of typical ACO implementations for network routing [17].

### 3. LITERATURE SURVEY

#### 3.1 MANET

MANET is an autonomous collection of mobile users that communicate over relative bandwidth constrained wireless links. Since the nodes are mobile, the network topology changes rapidly and unpredictably over time. The network is decentralized; where all network activity including discovering the topology and delivering messages must be executed by the nodes themselves i.e. routing functionality will be incorporated into mobile nodes.

MANETs support multi-hop feature, which makes communication between nodes outside direct radio range of each other possible, which is probably the most distinct difference between mobile ad hoc networks and wireless LANs. The MANETs main characteristics [11] are:

*Dynamic topology, Energy-constrained operation, Limited physical security and scalability to name a few.*

#### 3.2 Bio-Inspired Protocol

It is based on the application of social behavior of insects and other animals to solve the problems of routing [12]. Some of the Bio-inspired routing protocols are: AntHocNet, ARA (Ant-colony based Routing Algorithm), BeeAdHoc, ANSI (Ad hoc Networking with Swarm Intelligence), etc.

Swarm Intelligence (SI) is an artificial bio-inspired intelligence technique based on the study of collective behavior in decentralized, self-organized systems. Since 1999, there is a great interest in applying swarm intelligence to solve hard static and dynamic optimization problems. These problems are solved using cooperative agents that communicate with each other modifying their environment, like ant colonies or others insects do. This is the reason why these agents are commonly called ants.

Key characteristics of these models are:

- Large numbers of simple agents.
- Agents may communicate with each other directly.
- Agents may communicate indirectly by affecting their environment, a process known as stigmergy.
- Intelligence contained in the networks and communications between agents.
- Local behavior of agents causes some emergent global behavior.

Ant routing is the result of using swarm-intelligence in systems for routing within communications networks. Ant Colony Optimization (ACO) is popular among other Swarm Intelligent Techniques.

#### 3.3 ACO

The main idea behind ACO routing algorithms is that they gather routing information through repeated sampling of full paths using small control packets, which are called ants. This is in line with the behavior of ants in nature, where a large number of ants continuously move between their nest and the food source, and with the working of ACO algorithms for combinatorial optimization, where multiple artificial ants repeatedly and in parallel construct sample solutions for the problem at hand.

The ants are generated concurrently and independently by the nodes, with the task to test a path to an assigned destination. An ant going from source node 's' to destination node 'd' collects information about the quality of the path and uses this on its way back from 'd' to 's' to update the routing information at the intermediate nodes. Ants always sample complete paths, so that routing information can be updated.

The routing tables contain for each destination a vector of real-valued entries, one for each known neighbor node. These entries are a measure of the goodness of going over that neighbor on the way to the destination. They are termed pheromone variables, and are constantly updated according to path quality values calculated by the ants. The repeated and concurrent generation of path-sampling ants results in the availability at each node, a bundle of paths, each with an estimated measure of quality. In turn, the ants use the routing tables to define which path to their destination they sample: at each node they stochastically choose a next hop, giving higher probability to those links which are associated with higher pheromone values. This pheromone information is used for routing data packets, more or less in the same way as for the routing of ants: all packets are routed stochastically, choosing with a higher probability those links associated with higher pheromone values. There are also some initiatives for ant-routing algorithms in ad hoc networks other than AntHocNet, ARA [13], and PERA [14] among a few.

In case of wireless networks, AntHocNet is more efficient among all the considered ant based algorithms. This is because it has greater chance of exploring new paths based on probability. But it is costlier as more resources are required for implementing it. This is due to the fact that there is lot of ant traffic generated during the routing process.

#### 3.4 Agents for Hybrid Multipath Routing (AntHocNet)

AntHocNet is a multipath routing algorithm for mobile ad-hoc networks that combines both proactive and reactive components. It is based on AntNet [15], [18], designed for wired networks, with some modifications to be used on ad-hoc networks. AntHocNet emerges as a reactive, adaptive, multipath and proactive algorithm (hybrid) [17].

It is reactive because it has agents operating on-demand to set up routes to destinations. 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 launched by the source in order to find multiple paths to the destination, and backward ants return to set up the paths. The paths are represented in pheromone tables indicating their respective quality. After path setup, data packets are routed stochastically as datagrams over the different paths using these pheromone tables. While the data session is open, paths are monitored, maintained and improved proactively using different agents, called proactive forward ants. The algorithm

reacts to link failures with either a local route repair or by warning preceding nodes on the paths.

## 4. SYSTEM DESIGN AND IMPLEMENTATION

### 4.1 Main design criteria

*Simulator chosen:* The simulator chosen to evaluate the two protocols is QualNet 5.0 as it offers a number of important advantages when compared to other simulators. Some of the features of QualNet are: it includes an extensive documentation and technical support, user-friendly tools, tools for building scenarios and analyzing simulation output. It offers large set of modules and protocols for both wired and wireless networks (local, Ad hoc, satellite and cellular).

The key to successful deployment of wireless networks in QualNet is its speed, scalability, accuracy and portability. QualNet offers highly detailed models of all aspects of networking. This ensures accurate modeling results. Scalability in QualNet is necessary for prediction of large network behavior of thousands of nodes. QualNet runs on all common platforms (Linux, Windows, and Solaris).

A feature-rich visual development environment offered by QualNet allows users to set up models quickly, efficiently code protocols and then run models that present real-time statistics. It also provides packet-level debugging insight.

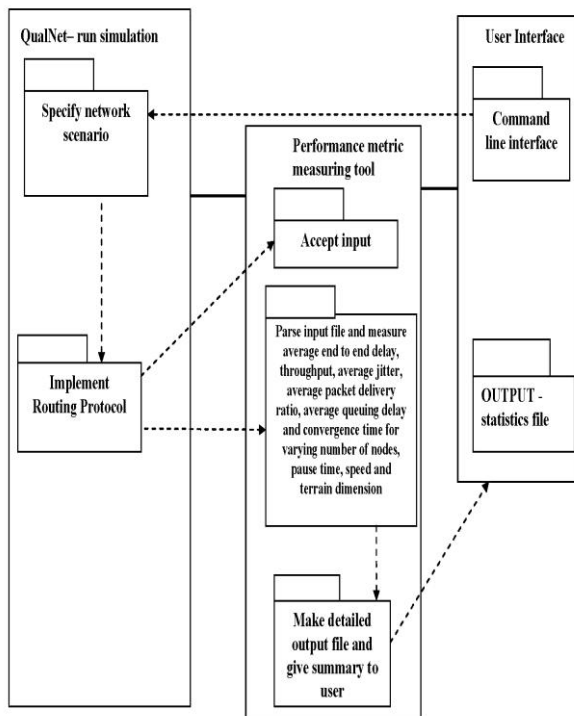


Fig 1: Subsystem Design- modules and their interaction.

All QualNet libraries are available for parallel execution. QualNet seems to be the most complete network simulator, in terms of available protocols, models and tools for simulating the mobile ad hoc networks.

*Algorithms chosen:* One representative algorithm from traditional and bio-inspired algorithms each was chosen for comparison. This would give a broad picture of which type of the chosen algorithm performs well in which environment. The specific algorithms chosen within each category were AODV for traditional and AntHocNet for hybrid. The subsystem modules and their interactions are shown in the Figure 1.

### 4.2 Implementation

*Network Scenarios:* In order to do conducted the tests in a controlled way, we define a common scenario for both AntHocNet and AODV, by varying relevant parameters such as the terrain size, RWP max-speed, node density and pause time. We consider the following settings:

- Mobility model for nodes as the random waypoint propagation mobility model.
- Simulation time is 180s.
- Data traffic is generated by constant bit rate (CBR) sessions.
- Radio propagation, we use the two-ray signal propagation model.

*Evaluation Measures:* The different measures for evaluating the chosen protocols are as follows:

- The first one is the packet delivery ratio. This is the fraction of correctly delivered data packets versus sent packets.
- As a second measure, we consider the average end-to-end packet delay. This is the cumulative statistical measure of the delays experienced by packets traveling between source and destination.
- Thirdly, we use the average jitter. This is the variation in the time interval between the arrivals of subsequent packets.
- As a fourth measure, we have considered throughput; this is the measure of number of packets sent in unit time.
- As a fifth measure, we considered convergence time; this is the time between a fault detection, and restoration of new, valid, path information.
- The sixth is average queuing delay; which is the average amount of time the packet spends waiting to be dequeued.

## 5. SIMULATION RESULTS

In order to be able to cover all the types of scenarios the algorithms might face, we varied node density (number of nodes), terrain size and the node mobility (pause time and rwp max-speed). The node density (number of nodes) was varied in the range [20, 100] in steps of 20 (5 different node densities). Pause time was varied in the range [3, 180] (20 different pause times). RWP max-speed was varied in the range [20,100] in steps of 20 (5 different scenarios). The terrain size was varied in the range [250, 1000] (4 different terrain dimensions).

### 5.1. Average end-to-end delay

From Figure 2 and 3, it is observed that AODV has lower average end-to-end delay when compared to AntHocNet. The results for average end-to-end delay reflect the increasing level of difficulty of the scenarios owing to which the delay increases with increasing node speeds and node densities.

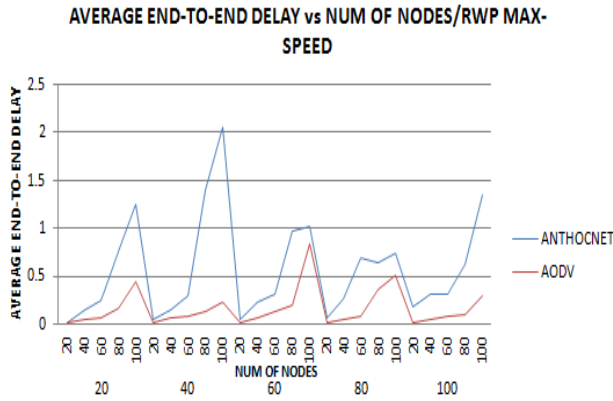


Fig 2: Average end to end delay with varying rwp max-speed

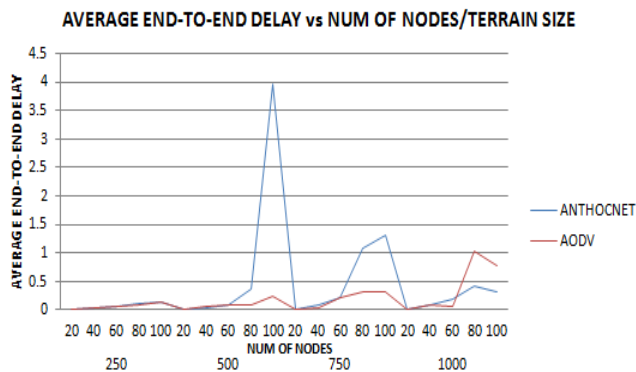


Fig 3: Average End to End Delay with varying terrain size

## 5.2. Average Jitter

From Figure 4 and 5 below, it can be seen that for both the algorithms, jitter increases with increase in the number of nodes and higher pause times with slight advantage towards AntHocNet which has less jitter overall. Since AntHocNet is a multipath protocol, two subsequent packets may follow different paths and reach the destination. Hence the delay incurred between the arrivals of these packets is small.

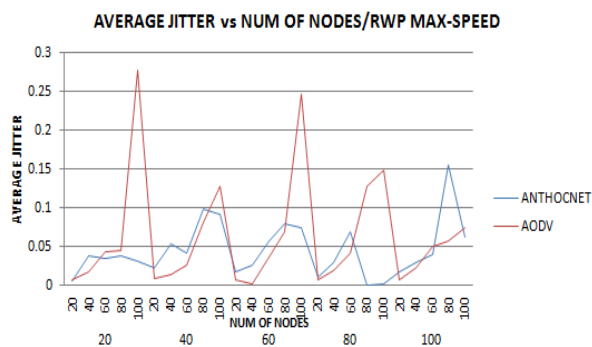


Fig 4: Average jitter with varying rwp max-speed

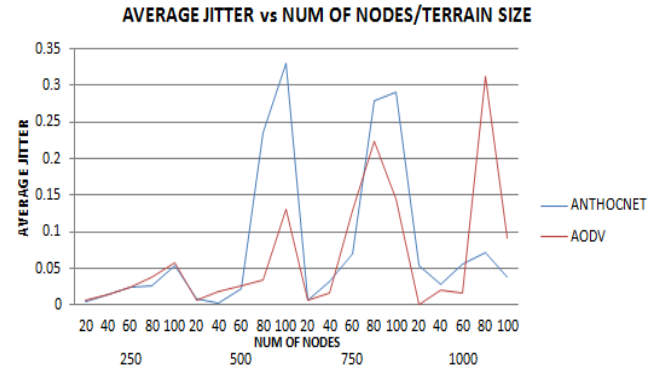


Fig 5: Average jitter with varying terrain size

## 5.3. Convergence time

From Figure 6 and 7, it can be seen that in both AntHocNet and AODV convergence time is low for lower node densities, it increases as the number of nodes increases. In Figure 6 this can be owed to the fact that nodes are highly mobile as the speed is varied and the path is not stable. In Figure 7 the terrain size is varied and the nodes are spread far away from each other and hence setting up a path from the source to the destination is very difficult.

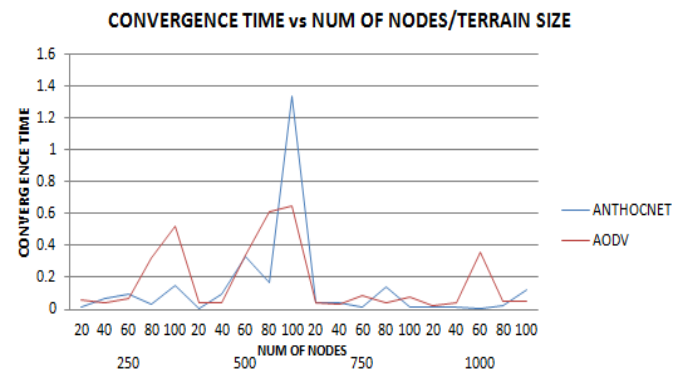


Fig 6: Convergence time with varying rwp max-speed

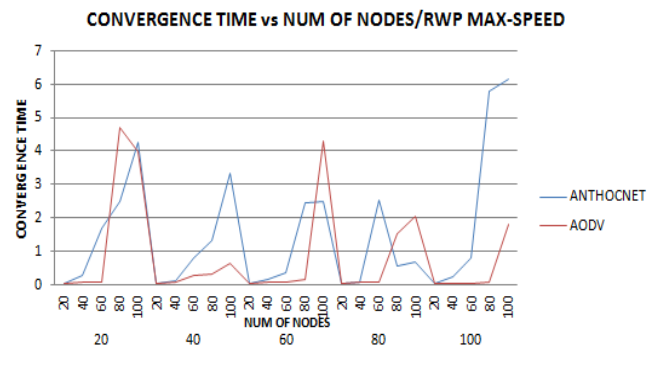


Fig 7: Convergence time with varying terrain size

#### 5.4. Average Packet Delivery Ratio

From Figure 8 and 9, it is seen that AntHocNet outperforms AODV in terms of packet delivery ratio. AntHocNet uses different kinds of ant packets like FANT, BANT etc in order to adapt to changing MANET environment. Hence it computes many optimal routes thereby reducing the number of packet drops. It is observed from Figure 9 that as terrain dimension increases the packet delivery ratio decreases because the nodes are distributed randomly across large dimensions and also since they are mobile the connectivity between the nodes keeps breaking.

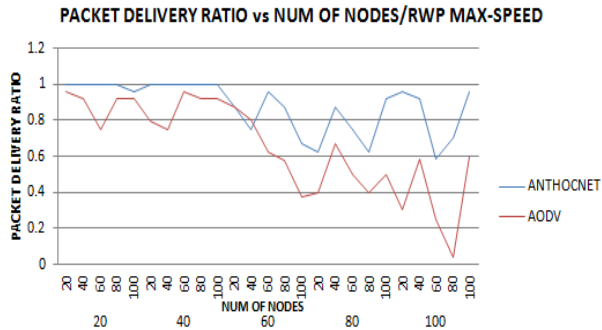


Fig 8: Average packet delivery ratio with varying rwp max-speed

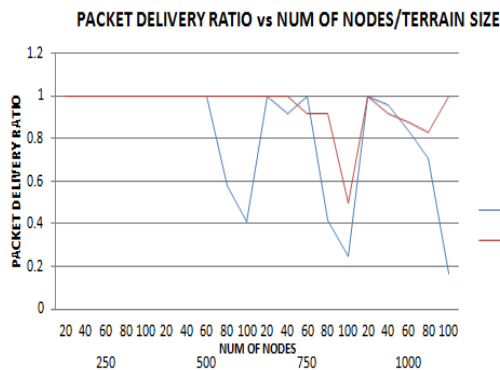


Fig 9: Average packet delivery ratio with varying terrain size

#### 5.5. Average Queuing delay

It can be observed from Figure 10 and 11 that the average queuing delay is less for AntHocNet for varying pause time and terrain size when compared to AODV. Average queuing delay is the average time spent by the packets in the queue. As AntHocNet is multipath routing algorithm the amount of time the packets spend in the queue is lesser when compared to AODV which is single path routing.

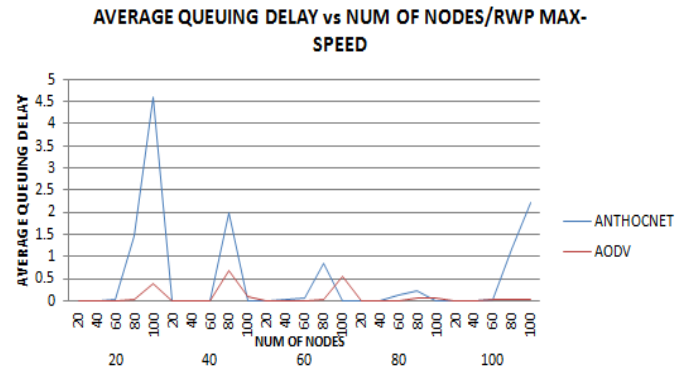


Fig 10: Average queuing delay with varying rwp max-speed

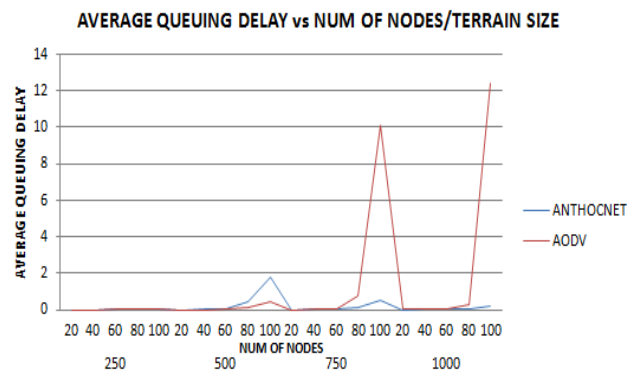


Fig 11: Average queuing delay with varying no. of nodes.

#### 5.6. Throughput

From the Figure 12 and 13 below, it can be seen that AODV has greater throughput compared to AntHocNet. The expected throughput of AntHocNet decreases as speed increases. This can be accounted to the fact that as nodes become more dynamic, the route discovery process generates more routing traffic. Therefore less of the channel will be used for data transfer, thus decreasing the overall throughput.

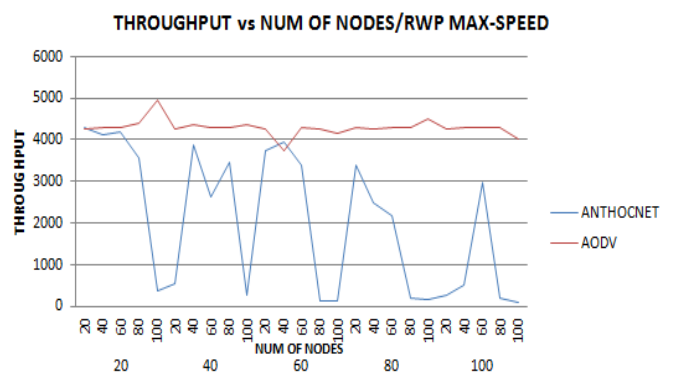


Fig 12: Throughput with varying rwp max-speed

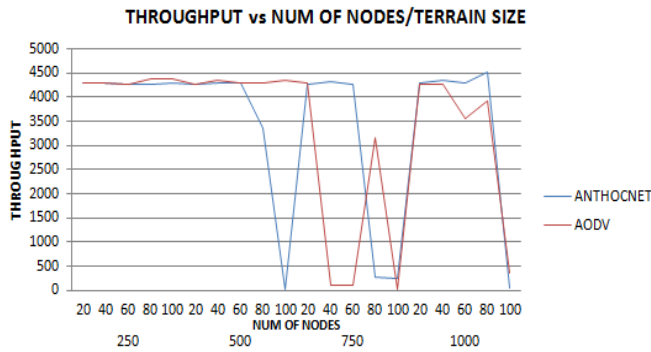


Fig 13: Throughput with varying terrain size

## 6. CONCLUSION and FUTURE WORK

The comparison between AnthoNet and AODV is made based on the performance metrics - packet delivery ratio, average jitter, throughput, queuing delay, convergence time and average end to end delay. QualNet 5.0 was chosen to simulate these algorithms, and a C++ script written to measure the metrics. It is observed that AnthoNet outperforms AODV in most of the test cases as discussed in the section V.

Future improvements with respect to AnthoNet can be to enhance the protocol by fine tuning the control packet overhead. This could be controlled by monitoring the number of forward ants generated. Apart from controlling the control packet overhead, the other improvements that can be made are with respect to implementing a priority concept at the node level where important packets could be sent first followed by the rest of the packets. These suggested improvements could add up to improvise the AnthoNet algorithm's performance even better.

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