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Performance Analysis of AD-HOC on-Demand Distance Vector Routing Protocol

N. M. Balamurugan[1*] and S. Appavu Alias Balamurugan[2]

[1]CSE Department, Sri Venkateswara College of Engineering, Sriperumbudur, Tamilnadu, India; nmbalgan@gmail.com

[2]Department of IT, KLN College of Information Technology, Sivagangai, Tamil Nadu, India; datasciencebala@yahoo.com

Abstract:

Background/objectives: The performance of the Ad-hoc On-demand Distance Vector routing protocol is analyzed by simulation in this paper. **Method/Statistical Analysis**: The simulation is developed employing the libraries provided by the simulator. The simulation is developed to model the communication of multimedia packets in an ad hoc wireless network which deploys the AODV routing protocol. **Findings:** The characteristics of the multimedia packets are in accordance with the Traffic dimensioning principles for multimedia wireless networks. **Applications/Improvements:** The simulation results are obtained and plotted for throughput, latency and control packet overhead which can be used to adjudge the performance of the protocol.

Keywords: Ad hoc Routing Protocols, Wireless Networks

1 Introduction

Ad hoc wireless networks are becoming ubiquitous with advances in performance of mobile devices, capability of the wireless media and the need for an infrastructure-free network. The performance of such network banks on the various protocols deployed at each layer of the network. Routing protocols play a pivotal role in the performance of ad hoc network. Routing protocols used in wired networks cannot be used in ad hoc networks because if the distinctive nature of the latter. This resulted in the emergence of a class of specialized protocols called the Ad hoc Routing Protocols. Perkins et al [1] presented a distance vector algorithm that is suitable for use with adhoc networks and avoids problems with DSDV protocols.

Ad hoc Routing Protocols cater specially the needs of the ad hoc networks such as memory, power and mobility management. Varying requirements has led to development of various classes of ad hoc routing protocols. On-demand protocols are those ad hoc routing protocols that involve in route establishment process only when a route is solicited between the source and the destination. Ad hoc On-demand Distance Vector routing protocol proves to be an effective and efficient protocol for a typical wireless environment. Lin et al [2] implemented the AODV protocol as part of a scalable wireless adhoc network simulation (SWANS). SWANS is built upon a novel Java -based simulation framework called JiST. The performance of AODV is analyzed in this paper. Multimedia wireless network is the scenario modeled in the simulation. The modeling techniques for multimedia wireless networks are incorporated in the simulation design. Multimedia wireless networks involve the communication of multimedia packets which differ from the numeric or alphanumeric data messages used in networks that do not use multimedia content. Ribeiro et al [3] proposed a practical framework to characterize the traffic offered to multimedia wireless systems that allows proper dimensioning and optimization of the system for a particular demand scenario. The framework proposed includes a methodology to quantitatively and qualitatively describe the traffic

*Author for correspondence

offered to multimedia wireless systems, solutions to model that traffic as practical inputs for simulation analysis, and investigation of demand-sensitive techniques for system dimensioning and performance optimization.

Multimedia packets are generally higher in size compared to the text messages. In such networks, the capability of the mobile devices needs to be high to use the services offered. For example, in cellular communication deploying GSM, the mobile phones with multimedia capabilities can use Multimedia Messaging Service (MMS) while those without such capabilities have to confine to the text based Short Messaging Service (SMS). Abolhasan et al [4] studied a performance comparison of all routing protocols and suggested which protocols may perform best in large networks. Barr et al[5] used the bidirectional coupled network and vehicular traffic simulator such as Jist and SWANS to properly validate the AODV protocols.

In analyzing the performance of a routing protocol, certain parameters, namely, throughput, latency and control packet overhead are very useful. The parameters can be used to address certain issues such as rate at which the packets transferred sent in a network, the delay experienced by the communicating nodes and the number of protocols packets needed to transfer a particular number of data packets.The analysis can be used to determine modules in the protocol that need to be improvised. Also, the analysis suggests the ways in which the current protocol can be used to realize best result. EI-fishawy [6] investigated the capability of the medium access control (MAC) protocol for wireless local area network (WLAN) to transmit burst and sensitive time traffic. The burst traffic is represented in a realistic model, which is more suitable for Internet traffic applied over WLAN.

Ad hoc routing protocol can be broadly classified into 3 types as follows (1)Pro Active (Table Driven Protocols (2) Reactive (AD-HOC) Protocols , (3) Hybrid (Proactive / Reactive) Protocols . The different ad hoc routing protocols are presented in Table 1.

Due to issues in an ad hoc network environment, wired network routing protocols cannot be used in ad hoc wireless networks. Hence ad hoc wireless networks require specialized routing protocols that address the challenges of ad hoc wireless networks. Safevian [7] discussed about how to dimension wireless networks for packet data services with guaranteed QOS. Barr [8] discussed about how to use JiST to construct efficient, robust and scalable simulations. Kouchryavy[9] focusing on traffic engineering of different UMTS service classes by providing efficient QoS mapping

Table 1. Ad hoc Routing Protocols

Table driven (proactive)	On-demand driven (reactive)	Hybrid
Destination Sequenced Distance Vector (DSDV)	Signal Stability Routing (SSR)	Zone Routing Protocol (ZRP)
	Dynamic Source Routing (DSR)	
Wireless Routing Protocol (WRP)	Temporary Ordered Routing Algorithm (TORA)	
Cluster Switch Gateway Routing (CSGR)	Ad Hoc on Demand Distance Vector Routing (AODV)	
	Relative Distance Microdiversity Routing (RDMAR)	
Source Tree Adaptive Routing (STAR)	Associativity Based Routing Protocol (ABR)	

using two common queuing disciplines; Priority Queueing (PQ) and Low Latency Queueing (LLQ), which are likely to be used in future all-IP based packet transport networks

AODV is a routing protocol, and hence it deals with routing table management. Routing table information must be kept for all known routes. AODV works efficiently satisfying the requirements of an ad hoc network such as managing mobility, power and memory offering dynamic route establishment in a typical ad hoc wireless network. Gopinath et al[10] proposed an optimized Multicast Backbone Routing for Increasing Residual Energy in MANET. Jinil Persis et al[11] introduced Ant Based Multi-objective Routing Optimization in Mobile AD-HOC Network. Kuen Han Li[12] used the clustering concept of WCDS to propose an improved ant-based on-demand clustering routing (AOCR) protocol for wireless ad-hoc networks. Mawloud Omar et al[13] proposed on-demand source routing with reduced packets protocol in mobile ad-hoc networks. It is based on source routing when the source node embeds the route information in the data packet allowing to drive intermediate nodes in order to reach the intended destination. Elizabeth et al[14] described the current state of AODV, including its base functionality as well as optional features that improve performance and add capabilities. Hui Xia et al[15] investigated the Impact of trust model on on-demand multi-path routing in mobile ad hoc networks. Extensive experiments have been conducted to evaluate the efficiency and effectiveness of the proposed mechanism in malicious node identification and attack resistance.

2 Proposed Method

Wireless networking research is fundamentally dependent upon simulation. JiST can be used to construct efficient, robust and scalable simulations.

2.1 Architecture Of Jist

The benefits of this approach to simulator construction over traditional systems and languages approaches are numerous. Embedding the simulation semantics within the Java language allows us to reuse a large body of work, including the Java language itself, its standard libraries and existing compilers. JiST benefits from the automatic garbage collection, type-safety, reflection and many other properties of the Java language. The overall architecture of JiST is shown in Figure 1.

2.2 Swans Design Highlights

The SWANS software is organized as independent software components that can be composed to form complete wireless network or sensor network simulations, as shown in Figure 2. Its capabilities are similar to NS2 and GloMoSim, two popular wireless network simulators. There are components that implement different types of applications; networking, routing and media access protocols; radio transmission, reception and noise models; signal propagation and fading models; and node mobility models. Instances of each component type are shown italicized in the figure.

The development of SWANS has been relatively easy. Since JiST inter-entity message creation and delivery is implicit, as well as message garbage collection and typing,

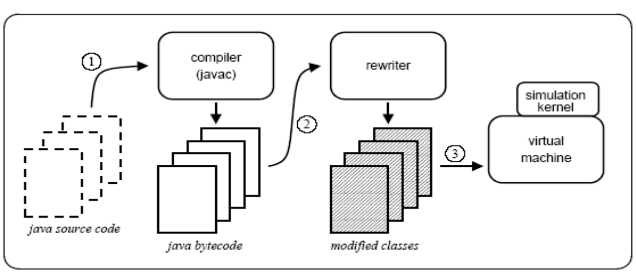


Figure 1. The JiST system architecture .

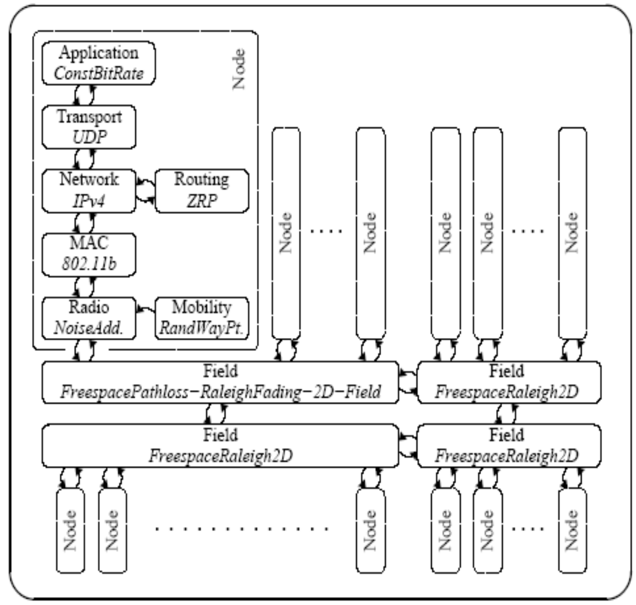


Figure 2. The SWANS Architecture.

the code is compact and intuitive. Components in JiST consume less than half of the code (in uncommented line counts) of comparable components in GloMoSim, which are already smaller than their counterpart implementations in NS2.

Every SWANS component is encapsulated as a JiST entity: it stores it own local state and interacts with other components via exposed event-based interfaces. SWANS contains components for constructing a node stack, as well components for a variety of mobility models and field configurations. This pattern simplifies simulation development by reducing the problem to creating relatively small, event-driven components. It also explicitly partitions the simulation state and the degree of inter-dependence between components, unlike the design of NS2 and GloMoSim. It also allows components to be readily interchanged with suitable alternate implementations of the common interfaces and for each simulated node to be independently configured. Finally, it also confines the simulation communication pattern.

It is important to note that, in JiST, communication among entities is very efficient. The design incurs no serialization, copy, or context-switching cost among co-located entities, since the Java objects contained within events are passed along by reference via the simulation time kernel. Simulated network packets are actually a chain of nested objects that mimic the chain of packet headers added by the network stack. Moreover, since the packets are timeless by design, a single broadcasted packet can be safely shared among all the receiving nodes and the very same object sent by an entity on one node will be received at the same entity of another node.

Dynamically created objects such as packets can traverse many different control paths within the simulator and can have highly variable lifetimes. The accounting for when to free unused packets is handled entirely by the garbage collector. This not only simplifies the memory management protocol, but also eliminates a common source of memory leaks that can accumulate over long simulation runs.

The partitioning of node functionality into individual, fine-grained entities provides an additional degree of flexibility for distributed simulations. The entities can be *vertically* aggregated, as in GloMoSim, which allows communication along a network stack *within* a node to occur more efficiently. However, the entities can also be *horizontally* aggregated to allow communication *across* nodes to occur more efficiently. In JiST, this reconfiguration can happen without any change to the entities themselves. The distribution of entities across physical hosts running the simulation can be changed dynamically in response to simulation communication patterns and it does not need to be homogeneous.

2.3 Performance

The performance of JiST was compared with the two most popular ad hoc network simulators such as NS2 and *Glomosim*. The UDP-based beaconing Node Discovery Protocol (NDP) was used for the performance analysis. NDP is chosen as its an integral part of most of the ad hoc network protocols and applications. Identical scenario was developed in ach of the simulation platform to facilitate the study.

The throughput results are plotted both on log-log and linear scales in Figure 3. As expected, the simulation times are quadratic functions of n, the number of nodes, when using the naïve signal propagation algorithm. Even without node mobility, NS2 is highly inefficient. SWANS outperforms GloMoSim by a factor of 2. SWANS-hier uses the improved hierarchical binning algorithm to perform signal propagation instead of scanning through all the radios. As expected, SWANS-hier scales linearly with the number of nodes. The graph depict clearly that SWANS significantly outperforms NS2 and Glomosim in the simulation of NDP.

The memory footprint results are plotted in Figure 4 on log-log scale. JiST is more efficient than GloMoSim and NS2 by almost an order and two orders of magnitude, respectively. This allows SWANS to simulate much larger networks. The memory overhead of hierarchical binning is asymptotically negligible.

2.4 Poisson Distribution

The Poisson distribution can be used for modeling applications that involve inter-arrival time. Multimedia wireless networks involve the transfer of messages which is evidently used presentation in multiple media. In this scenario, there are messages, not certainly data messages, arriving at each node. The time between the arrivals of two consecutive messages can be regarded as the inter-arrival time. In most of these situations; it is assumed that the packets follow a Poisson distribution. This is supported by a number of technical papers that focuses on the characteristics of the packets. Some examples are Traffic Dimensioning for Multimedia Wireless Networks by Ribeiro, Traffic Engineering and QoS Control in Multimedia – enabled Wireless Networks by Yevgeni Kouchryavy and Quality of Service Investigation for Multimedia Transmission over Wireless Local Area Networks by Fish away. It can be the proven that other distributions can not appreciably model the scenario.

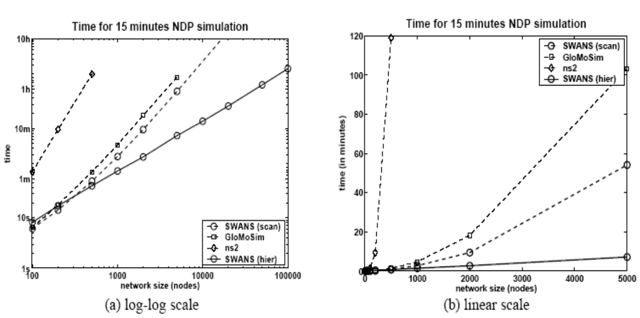
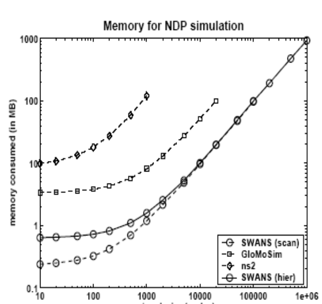


Figure 3. Throughput results.



nodes	simulator	time	memory
500	**SWANS**	**54** s	**700 KB**
	GloMoSim	82 s	5759 KB
	ns2	7136 s	58761 KB
	SWANS-hier	*43 s*	*1101 KB*
5,000	**SWANS**	**3250** s	**4887 KB**
	GloMoSim	6191 s	27570 KB
	SWANS-hier	*430 s*	*5284 KB*
50,000	**SWANS**	**312019** s	**47717 KB**
	SWANS-hier	*4377 s*	*49262 KB*

Figure 4. Memory Usage.

Summarizing, Poisson distribution can be used in situation that involve inter-arrival time of events. Multimedia messages are analogous to scenario of this genre and Poisson distribution can be used for modeling.

3 Simulation Design And Results

The simulation is developed based on the facts explained in the earlier chapters. The simulation engine is used to model an ad hoc wireless network deploying the Ad hoc On-demand Distance Vector routing protocol and communicating multimedia packets among themselves. The simulation uses largely the libraries provided by the simulator. The key issues of any routing protocol such as throughput, latency and control packet overhead play a vital role in analyzing the performance of the protocol.

3.1 Simulation Design

The objective is to simulate the communication of multimedia packets in ad hoc network deploying the AODV routing protocol. The pickets are Poissonian in nature. Hence, the prominent tasks in simulation are developing classes that accomplish

- Generating Multimedia Packets
- Generating Poisson Variables
- Porting to AODV simulation

3.2 Generating Multimedia Packets

Multimedia data is communicated in the ad hoc network using multimedia streams. The multimedia streams are of a fixed size represented in Kilo bytes. A multimedia stream consists of a number of packets called the multimedia packets. Alike multimedia streams, the size of multimedia packets also have a range. In the implementation, multimedia packets are simulated using the class MediaPacket. The description of the class is presented as follows

Class : MediaPacket,Members :MESSAGE_SIZE, Type: Integer
Methods : getSize() -returns an integer representing the size of the MultimediaPacket.
Constructor : MediaPacket(int messageSize) - creates an instance of the MediaPacket() class with messageSize as the size of the MediaPacket

Multimedia streams are simulated using the class MediaStream. The description of the class is presented as follows

Class : MediaStream, Members :total Media Length, Type: Integer
Methods : getMediaPacket(int length) - returns a MediaPacket with length as the size of the MediaPacket()
Constructor : MediaStream(int totalMediaLength) – creates an instance of the MediaStream() class with totalMediaLength as the size of the Media stream

Size of the media stream is assigned as 128KB. Multimedia packets are generated until the sum of all media packets equal the size of the media stream. The size of the media packets is constrained between 10 and 100.

3.3 Generating Poisson Variable

In a typical multimedia wireless network, the data packets that is media packets are assumed to follow Poisson distribution. Poisson variables are generated and supplied as the size of the media packets. The Poisson variables are generated using the class *GeneratePoisson*. The description of the class is presented as follows

Class : *GeneratePoisson*, Members: *poissonVarList*, Type: *Linked List*
Methods

- *poissonList(int num)* – returns a linked list of Poisson variables. The argument *num* specifies the number of Poisson variables required.
- *Poisson Val(double x, double lambda)* – returns a double value representing the Poisson variable for a particular value of *x* and with mean as *lambda*. The computation is governed by the equation $f(k,\lambda)=\dfrac{e^{-\lambda}\lambda^{k}}{k!}$,
- *factorial(int x)* – returns an integer representing the factorial value of *x*.
- *stabilize(double val)* – returns an integer which is the representative (falling between 10 and 100) of the double value *val*.

Data flow diagrams can be used to depict the flow of data in a system or a particular module of the system. The generation of media packets is shown in the Data Flow Diagram in Figure 5.

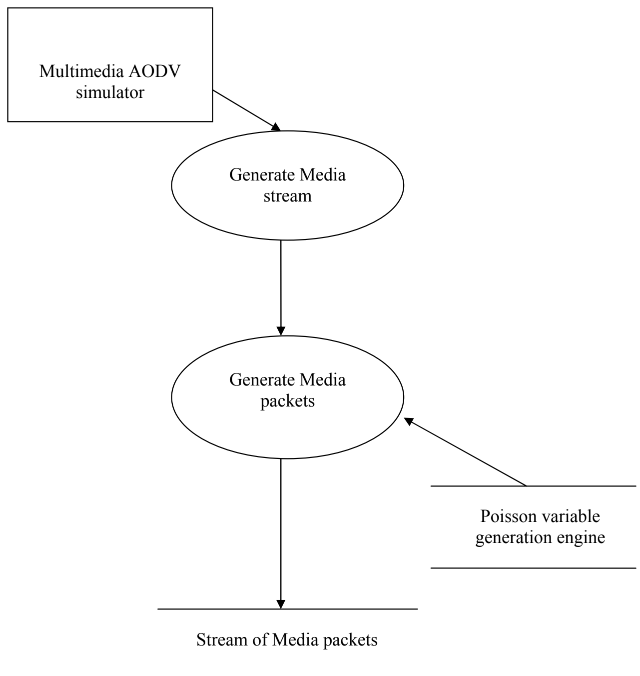


Figure 5. Data Flow Diagram for media packet generation.

3.4 Porting To Aodv Simulation

Primarily, the simulation calculates the *number of messages* from the arguments such as send rate, number of nodes and duration. This parameter corresponds to the number of media packets that can be sent. This is the argument that corresponds to the size of the linked list containing Poisson variables. The variables are used to generate the media packets.

Secondarily, transport layer UDP messages are created which contain the media packet attached to them as data. The User Datagram Protocol is used at this stage.

Finally, network layer messages are created through which the UDP messages are transmitted to the destination. This is depicted in the Figure 6 as a Data Flow Diagram.

3.5 Simulation Results

The prominent parameters that can be used to analyze the performance of a routing protocol are throughput, latency and control packet overhead. The simulation is run with varying values of number of nodes, mobility and arrangement. The desired parameters are tabulated and graphs are plotted. The simulation results can be categorized as follows

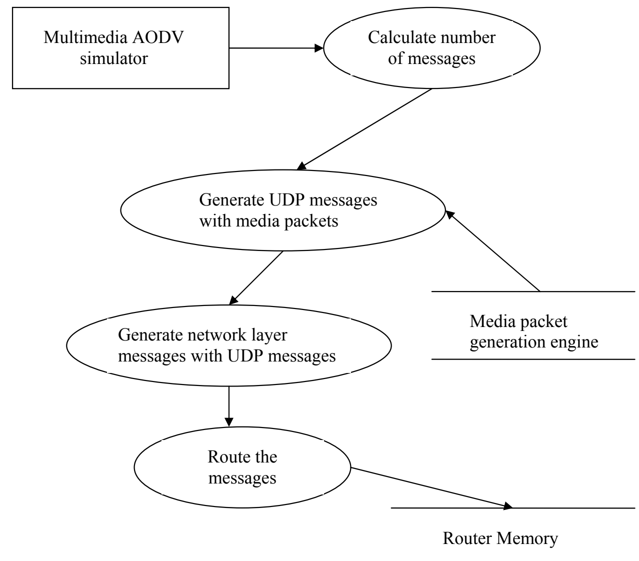


Figure 6. Data Flow Diagram for Porting to AODV simulation.

3.5.1 Throughput Results

Throughput can be defined as the ratio size of messages sent to the time needed for sending those messages. In the following analysis, its expressed in Kilo bytes per second – *kbps*. The time needed for sending all the messages is recorded and throughput is calculated. Two distinct scenarios are considered in throughput analysis, on with nodes arranged in rectangular grids and another with random arrangement. The result of throughput rates are shown in Table 2.

The results indicate that the throughput is higher for nodes arranged in rectangular grids when the number of nodes is *less than thirty*. With increasing number of nodes, the throughput gradually drops down. Hence, nodes can be arranged in rectangular grids to achieve greater throughput, provided the number of nodes are not higher than thirty. This is shown in the graph in Figure 7.

3.5.2 Latency Results

Latency refers to the delay experienced in sending a packet from the source to the destination. To calculate the delay, the time needed to send all the packets is recorded. Graphs are plotted as shown in Figure 8. Its clearly shown that the delay incurred in sending media packets increases with the increase in the number of nodes.

Table 2. Throughput Results

Number of nodes	Throughput in kbps for random arrangement	Throughput in kbps for rectangular grid arrangement
5	455.52	512
10	272.92	315.27
15	178.03	199.69
20	134.31	149.01
25	84.49	98.69
30	68.82	68.82
35	56.51	41.80

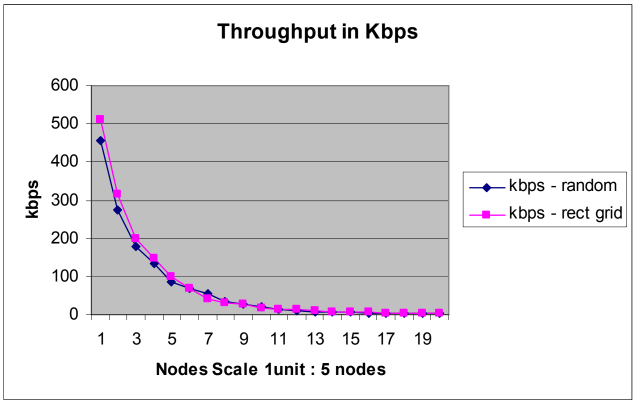


Figure 7. Throughput Results.

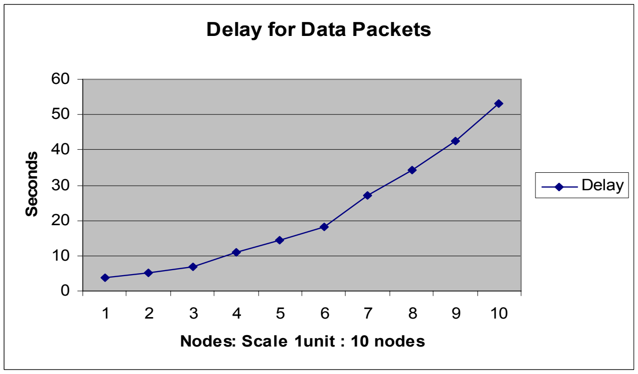


Figure 8. Delay Results.

3.5.3 Control Packet Overhead

Control packet overhead is realized by plotting the number of control packets that is the protocol messages to the data messages. From this analysis, the number of control messages needed to send a particular number of data messages can be visualized. This is shown in Figure 9.

3.5.4 Effect Of Mobility

Mobility, a prominent issue in ad hoc networks has an effect on the performance of the protocol. Consider a situation in which the route discovery process is completed. Suppose a node on the chosen route moves away, *RouteError* messages are transmitted to source and other nodes. Subsequently, route discovery process is *re-initiated*. This involves in re-iteration for route establishment between the source and the destination. Hence, additional control packets and time is needed to establish the route again. The effect of mobility is analyzed by recording the number of RouteError *RERR* messages generated. The values are obtained for two kinds of mobility, one with mobility static and other in which the nodes walk within the specified radius. The results are depicted in Figure 10.

In summary, the performance of the AODV protocol in sending multimedia packets is analyzed with various

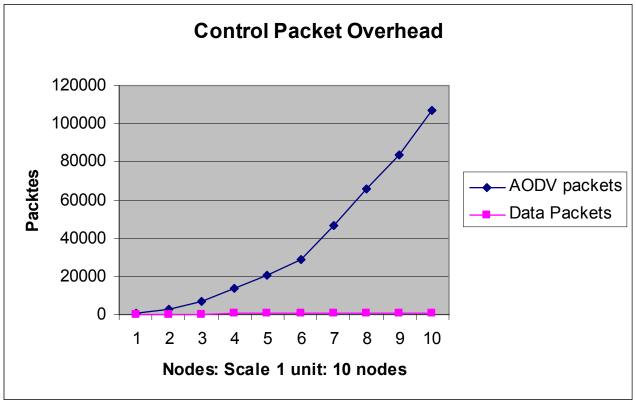


Figure 9. Control Packet Overhead.

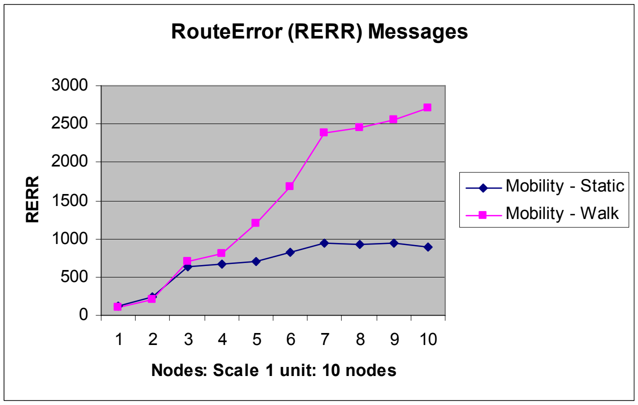


Figure 10. Effect of Mobility.

situations. Mobility, number of nodes and their arrangement have an effect on the performance of the protocol.

4 Summary and Conclusion

The performance of the Ad hoc On-demand Distance Vector routing protocol have been studied and simulation was developed to model multimedia wireless networks. The Poissonian nature of multimedia packets was incorporated in the simulation. The following inferences were made from the simulation results:

1. To ensure higher throughput, the nodes should be arranges in rectangular grids, provided the number of nodes is less than twenty five, approximately.
2. Delay experienced in sending the data messages increases with increasing number of nodes.
3. Alike delay, the control packet overhead also increases with increasing number of nodes.
4. Mobility has an impact on the performance of the protocol. Increased mobility increases the control packet overhead and delay.

Thus the multimedia packets were simulated and a Poisson variable generation engine was used to specify the sizes of the media packets. The generated packets were ported to AODV simulation. The simulation results were tabulated and corresponding graphs were also drawn.

In conclusion, certain optimization can be done to the protocol to reduce the increases of delay and control packet overhead with increasing number of nodes. In most cases, AODV works well with dynamic link conditions, mobility and imposes low memory overhead in achieving on-demand routing for ad hoc wireless networks.

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