B-Tech Project

Report

Mobility Control For Reliable Transmission in MANET

A Project Report Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

Submitted by

Tharun Reddy, 14CS01013

Under the guidance of

Dr. Padmalochan Bera

School of Electrical Sciences

INDIAN INSTITUTE OF TECHNOLOGY BHUBANESWAR

Bhubaneswar,Odisha, India – 752050

2017

School of Electrical Sciences

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This is to certify that the project work entitled **Mobility Control For Efficient Transmission in MANET** was carried out by **Mr. Tharun Reddy**, Roll No. **14CS01013**, a bonafide student of Indian Institute of Technology, Bhubaneswar in partial fulfillment for the award of Bachelor of Technology in Computer Science and Engineering during the year 2017-18. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea / data / fact / source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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(Name of the student)

(Roll No.)

Acknowledgments

With deep regards and profound respect, I avail this opportunity to express my deep sense of gratitude and indebtedness to my supervisor **Dr. Padmalochan Bera**, School of Electrical Sciences, Indian Institute of Technology, Bhubaneswar for his inspiring guidance, constructive criticism and valuable suggestion throughout this work. It would have not been possible for me to bring out this thesis without his help and constant encouragement.

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Abstract

One of the challenges in the MANET is the evaluation and design of an effective Mobility Control protocol that works at low data rates and responds to dynamic changes in the network topology for different Mobility Models. Several ad hoc protocols have been designed for accurate, fast, reliable routing for a high volume of changeable network topology. Such protocols must deal with the typical limitations of changeable network topology, which include high power consumption, low bandwidth, and high error rates.

In this paper, we proposed a new mobility control algorithm for improved route availability in highly dynamic safety critical environment where the ad-hoc nodes may potentially move out of range from others. The Ad-hoc network is divided into clusters and a cluster head is selected from each cluster periodically using weighted cluster algorithm. Using extreme machine learning approach, these cluster heads predict the trajectories of all the nodes in its cluster and run mobility control function for all those nodes that may move out of range from other nodes. This mobility control function updates the future mobility states of the selected node. The simulation results report that the proposed approach yield better performance than state of art approaches.

Contents

Chapter 1

Introduction

1.1 Objective

Developing an effective Mobility Control protocol that works at low data rates and responds to dynamic changes in the network topology for different Mobility Models of Mobile Ad-hoc Networks.

1.2 Motivation

Efficient routing is one of the key challenges in Mobile Ad-hoc Networks (MANETs) due to stringent requirements and deployment demands in many safety-critical application contexts such as disaster rescue operations, battlefields, etc. In most cases, the autonomous nature of node mobility causes frequent link failures and critical packet loss which affects the overall performance of the underlying routing function.

This motivated in developing an effective mobility control protocol that ensures reliable end-to-end data transmission without compromising the performance of the underlying network thereby improving the efficiency of routing protocols.

1.3 Overview

One of the challenges in the MANET is the evaluation and design of an effective Mobility Control protocol that works at low data rates and responds to dynamic changes in the network topology for different Mobility Models.Several Ad-hoc protocols have been designed for accurate, fast, reliable routing for a high volume of changeable network topology. Such protocols must deal with the typical limitations of changeable network topology, which includes high power consumption, low bandwidth, and high error rates.

Mobile ad hoc networks (MANETs) represent self-configuring and self-organizing multi-hop wireless networks with no centralized control.In Manet wireless connection and spontaneous interaction take place between many mobile nodes in a highly dynamic environment.

The widespread availability of wireless communication services and rapidly emerging deployment demands over last few decades have steered researchers on Mobile Ad-hoc Networks (MANETs) in many application contexts. This application contexts may vary from acritical social networks to safety-critical domains such as disaster rescue operations, battlefields, etc. In the absence of centralized authority, the cooperative communication in MANET is the only means of data transmission over the open wireless medium.The use of node mobility in such cooperating communication environment is beneficial for desired service provisioning as well as improving communication performance [4]. Several reactive and proactive mobile ad-hoc routing protocols [5], such as AODV, OLSR, DSR, etc. have been proposed till date for realizing necessary communication among nodes

MANETs are self-organizing networks because they do not use any infrastructure such as base station or router. This implies that every node performs as a host as well as a router since it is in charge of routing information between its neighbors, contributing to and maintaining connectivity of the network. Thus, in a MANET, the mobility control approach used is of primary importance because it determines how a data packet is transmitted over multiple hops from a source node to a destination node.

The route formation should be performed rapidly, with minimal overhead. The routing protocol must also adapt to frequently changing network topologies caused by nodes mobility, as well as other network characteristics.

An example of mobile ad hoc networks can be described as a group of soldiers in a war zone, wirelessly connected to each other with the help of limited battery-powered devices and efficient ad hoc routing protocols that help them to maintain the quality of communication while they are changing their positions rapidly. Therefore, routing in ad hoc wireless networks plays an important role of a data forwarder, where each mobile node can act as a relay in addition to being a source or destination node.

A mobility control protocol is a convention, or standard, that controls how nodes decide which way to route packets between computing devices in a mobile ad hoc network. In ad hoc networks, nodes are not familiar with the topology of their networks. Instead, they have to discover it. Typically, a new node announces its presence and listens for announcements broadcasted by its neighbors. Each node learns about others nearby and how to reach them and may announce that it too can reach them. A major class of research in MANETs is focused on developing several efficient mobility control approaches which incur minimum costs in terms of security, bandwidth and battery power Nodes in wireless sensor networks are low cost and economical to use. Hence there is no problem of limitation of resources. Battery drained nodes can be replaced by new nodes instead of replacing the only battery.

In addition to the autonomous nature of node mobility, the inherent resource constraints such as energy, bandwidth, radio range, etc. cause frequent route failures and critical packet loss in MANET. This, in turn, affects the reliability of data transmission along with the overall performance of the underlying routing protocol in the backbone ad-hoc network. The state-of-art routing protocols can barely adapt to the frequently changing channel and network topology conditions.

Most of the topology control protocols developed so far are localized versions and regulate the mobility of the nodes by adjusting their transmission range as desired. The reason this idea not being a practical one in the context of MANET is that there will be a heavy impact on the power degradation and mobile nodes are not possible to extend their transmission ranges without high power backup. In addition, the transmission range of an ad-hoc node is restricted to a certain level which limits the applicability of topology control algorithms in the context of MANET. On the other hand, few researchers have contributed towards actually controlling the mobility of the nodes in MANET up to a certain level.

Most of the researchers on mobility control contributed only on optimizing the power level of each node and minimizing the network interference. In addition,a majority of the algorithms yield a minimally connected domain, which suffers from frequent link failures. Link failures result in critical packet loss and retransmissions that have a huge impact on the network performance.

Majority of the research activities focus on topology control approach [6], [7] in specific application contexts in order to achieve better coverage and ensure higher connectivity. Hence, it is necessary to consider the effect of node mobility on the performance of In mobile Ad-hoc networks. For a lower mobility scenario, the impact of mobility on delay, throughput and Packet delivery ratio can be ignored. But, for higher mobility scenarios, the node may move out of the others radio range frequently and quickly so that the links become unstable leading to unexpected route failure. Hence, the transmission delay, throughput and Packet delivery ratio gets affected significantly. Hence, the state-of-art topology and mobility control mechanisms fail in providing reliable end-to-end transmission along with improved overall performance in highly mobile tactical and safety-critical ad-hoc environments.

1.4 Thesis Outline

The Thesis is organized as follows: In Chapter 2, the related work done previously in this domain is explained in detail. In Chapter 3, an overview of the proposed Mobility control protocol is presented in detail. In chapter 4, simulation results of our proposed algorithm are presented. In chapter 5, the thesis is concluded and the work remaining to be carried out in future is described.

Chapter 2

Related Works

Many Mobility control algorithms are proposed in mobile ad-hoc networks but these do not guarantee connectivity among nodes all time. Many topology and mobility control schemes have been contributed towards maintaining network connectivity while using a limited transmission range to conserve power level and bandwidth utilization. Centralized algorithms [17], [18], [19] provide optimized solutions based on global view and, hence, are not feasible in infrastructure-less ad-hoc networks. Probabilistic algorithms [18], [20], [21] maintain connectivity among nodes by adjusting transmission range along with balancing power consumption and contention level. However, 3 these approaches do not guarantee connectivity among nodes all the time.

Mousavi et al. introduced an adaptive mobility prediction based distributed topology control mechanism with the aim to reduce power consumption of mobile nodes[15]. Later on, they proposed a mobility prediction method based on pattern matching in which each node predicts its future position through finding identical patterns in its movement history. This results in improved prediction accuracy and reduced energy consumption in MANET. In 2009[10], another group of researchers proposed a different approach to control speed and directions of the knowledge sharing agents based on genetic algorithms (GAs) to obtain a uniform distribution of the ad-hoc nodes over a geographical region. Using a simplified particle swarm optimization, Hunjet et al. reduced the interference and energy consumption placing additional nodes at crucial points simultaneously controlling nodes transmission range. As a security application, Patrick Tague in 2010[11], presented a mobility control framework in the adversarial ad-hoc network to reconfigure the nodes geometry to improve attack impact and protocol performance.

On the other hand, the localized topology control techniques use nonuniform transmission ranges estimated from 1-hop physical location information. In few other localized topology control protocols [22], [23], the logical neighbor set of each node is determined based on 1-hop neighbors position. Rodoplu and Meng [24] proposed a method for optimizing the number of edges while maintaining connectivity along with preserving all minimum-energy paths. Li and Halpern [25] enhanced this approach by using k-hop (k 2) paths to minimize the number of edges optimizing the computation overhead. In both of these protocols [24] and [25], each node gathers location information of nodes within a limited search domain to optimize overhead of control messages instead of choosing logical neighbors from the usual 1-hop neighbor set. If the search domain is the total 1-hop neighborhood set, then Li and Halpern's approach [25] is identical to building a local shortest path tree in which only neighbors of the root of this tree are the logical neighbors. In another work, Li et al. [26] constructed a local minimal spanning tree at each node based on 1-hop location information selecting neighbors in the tree as logical neighbors. Span [27], a power saving topology maintenance approach adaptively chooses coordinators from all nodes to design the routing path while turning off other nodes to conserve energy.

In a simulation based study, Williams and Camp [28] observed that localized broadcast protocols in MANET yield low packet delivery ratio in a highly congested and mobile environment. Later in an observation, Dai and Wu [29] reported that the mobility and contention are the key factors for causing the low packet delivery ratio. Hence, to minimize contention, fewer forwarding nodes can be selected to reduce redundancy. However, with low redundancy, a broadcast protocol suffers from more packet losses due to the random mobility of nodes. Later, in their work, Wu and Dai [30] proposed a mobility sensitive topology control algorithm that uses consistent local views to avoid outdated information and delay integrated with mobility management. On the other hand, Dalu et al. [32] in 2008 implemented mobility control of ad-hoc nodes equipped with a transceiver and a GPS receiver based on Nomadic Community Mobility model without the use of any control message.

Prior to this, in 2007, Mousavi et al. [31] introduced an adaptive mobility prediction based distributed topology control mechanism with the aim to reduce power consumption of mobile nodes. Later on, they [33] proposed a mobility prediction method based on pattern matching in which each node predicts its future position through finding identical patterns in its movement history. This results in improved prediction accuracy and reduced energy consumption in MANET. In 2009, another group of researchers [34] proposed a different approach to control speed and directions of the knowledge sharing agents based on genetic algorithms (GAs) to obtain a uniform distribution of the ad-hoc nodes over a geographical region. Using a simplified particle swarm optimization, Hunjet et al. [35] reduced the interference and energy consumption placing additional nodes at crucial points simultaneously controlling nodes transmission range. As a security application, Patrick Tague in 2010, presented a mobility control framework in the adversarial ad-hoc network to reconfigure the nodes geometry to improve attack impact and protocol performance.

Another group of researchers proposed a distributed and adaptive power and position control algorithm based on the computation of mobile agents cost functions for noncooperative robotic ad hoc and sensor networks. As an improvement to this work, Hee-Tae Roh and Jang-Won Lee[17] formulated a joint mission and communication aware mobility control protocol converging to the Nash equilibrium for Mission-critical ad-hoc networks. Here, the individual nodes have their own specific missions and have a goal to achieve a certain degree of satisfaction as well as good communication quality that depends on their locations. In 2013, Le et al.[18] proposed RoCoMARMoP (Robots Controllable Mobility Aided Routing with Mobility Prediction) that comprises of the link quality based route discovery and the link reinforcement process that provides high-quality data transmission in MANETs. Another work, i.e., B.A.T.Mobile, an extension of the B.A.T.M.A.N[19] routing protocol leverages the knowledge derived from mobility control process guiding the routing behavior of unmanned autonomous vehicles (UAVs) to accomplish a dedicated task in MANET.

From the literature survey, it is evident that the node mobility in MANET plays a key role in routing and affects the performance of the underlying routing protocol. The major class of researchers on topology and mobility control focused mainly on reducing the energy level of the nodes and the network interference. However, these are prone to suffer frequent link failures in a highly mobile environment with limited individual radio range and deteriorate the network performance, i.e., the Packet Delivery Ratio (PDR), throughput and End-to-end delay (E2E delay). In addition, the lack of high power backup and the limited transmission the range of an ad-hoc node restricts the applicability of state-of-art topology and mobility control algorithms in a highly mobile tactical and safety-critical ad-hoc environments. Therefore, an adaptive mobility control approach is desirable in the context of MANET that ensures improved performance irrespective of the varying mobility level without affecting the overall performance.

Most of the proposed algorithms have been contributed towards maintaining network connectivity while using a limited transmission range to conserve power level and bandwidth utilization. They do not guarantee connectivity among nodes all time.

Chapter 3

Mobility Control Protocol

3.1 Overview

The on-demand wireless communication services necessitate the deployment of an ad-hoc network with appropriate geographical and topological information depending upon the specific application context and requirements. The autonomous mobility nature of the nodes imparted by the respective mobility model [41] allows the nodes to move randomly frequently leading to unexpected link failure and significant packet loss. As discussed in the above section, the state-of-art topology and mobility control approaches in the context of MANET 4 barely ensures reliable delivery of critical information along the volatile route.

The overview of the proposed mobility control protocol is shown in Fig. 3.1. The proposed mobility control protocol is implemented on the top of the routing protocol. Our mobility control approach consists of 3 phases which are briefly described as follows.

1. We first considered the dynamically changing topology of the network into account. So predicting the mobility state of the nodes which may potentially

move out of range from others is the first task. Using Weighted clustering algorithm, we divided the network into different clusters and a cluster head is selected from each cluster based on different criteria.

2. Nodes that are within the transmission range of two cluster heads are called gateways, and they usually handle inter-cluster communication. As all other nodes in the network, a gateway may belong to one cluster only. A cluster-head maintains a list of all its members along with their trust values, while a cluster member only knows its cluster-head and monitors continuously its trust value.

3. Once the Cluster heads are selected, it iteratively executes the extreme learning machine based one-hop prediction function to determine the future trajectories of those nodes which may potentially move out of range from others. Accordingly, the Cluster head sets flag in its routing table for the entries of those nodes which are predicted to move out of its range, so that it is not selected as cluster head in near future.

4. In this phase, Cluster head detects the nodes in that cluster that may potentially move out of range from it. Cluster head runs mobility control function and sends appropriate packets to those potential nodes to change those trajectories.

3.2 Flowchart

The presented a novel mobility prediction and control mechanism for MANET that ensures reliable end-to-end data transmission with the improved overall performance of the underlying network. The overview of the proposed mobility

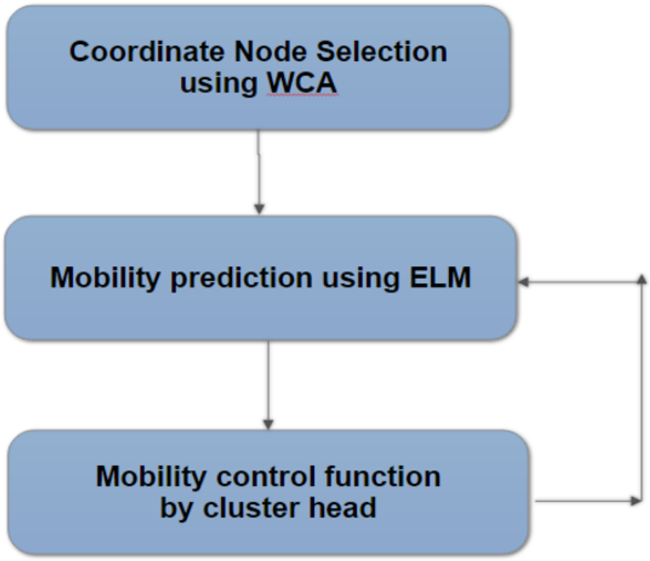

Figure 3.1: Flowchart

control protocol is shown in the below figure. Any Routing Algorithm can be used for reference and End-to-end transmission delay, Throughput along with Packet delivery ratio without mobility control is compared.

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3.3 Cluster Head Selection

In order to realize the mobility prediction and control process in a distributed and infrastructure-less ad-hoc environment first, the network is logically divided into various clusters using Weighted Clustering Algorithm (WCA) [15] based on optimizing the number of clusters in MANET [16].

The cluster head selected by WCA is alternatively called as coordinator node.So the entire MANET is logically divided into clusters and a cluster head is selected for each cluster using Weighted Cluster algorithm. In this way Logically dividing the clusters make control process easier as MANET is a distributed and

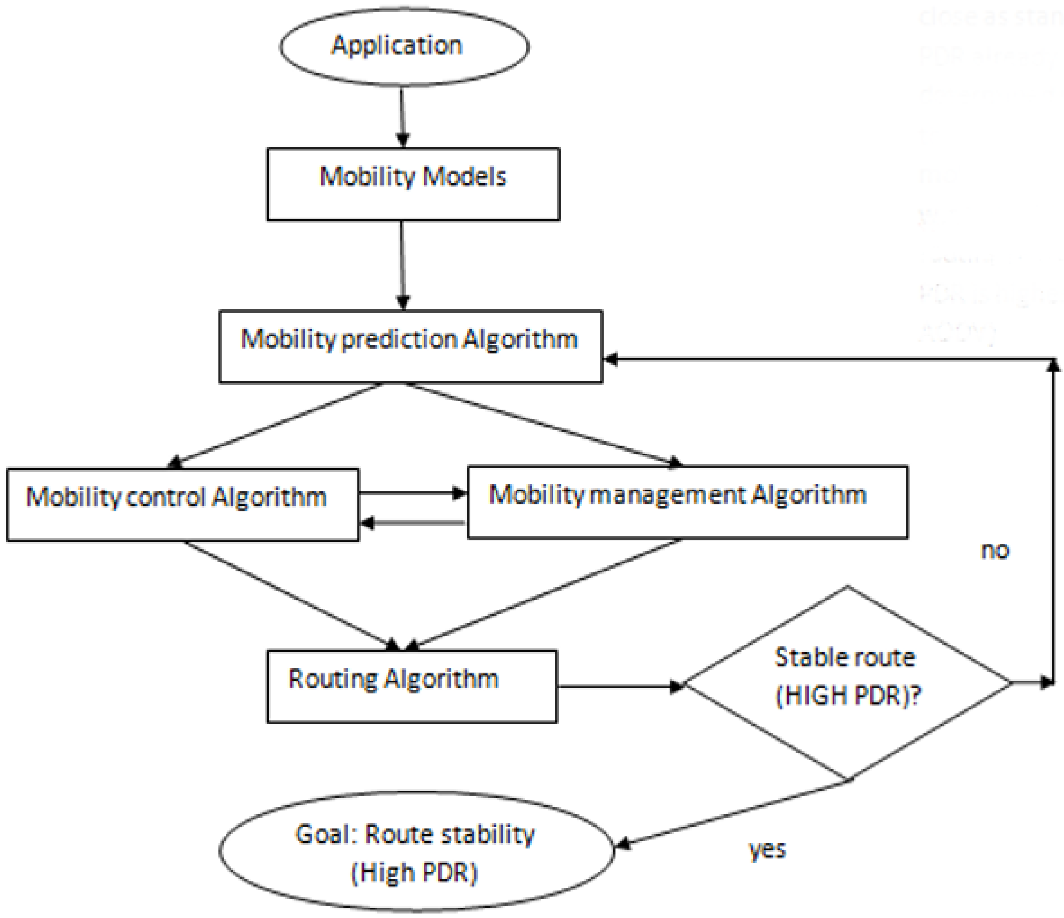

Fig. .: Cross-layer solution: utilizing the mobility control in routing

infrastructure-less network.

In our work, we have considered nodes in the network in 3-D Cartesian coordinate system which is significant in recent Mobile Ad-hoc Network application contexts. The cluster head selected by WCA is alternatively called as coordinator node in our work which iteratively executes the prediction and control function till convergence.

Weighted clustering algorithm (WCA) effectively integrates the above network parameters with certain weights selected according to the requirements. For example, in CDMA networks as power control is very important, so larger weight of the respective parameter is chosen. The number of nodes that a cluster head can handle ideally is limited to δ to ensure that cluster heads are not over-loaded. Thus, the efficiency of the network is maintained at the desired level. The cluster head election procedure is invoked at the time of network deployment and when the existing dominating set fails to cover all the nodes. Each invocation of the election algorithm does not necessarily mean that all the cluster heads in the previous dominating set are modified. If a node detaches itself from its current cluster head and attaches to another cluster head then the respective cluster heads update their neighboring list instead of invoking the whole election algorithm.

The clustering procedure considers several network parameters such as: the node degree, the battery power, transmission power, and mobility of the nodes. Depending on specific application and context, any or all of these parameters are used in the metric to elect the cluster heads to deal with the trade-off among a number of cluster heads, cluster size, latency, power consumption, and information processing per node. WCA elects a minimum number of cluster heads to support all the nodes in the network satisfying all constraints.

To decide the suitability of a node to be a cluster head, WCA takes into account its degree, battery power, transmission power, and mobility. We have considered the following features in our clustering algorithm:

i. Optimization of the degree of each cluster head to assure efficient medium access control (MAC) functioning.

ii.Selection of a node as cluster head that is not a target node in the past.

iii. Efficient use of the battery power within certain transmission range.

iv. Non-periodic execution reducing system updates thereby minimizing computation and communication overhead.

v. Selection of a node as cluster head that has low mobility frequency.

Weighted clustering algorithm (WCA)[20] effectively integrates the above network parameters with certain weights selected according to the requirements.It consists of following steps.

Step 1: Remaining power or battery left for each node $v$is computed B_v

Step 2: The neighbors of every node v is defined as its degree d_v and is determined as

$d_v = |N(v)| = \sum_{v' \in V, v' \neq v} dist(v, v') < tx_{range}$

Step 3: The degree-difference for every node v is computed as,

$\triangle_v = |d_v - \delta|$

Step 4: For each node, the sum of the distances with all its neighbors is denoted as D_v and is determined as,

$D_v = \sum_{v' \in N(v)} dist(v, v')$

Step 5: Calculate the average of the speed for each node till current time instant T. This defines the measure of mobility which is denoted by M_v. It is defined as,

$1/T(\sum_{t=1}^{T} \sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2 + (Z_t - Z_{t-1})^2})$

where (X_t, Y_t, Z_t) and (X_t1, Y_t1, Z_t1) are the Cartesian coordinates of the node v at time t and (t 1), respectively.

Step 6: Then the cumulative time, P_v, during which a node v acts as a cluster head, is computed. P_v indicates how much battery level has been consumed for being a cluster head as compared to an ordinary node.

Step 7: The total weight W_v for each node v is calculated as,
$W_v = w_1\Delta_v + w_2D_v + w_3M_v + w_4P_v$ + $\mathrm{w}_5 B_v$
where w_1, w_2, w_3 ,w_4 and w_5 are the weights chosen for the corresponding network parameters.

Step 8: The node with the smallest W_v value is chosen as the cluster head. The neighbors of the chosen cluster head do not participate in the election procedure.

Step 9: Follow steps 2 - 7 for the remaining nodes those are not yet elected as a cluster head or are members a cluster.

All of the parameters, i.e., degree difference (δ_v), sum of the distances D_v, mobility M_v, and the total (cumulative) time P_v a node acts as cluster head are normalized which means that their values lie in a pre-defined range. The corresponding weights, i.e., w_1, w_2, w_3 ,w_4 and w_5 are chosen appropriately as per the application context.

The load handled by a cluster head depends on the number of nodes supported by it. The elected cluster heads are used as coordinator nodes in our work. The coordinator nodes efficiently execute 1-hop mobility prediction function for necessary mobility control which is discussed in the subsequent in details.

3.4 Mobility Prediction

Once the coordinator nodes are selected from the set of nodes in the network, they execute the mobility prediction function periodically to identify the nodes potentially going out of range. Mobility prediction approach based on historical data has attracted a lot of attention in recent studies, the reason being that it offers the convenience of using previously accumulated mobility information to subsequently determine future trajectory using predictive algorithms. However, Prediction accuracy is usually affected by the techniques and devices used as well as the algorithms applied.

This architecture is composed of three layers arranged in a feed-forward fashion: The first layer is the input layer which represents the dynamic memory of network. This memory is originated by a feedback between the output layer and the input layer; as well as feedbacks between neurons themselves from an input layer. The activation function used is sigmoid function and the total number of hidden layers are 1.

Machine learning approaches have been proved useful compared to the prediction techniques such as pattern matching as the learning models are exposed to new real-world data and they are able to independently learn from previous computations to produce reliable, repeatable decisions and more accurate results [42]. Unlike multilayer perceptrons (MLPs), extreme learning machine (ELM) [43] capture better the existing interaction/correlation between the Cartesian coordinates of the arbitrary nodes leading to more realistic and accurate mobility prediction based on several standard mobility models.

Our proposed mobility prediction function is illustrated as follows.

Step 1: In each cluster, the cluster head or the coordinator observes the current mobility states of the neighboring nodes. The mobility state M_n of a node n $(n \in N)$ is a two tuple $< P_n, V_n >$, where $P_n = (X_n, Y_n, Z_n)$ is the current Cartesian coordinate of the node n and V_n is the velocity with which node n has moved from the previous position to current position. The neighboring nodes observe the current mobility states of their neighbors. This process is followed up to only 2-hop neighboring nodes from the coordinator node.

Step 2: The mobility state information of the nodes are a collection for a series of time sequence t_i , t_{i1}, t_{i-2}, ... as stated above. Now, the coordinator node has mobility information of each of its neighbor in its cluster as well as of nodes of neighboring clusters as each cluster is a 1-hop domain.

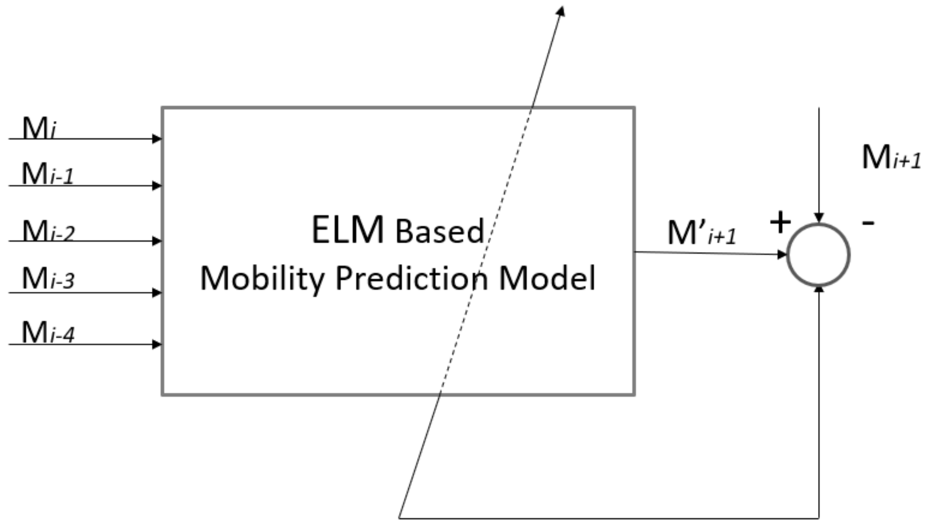

Figure 3.2: Mobility prediction model

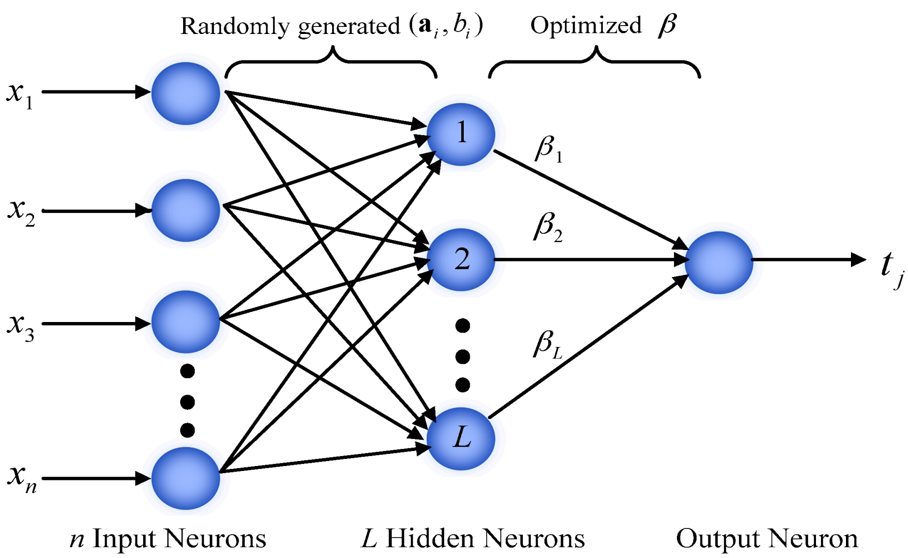

Figure 3.3: Extreme Learning Machine Model

Step 3: The mobility information of the nodes for a series of the time sequence are fed to the extreme learning machine algorithm to determine the future mobility information as shown in fig 3.2. The typical extreme learning machine model is shown in fig. 3.3 which is a single-hidden layer feedforward networks (SLFN).

The length of time sequence used for prediction is termed as prediction width. The size of prediction width, i.e., the length of time sequence is optimized depending on the factor called entropy. Entropy determines predictability and randomness, with higher values of entropy always related to less system order and more randomness.

Step 4: The coordinator node then determines which nodes are moving out of range by comparing the transmission range with the predicted mobility state. If a coordinator node n_1 finds $dist(p(n_1), p'(\mathrm{n}_2)) > \mathrm{tx}_{range}$ for a node n_2, then the node n_2 is assumed to be moving out of range of n_1. Here, $p(n_1)$ is the current Cartesian coordinate of the coordinator node n_1 and $p'(n_2)$ is the predicted Cartesian coordinate of the coordinator node n_2. These nodes are marked as target nodes and the coordinator node sets a flag for the target nodes in its routing table.

Once the target nodes are identified by the coordinator nodes, appropriate control packets are sent to them for updating the future trajectories of the target nodes. The necessary mobility control function is discussed in details in the following subsection.

3.5 Mobility Control

The Cluster head sets flag for the nodes that potentially move out of range from its range. Then the cluster head runs Mobility control function for those target nodes to change their trajectory and bring into its range. The process for mobility control on each coordinator node is explained as follows.

Step 1: The coordinator node sends a control packet to the target node to modify its next mobility state. The control packet contains

1. Source discriminator
2. destination discriminator
3. Verification Flag
4. Checksum
5. Type
6. Priority
7. Length
8. Mobility State

The *source discriminator* contains the coordinator nodes ip address and port number, where as the *destination discriminator* contains the target nodes ip address and port number. The $verification\ flag$ is a 32 bit session id. 32 bit $Checksum$ is used for necessary error control so as to ensure that control packet is error-free. The field $Type$ differentiates control and data packet. $Priority$ is a special field which indicates the of number of times it has been treated as target node. *Length* is the length of the control packet. The $Mobility\ State$ consists of the Cartesian coordinate, velocity and a tuning parameter. The tuning parameter is a probabilistic random variable whose value lies between 0 and 1. Higher is the value of tuning parameter, more is the randomness in mobility of the target node.

Step 2: After receiving the mobility control packet from the coordinator node, the target node updates its next mobility state and follows the trajectory accordingly instead of applying the mobility information of the mobility model used.

Step 3: Then, the coordinator node determines the communication quality of the link to the target node. For computation of communication quality the following parameters are considered.

1. End-to-End delay(E2E):E2E delay for the current position of the target node is calculated as:
   $t_e = \sum (t_p + t_l + Q(t))$
   where t_p is packetization delay, t_l is propagation delay and $Q(t)$ is queuing delay.

2. Packet Delivery Ratio (PDR):The packet delivery ratio between the coordinator node and the target node is determined as the ratio of number of packets received by the target node to the number of packets delivered by the coordinator node.

3. Transmission rate: First of all, determine Signal to noise ratio (SNR) of the link to the current position of the target node. Then, using the Shannon theorem, transmission rate for the current position of the target node is calculated as:
   $T_r = B{*}\log_2(1{+}\mathrm{SNR})$.

The communication quality C is a qualitative parameter and is mathematically modeled as follows by considering the above performance parameters.

$C = w_{T_r}\mathrm{T}_r + w_{t_e}\mathrm{t}_e + \mathrm{w}_E E + w_{PDR}PDR$

where, w_{T_r} , w_{t_e} , w_E, and w_{PDR} are the probabilistic decision variables or weights associated with each of the performance parameters and their values lie between 0 to 1.

Step 4: Step 4. Compare the communication quality C determined in Step 2 to the route stability threshold. The route stability threshold is computed using a simulation environment for MANET with standard AODV protocol as the communication quality for AODV protocol is the most suitable one as compared to other routing protocols. If the computed communication quality is close to the route stability threshold then exit as the target nodes current position is the most appropriate position for reliable data transmission, else go to Step 1.

Hence, the mobility control process is terminated when the target nodes are placed appropriately for ensuring higher route availability and reliable data transmission. The target position of the nodes are fed back to the mobility prediction phase for recurrent mobility control execution. The proposed mobility control protocol is evaluated in a highly scalable adhoc networking environment with random variation in mobility and the efficacy of the protocol are reported with in-depth simulation results in the next chapter.

Chapter 4

Simulation results

Simulation is carried using Tetcos Netsim(Version 10.2.10)interlinked with Matlab(version 9.1) and Visual studio inWindows 8.1 OS platform. We have created network size from 10 to 30 nodes. Using cluster head selection the network is divided into 4 clusters as shown in the figure. Each cluster has a cluster head and selected as using the cluster head selection algorithm.

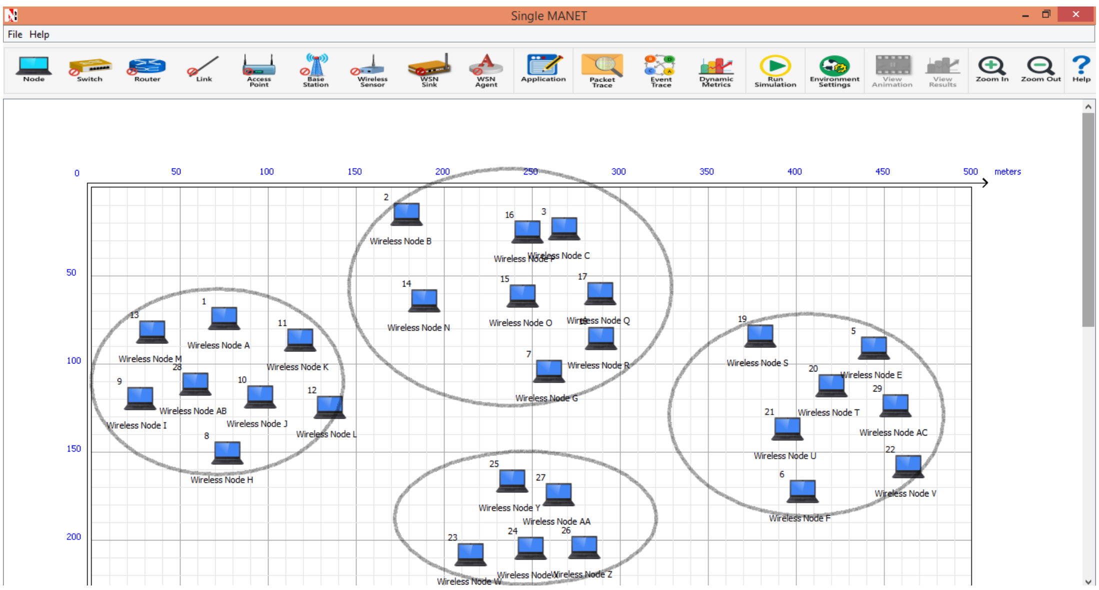

Figure 4.1: MANET model

We have created network size from 10 to 30 nodes. Using cluster head selection the network is divided into 4 clusters as shown in the figure 4.1. Each cluster has a cluster head and selected as using the cluster head selection algorithm stated above.

Cluster Node 3D figure is shown in fig 4.2. The simulation of the above network in tetcos network simulator using the steps stated above for cluster head selection gives the following result. Four peaks show that the network is divided into 4 clusters and each cluster has a cluster head. It contains peaks which have information about cluster head coordinates.

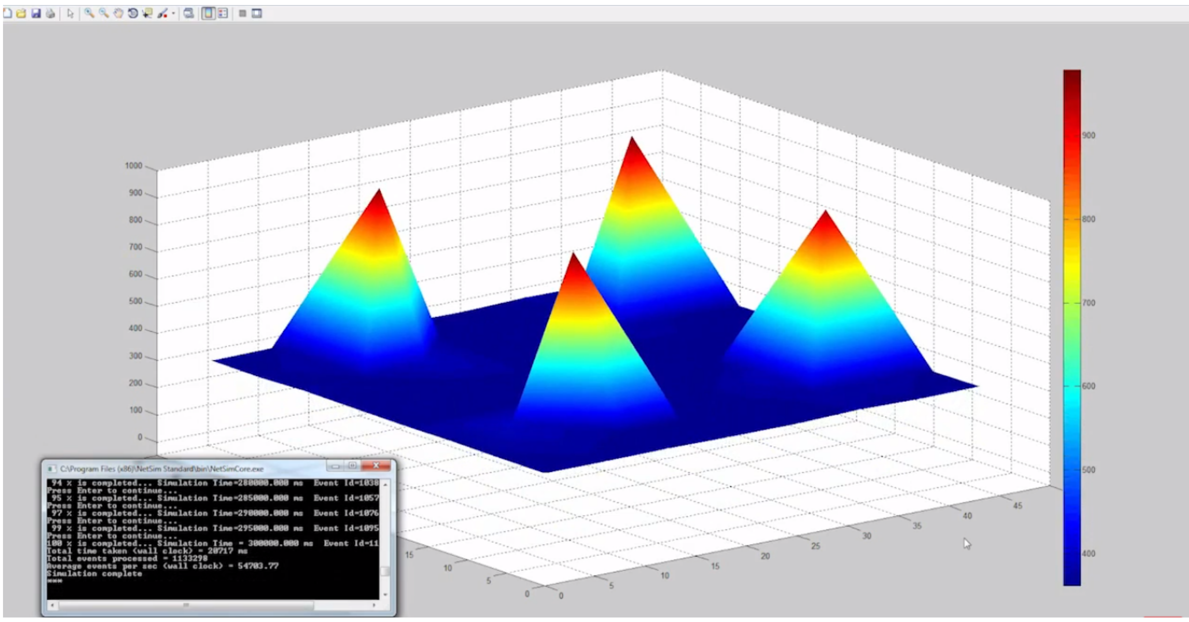

Figure 4.2: Cluster head Selection results

After Cluster head is selected, Extreme machine learning approach is used for Mobility prediction. Figure 4.3 shows actual values of mobility state vs predicted values.Mobility states are takes as function values of $< X_i, Y_i, Z_i >$.

The results of Extreme machine learning approach gives that the function of

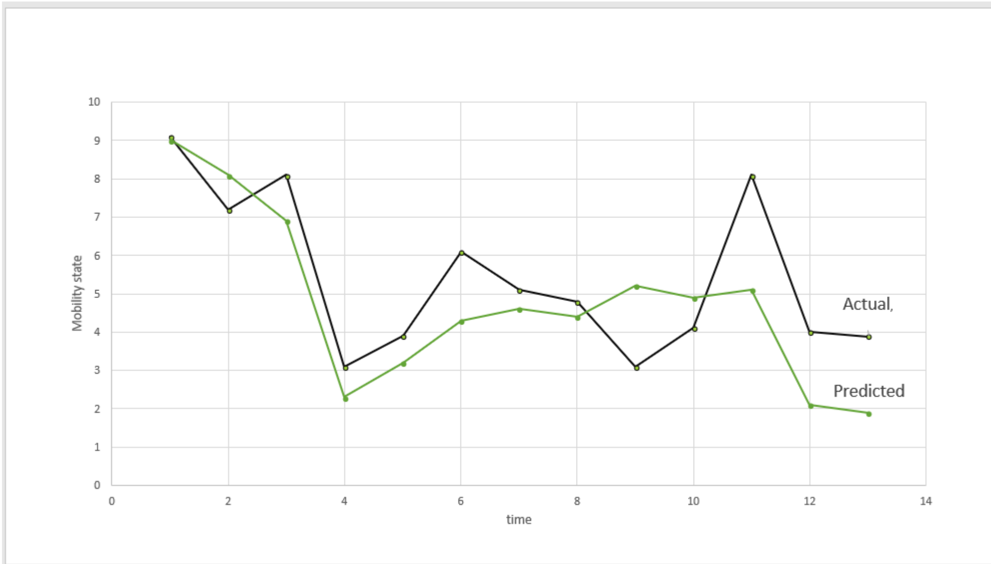

Figure 4.3: ELM results

predicted values of Mobility state is very close to the actual mobility state values.

We have Considered the following parameters for evaluating the Mobility control protocol. We have compared our mobility control protocol with AODV routing protocol based on the following parameters.

(a)Packet Delivery Ratio (PDR) :It is the ratio of Total packets successfully received to the total sent.

(b)Throughput : It is the rate at which information is sent through the network i.e it is the total amount of data received by all nodes per unit time.

(c)End-to-End delay: Average of the delay (received time minus transmitted time) of every data packet. It is defined as the average time taken by data packets to propagate from source to destination across the network. This includes all possible delays caused by buffering during routing discovery latency, queuing at the interface queue, and re-transmission delays at the MAC, propagation and transfer times etc.

Fig. 4.3 presents the comparative result of Throughput of AODV routing protocol with and without using our proposed mobility control mechanism with respect to network size (i.e., the number of nodes). We observed that the AODV routing protocol with proposed mobility control mechanism yields better Throughput than the AODV routing protocol without mobility control technique. This is evident as mobility control avoids unexpected route failures by predicting and controlling the mobility of the nodes.

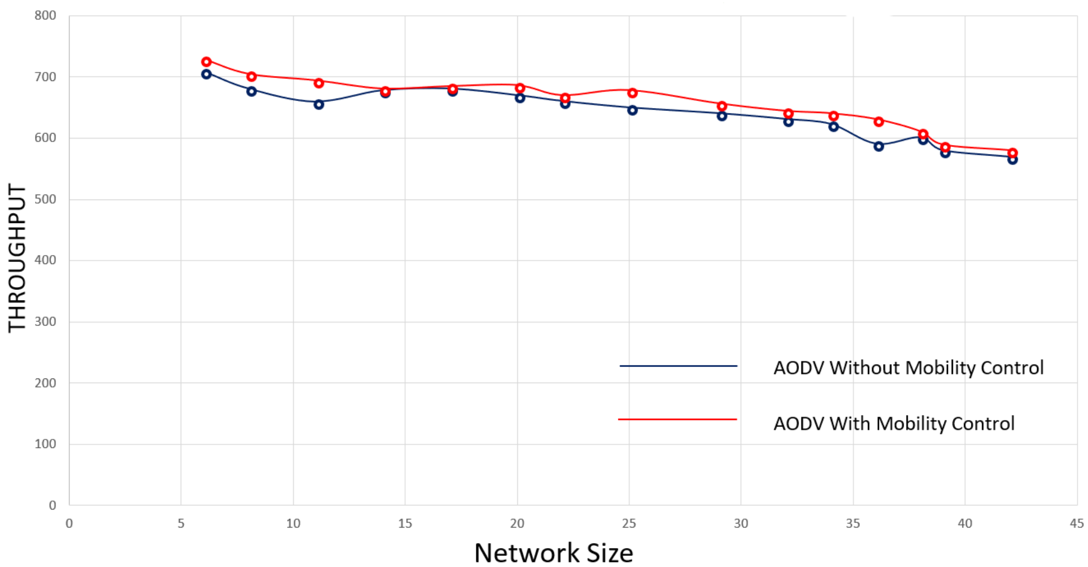

Figure 4.4: Comparision of Throughput with respect to Network size

Fig. 4.4 presents the comparative result of End to End delay of AODV routing protocol with and without using our proposed mobility control mechanism with respect to network size (i.e., the number of nodes). We observed that the AODV routing protocol with proposed mobility control mechanism yields lower End to End delay than the AODV routing protocol without mobility control technique.

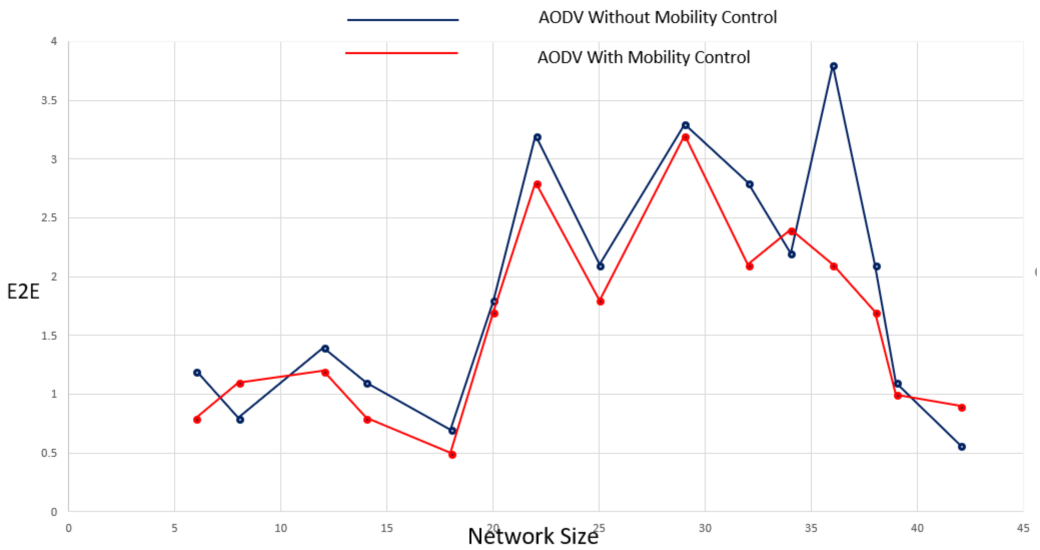

Figure 4.5: Comparision of End to End delay with respect to Network size

Fig. 4.5 presents the comparative result of PDR of AODV routing protocol with and without using our proposed mobility control mechanism with respect to network size (i.e., the number of nodes). We observed that the AODV routing protocol with proposed mobility control mechanism yields better PDR than the AODV routing protocol without mobility control technique.

In addition, we have also evaluated our proposed mobility control protocol with varying mobility. Mobility variation is a probability factor between 0 to 1 related to the randomness in mobility of the nodes. Higher is the mobility variation, more is the randomness in the nodes mobility behavior. We have simulated the proposed mobility control technique with a network size of 50.

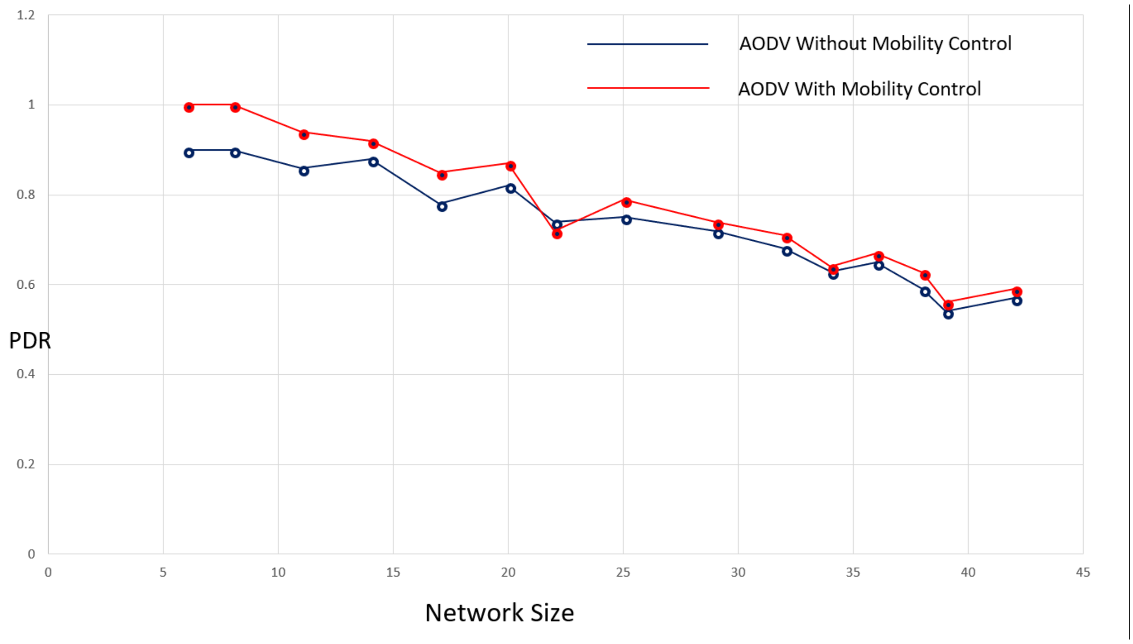

Figure 4.6: Comparision of PDR with respect to Network size

Chapter 5

Conclusion

In this paper, we have proposed a novel mobility control mechanism to handle the uncertain randomness in mobility of nodes in MANET. In the first phase, coordinator nodes are selected using Weighted Clustering Algorithm (WCA) to execute the mobility control process in small domains. In the next phase, based on extreme learning machine approach, the designated coordinator nodes periodically execute the mobility control function to identify and mark the target nodes which may potentially move out of range from others. Accordingly, in the final phase, appropriate control packets are sent by the coordinator nodes to the target nodes in order to modify their future mobility states. This , in turn drives the routing function by efficiently avoiding the unexpected route breaks and packet loss, rather yielding higher route availability. The efficacy of the proposed mobility control mechanism is reported with in-depth simulation results by varying network size and randomness in mobility.

It is evident from the above simulation results that our proposed mobility control protocol with all state-of-art routing as mobility control avoids unexpected route failures by predicting and controlling the mobility of the nodes. The proposed protocol also ensures the passage of packets through trusted routes only by making nodes monitor the behavior of each other and update their trust tables accordingly. The efficiency of the proposed mobility control mechanism is reported in-depth simulation results by varying network size and randomness in mobility.In future, we will consider the contextual and security features in the mobility control protocol for strengthening the security parameter in MANET.

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