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Research Article

Mobility Control for Reliable Transmission in Mobile Adhoc Networks

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ABSTRACT

Design and evaluation of Mobility Control protocol that responds to dynamic changes in the network topology and works at low data rates for different Mobility Models is one of the biggest challenges in Mobile Adhoc Network (MANET). Several Adhoc protocols have been designed for fast, accurate, reliable routing but those have limitations like high power consumption, high error rates and low bandwidth. In this paper, we proposed a new mobility control algorithm for improved route availability in highly dynamic safety critical environment where the Adhoc nodes may potentially move out of range from others. The MANET is divided into different 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 sele cted node. The simulation results report that the proposed approach yield better performance than state of art approaches.

Keywords: Mobile Adhoc Networks (MANET), Weighted Clustering Algorithm (WCA), Extreme Machine Learning, Clusters, Cluster Head, Coordinate Node, Mobility State, Mobility Prediction, Overhead, Routing, Topology

Introduction

Mobile Adhoc Networks (MANETs) represent self- configuring and self-organizing multi-hop wireless networks with no fixed infrastructure.[1] In MANET spontaneous interaction between many mobile nodes and their connection takes place in a highly dynamic environment.

In the last few decades due to the advanced development of communication services, their availability and rapidly emerging deployment demands, researchers on Mobile Adhoc Networks in different areas has been increased. These research areas vary from acritical social networks to safety-critical domains such as battlefields, disaster rescue operations, etc.[1] As MANET is de-centralized Network, communication in MANET is the only means of data transmission over the open wireless medium.[3] 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 Adhoc routing protocols[5], such as AODV, OLSR, DSR, etc. have been proposed till the date for realizing necessary communication among nodes. MANETs are self-organizing networks[6] because, they do not have fixed infrastructure using a base station or router. This implies that every node itself only has entire control over it, since it is in charge of routing information among 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 data packets can be transmitted from one node to another without any packet loss, link failure, etc. The route formation should be performed rapidly, with minimal overhead and also should adapt to frequently changing network topologies caused by nodes mobility, as well as other network characteristics.

During Military operations, Diaster rescue operations MANETs are used to establish connection between each other with the help of battery power and using Adhoc routing protocols that help for efficient communication. Therefore, routing in Adhoc wireless networks play an important role in a data forwarder, where each mobile node can act as a relay in addition to being a source or destination node. MANETs are very easy and fast to install. A mobility control protocol is a convention or standard, that controls how nodes decide the best way to route a data packet in a dynamically changing network. In Adhoc networks, nodes do not have any information about the network topology. Instead, they have to discover it. Generally, each node reports its essence, listens for acknowledgements from adjacent nodes and learns how to 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 bandwidth, security 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 Adhoc network. The state-of-art routing protocols[7] can barely adapt to the frequently changing channel and network topology conditions. Some of the researchers[8-10] those worked in the area of Mobility control in MANET focused and developed only localized versions of MANET 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. Another limitation of this applicability of Topology control algorithms in the context of MANET is the restricted range of Adhoc node to a certain level.[11] 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 re-transmissions that have a huge impact on the network performance. Majority of the research activities focus on topology control approach[12,13] 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 mobile Adhoc networks. For a lower mobility scenario, the impact of mobility on delay, throughput and PDR 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, PDR 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 Adhoc environments.

The motivation of developing an efficient and reliable mobility control mechanism in MANET has been driven due to all the above limitations in existing research works. In this paper, we have proposed a novel mobility prediction and control mechanism for MANET that ensures reliable end to end data transmission without compromising the performance of the underlying network. We have modeled and evaluated the network in a 3-D Cartesian coordinate system for realizing the proposed mobility control technique in real-world environments. The proposed approach is mentioned below:

- We first considered the dynamically changing topol- ogy 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
- Inter-cluster communication is generally handled by the nodes that are in the transmission range of multiple cluster heads which are called gateways. A gateway is handled only by a single cluster head. Every node in the cluster have information only about its cluster head and continuously monitor its trust value, while a cluster head has information about all the nodes in its cluster and their trust values
- Once the Cluster heads are selected, it iteratively executes the extreme learning machine based one hop pre- diction 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 the cluster head in near future

- 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

The proposed mobility control protocol is implemented on the top of the routing protocol. The flowchart of the proposed mobility control as shown in Figure 1, shows that the approach consists of 3 phases. They are described as follows.

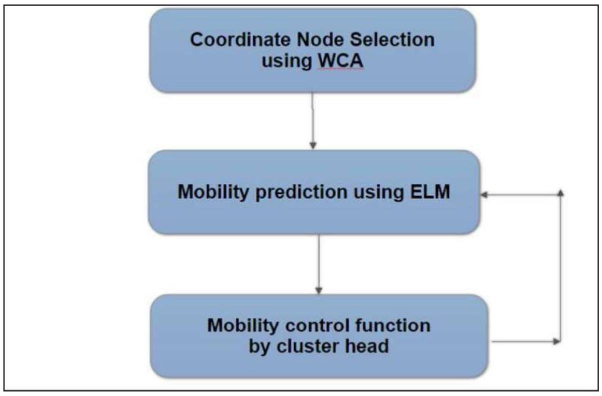

Figure 1.Flowchart

The rest of this paper is organized as follows. In Section II, we mentioned related previous works. We proposed mobility control protocol for highly dynamic mobile Adhoc environments in Section III. Section IV contains simulation results of our proposed protocol. Section V concludes the paper.

Related Works

Many Mobility control algorithms are proposed in mobile Adhoc networks but these do not guarantee connectivity among nodes all time. Probabilistic algorithms[14] maintain connectivity among nodes by adjusting transmission range along with balancing power consumption and contention level.[15,16] Nodes which are deployed without the need for any fixed infrastructure. Centralized algorithms provide optimized solutions based on global view, hence, are not feasible in infrastructure-less Adhoc networks.

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 Adhoc 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 Adhoc 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 non-cooperative robotic Adhoc 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 Adhoc 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 the their locations. In 2013, Le et al.,[18] proposed RoCoMARMoP (Robots Controllable Mobility Aided Routing with Mobility Prediction) that comprises of the link reinforcement process and the link quality based route discovery 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 effects 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 end to end delay (E2E delay), throughput and Packet Delivery Ratio (PDR). In addition, the lack of high power backup and the limited transmission range of an Adhoc node restricts the applicability of state-of-art topology and mobility control algorithms in a highly mobile tactical and safety critical Adhoc 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.

Mobility Control Protocol

In this section, we presented a novel mobility prediction and

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control mechanism for MANET that ensures reliable end to end data transmission with improved overall performance of the underlying network.The overview of the proposed mobility control protocol is shown in the below Figure 2.

Cluster Head Selection

Initially the entire MANET is logically divided into clusters and a cluster head is selected from each cluster using Weighted Cluster algorithm. In this way Logically dividing the clusters makes control process easier as MANET is a distributed and infrastructure-less network.

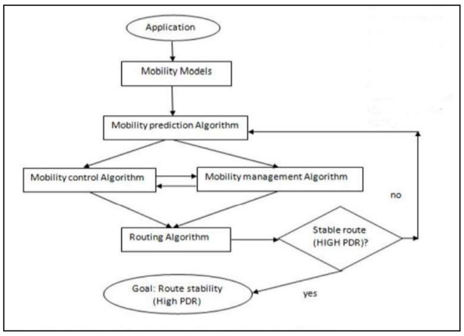

Figure 2.Cross Layer Solution Utilizing the Mobility Control in Routing

In our work, we have considered nodes in the network in 3-D Cartesian coordinate system which is significant in recent Mobile Adhoc 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.

The clustering procedure considers several network parameters such as: the node degree, the battery power, transmission power, 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 connecting all the nodes in the network and fulfilling all constraints.

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

- Optimization of the degree of each cluster head to assure efficient medium access control (MAC) functioning
- Selection of a node as cluster head that is not a target node in the past
- Efficient use of the battery power within certain transmission range
- Non-periodic execution reducing system updates thereby minimizing computation and communication overhead
- 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 iis computed Bi.

Step 2: The neighbors of ever y node i is defined as its degree di and are determined as

di = |N (i)| = it I,it i dist(i, iJ) < txran ge

Step 3: The degree-difference for ever y node i is computed as, Oi = |di

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

Di = it N (i) dist(i, iJ)

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 Mi. It is defined as.

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

Step 7: The total weight Wi for each node i is calculated as

Wi = w1 i + w2 Di + w3 Mi + w4 Pi + w5 Bi

where w1, w2, w3, w4 and w5 are the weights chosen for the corresponding network parameters.

Step 8: The node with the least Wi 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.

Mobility Prediction

Extreme machine learning[21] based approach is used for mobility prediction. Cluster head selected from the above approach runs Mobility prediction function periodically execute to identify the nodes potentially going out of range. The extreme learning machine model is arranged in a feed forward fashion and composed of three layers. The first layer is input layer or information layer. It represents the dynamic memory of network. This memory is originated by a feedbacks between neurons themselves from information layer and feedback between the yield layer and the information layer. The activation function used is sigmoid function and the total number of hidden layers is 1. Unlike

Multilayer Perceptrons (MLPs), extreme learning machine (ELM)[22] capture better the existing association between the Cartesian coordinates of the mobile nodes leading to more practical and precise mobility prediction.

Mobility Control Function

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 following steps

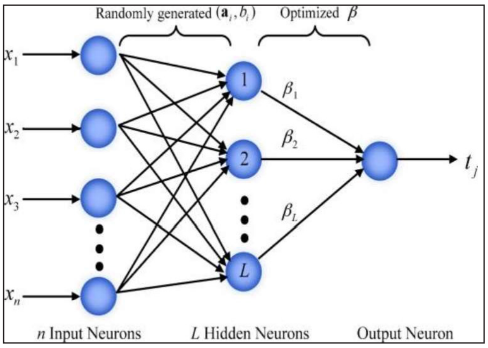

Figure 3.Extreme Learning Machine Model

- The Cluster head sends a control packet to the target node to modify its next mobility state. Control packet contains cluster head IP address, port number, target node IP address, port number and the mobility information that it should change
- The target node updates its trajectory i.e mobility state accordingly as sent by its cluster head
- The Cluster head then calculates the communication quality of the link on the basis of energy consumption, end to end delay, packet delivery ratio
- If the Communication quality obtained is above the route stability threshold then exit, 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 in-depth simulation results are reported in the next section.

Simulation Result

Simulation is carried using Tetcos Netsim(Version 10.2.10) interlinked with Matlab(version 9.1) and Visual Studio in Windows 8.1 OS platform.

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

Cluster Node 3D Figure is shown. 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 have a cluster head. It contains peaks which has information about cluster head coordinates. After Cluster head is selected, Extreme machine learning approach is used for Mobility prediction. Figure 5, shows actual values of mobilit y state vs predicted values. Mobility states are takes as function values of < Xi, Yi, Zi >.

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

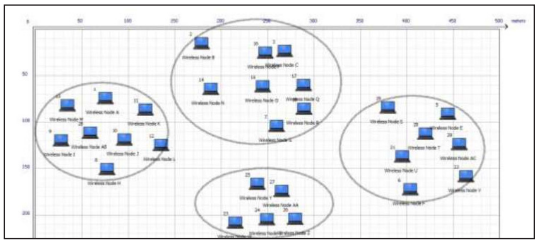

Figure 4.Manet Model

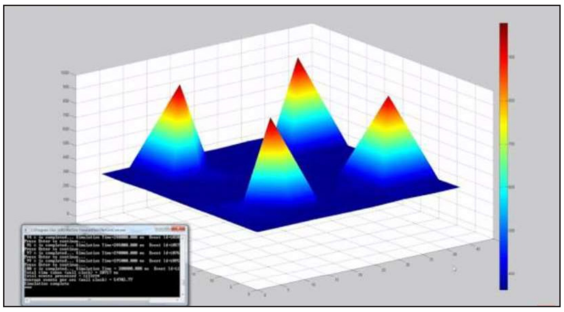

Figure 5.Cluster Head Selection Result

- **Packet Delivery Ratio (PDR):** It is the ratio of Total number of packets received successfully to the total sent
- **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
- **End to End Delay:** Average of the delay (received time minus transmitted time) of every data packet

Figure 7, 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 8, 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.

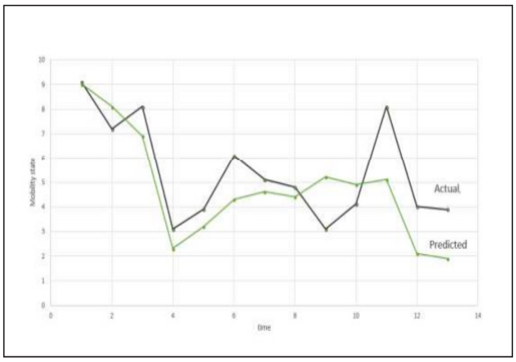

Figure 6.ELM Results

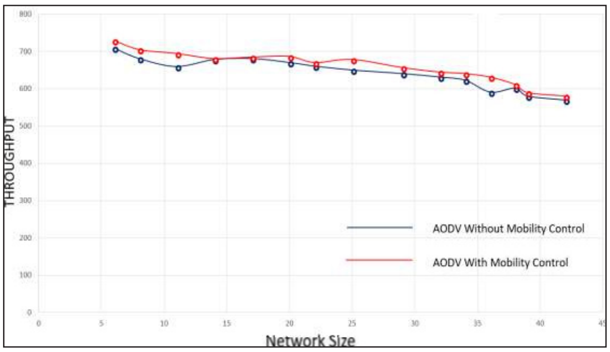

Figure 7.Comparision of Throughput with Respect to Network Size

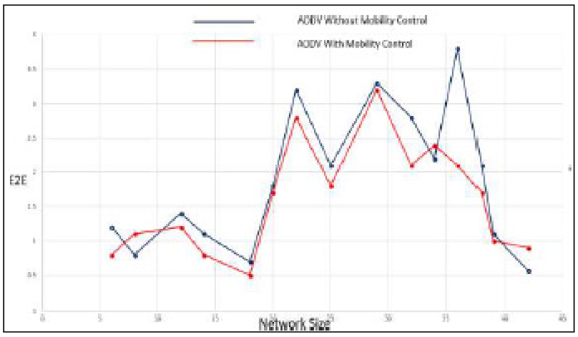

Figure 8.Comparision of End to End Delay with Respect to Network Size

Figure 9, 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.

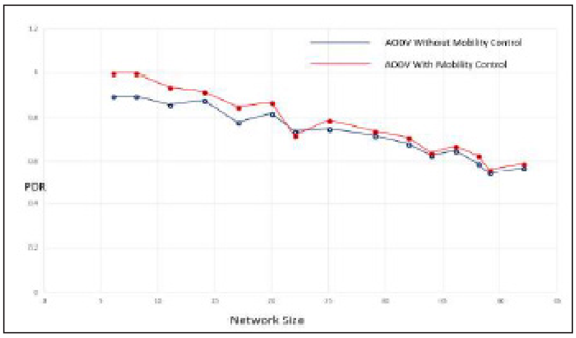

Figure 9.Comparision of PDR with Respect to Network Size

Conclusions

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 that the behavior of all nodes are monitored, packets are transmitted only through trusted nodes by updating their trust tables. through trusted routes only by making nodes monitor the behavior of each other, 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 con- sider the contextual and security features in the mobility control protocol for strengthening the security parameter in MANET.

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