A PROJECT PROPOSAL

ON

DESIGNING AND DEVELOPMENT OF A PROTOCOL-SPECIFIC MOBILE AD-HOC NETWORK (MANET)

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1. Introduction

Wireless network is an emerging technology by virtue of which users can access information and services electronically, regardless of their geographic position. Wireless networks can be broadly classified in two types, namely infrastructure based network and infrastructure less (ad hoc) networks.

Infrastructure based networks consist of fixed and wired gateways. A mobile host communicates with a bridge in the network, called the base station, within its communication radius. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with a new base station and starts communicating through it. This phenomenon is called handoff. In this infrastructure based approach of wireless communication, the base stations are fixed.

In contrast to the infrastructure based networks, in ad hoc networks all nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers, besides being the usual trans-receivers, and take part in discovery and maintenance of routes to other nodes in the network. Mobile Ad-Hoc Networks are projected to play a vital role in applications like search-and-rescue operations, meetings and conventions, multi-platform battle deployment, mobile sensors or satellite networks where quick sharing of information or data acquisition is required in inhospitable terrain.

To communicate between two arbitrary nodes in a mobile ad-hoc network, routing through mobile nodes is required. Since the mobile nodes move frequently hence it may so happen that when some node wants to transmit data to another node that node may fall outside the range of communication of the transmitting node. This is the reason why routing in MANET is essential. The current focus of many researchers is to find an efficient routing protocol which will ensure node connectivity all the time or whenever required without much delay and unnecessary overhead.

There are many existing routing schemes for MANET that can be divided into four basic types namely flooding, proactive routing, reactive routing and dynamic cluster based routing [1, 2].

Whenever no concept regarding the network topology is available, then flooding based routing can be incorporated because flooding based routing protocol does not require any knowledge about the network topology. It can be more or less robust under light traffic conditions. However, in case of large network it generates excessive amount of traffic and thus it becomes difficult to achieve flooding reliably. Proactive routing protocol is basically a table driven routing protocol where each node pre-computes the route to every possible destination as well as the path to be followed to minimize the cost. The protocol also periodically broadcasts routing information throughout the network. This approach however increases network traffic in highly dynamic networks. Several modified proactive routing protocol have been suggested to minimize the traffic [1]. M.Joa-Ng and I.T.Lu proposed a zone based routing protocol [6] where the network is divided into several non-overlapping zones. Although proactive routing protocol can ensure high quality routes in a static topology, it does not scale well to large and highly dynamic network.

Reactive routing is a very lazy on-demand approach in the sense that it takes a long time to find a route from source to destination and uses query-response mechanism to find the route. Ad-hoc on-demand distance vector (AODV) routing is a good example of reactive routing [7]. In this approach overhead may increase significantly due to frequent route finding for highly dynamic networks. Several reactive routing protocols have been proposed so far [1, 2]. C.K.Toh proposed association based reactive routing [8] to find a stable route. In this approach only those nodes that are in long association with the source node were considered to find a route. The temporary ordered routing algorithm (TORA) [9] is another reactive routing scheme where multiple nodes from source to destinations are calculated by localizing the control messages to a very small set of nodes. Some of the earlier works have also introduced transmitter range control to find stable route. The main drawback of reactive approach compared to proactive routing is the significant delay of route setup time and also the large volume of control traffic, which is required to support route query mechanism.

In dynamic cluster based routing protocol [10] the network is dynamically organized into partitions known as clusters to maintain a stable effective topology. Several clustering algorithms are also proposed, which differ from one another in the criteria used to organize the clusters, such as prediction of node mobility etc.

However, none of the proposed schemes guarantees constant network connectivity during the movement and each of these schemes have constant route maintenance overhead. A particular node may even be disconnected in the worst case.

In this proposal, we suggest an efficient self-adaptive movement control algorithm of mobile nodes to ensure the retention of network connectivity even during the positional variation of the nodes. The key concept is to elect a movement coordinator in the network to direct the movement of the other nodes. The nodes must move in such a fashion that the distance from any node to the coordinator does not exceed a predefined maximum value. This maximum range of movement will ensure that, two particular nodes those were neighboring nodes at the beginning, will remain so during the movement too. Eventually, the path between any two nodes will not change throughout the entire movement and hence the routing overhead can be eliminated.

The primary motive of our project is to implement a protocol-specific mobile ad hoc network, which will follow the above-mentioned protocol and will maintain communication within a group of mobile nodes, without any routing overheads.

2. Materials and Methods

Each individual node in MANET is a mobile trans-receiver. In our project, a node can also vary the transmission range stepwise whenever required. The algorithm uses three transmission ranges, the lower two for maintaining connectivity and sending control messages and the highest range to send actual message packets. Each node of the network must reside within the middle range from the movement coordinator.

2.1 Software

In this part of our project, we propose our algorithm and present the necessary theoretical and mathematical framework.

2.1.1 Proposed Algorithm

The proposed algorithm is divided into two parts: the coordinator election algorithm and the movement algorithm. Following assumptions are made in connection to the algorithm:

- All the nodes of the network are moving in the same direction.
- All nodes have a maximum velocity V_{max} with which they can rush.
- The nodes are assumed to undergo acceleration and deceleration instantaneously.
- If the nodes are within appropriate communication range, the messages will surely reach them.
- At the start of the movement, there must be at least one node whose distance from all the other nodes is within the zone of stability, as shown in *Figure 1* in section 2.1.1.1.
- Every node in the network knows the total number of nodes in the network.

This algorithm prescribes three different ranges for communication, (i) Shortest Range – for transmitting HELLO messages, (ii) Mid Range – for transmitting Instruction messages and (iii) Longest Range – for transmitting data packets.

As per *Lemma 1* in section 2.1.2, we take the proportion of the ranges as follows.
Longest Range : Mid Range : Shortest Range = 100 : 50 : 40

2.1.1.1 The Coordinator election Algorithm

The zone of stability is defined as follows. This is required for stability, which is proved in *Lemma 4* in section 2.1.2.

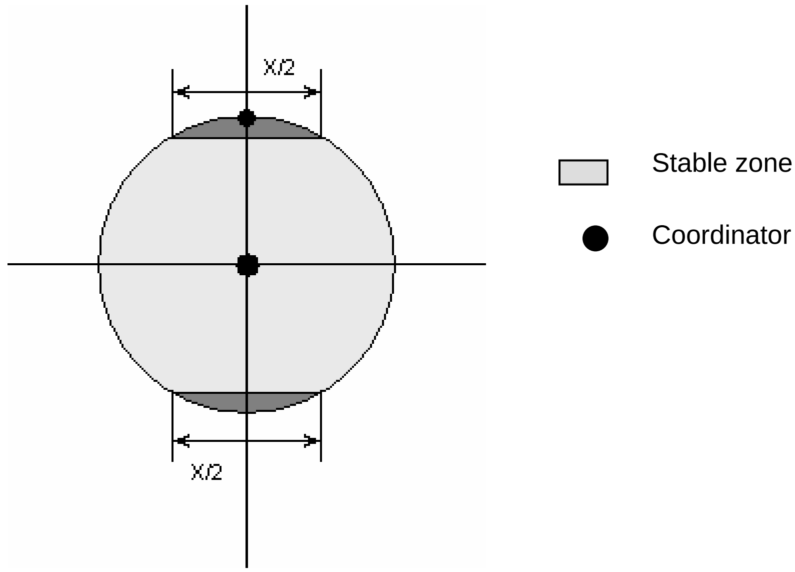

Figure 1: The zone of stability

Here, X is the radial distance between Short Range and Medium Range.
Any node, whose distance from all other nodes in the network is within the stable zone as defined above, is eligible for being the coordinator before the network starts moving. All the nodes are provided with a unique number and the eligible node having the least number is chosen as the coordinator in case of any conflict. Two extra messages namely elect and conflict are defined to elect the coordinator.

At the beginning of the movement, all nodes broadcast an elect message to all other nodes using the shortest range of communication. A node that receives the elect message from all other nodes automatically becomes eligible for being the coordinator. If multiple nodes are eligible for being the coordinator, the conflict situation arises. In this case, the node with the least number is elected as the coordinator. All the nodes, which are eligible to be a coordinator, send a conflict message to all other nodes along with a unique number, and thus all the nodes come to know about the eligibility of the other nodes. The eligible node that finds that all the other eligible nodes have numbers more than it declares itself as the coordinator. Then it sends the normal start message to all other nodes.

2.1.1.2 The Movement Algorithm

The algorithm defines four types of control messages, namely HELLO-message, START-message, STOP-message and RUSH-message. However, there are two types of RUSH messages: RUSH1 to rush for an interval of T/2 and RUSH2 to rush for an interval of T, where the time interval T is the time to cross the distance X, as stated earlier with the predefined maximum velocity V_{max}.

Each node sends HELLO message to the Coordinator periodically with a period of T/4, using the shortest communication range. The coordinator sends other Instruction messages to other nodes using the medium communication range. On receiving the START message, a node can decide to move with its own preferred velocity. RUSH message to a node indicates that the node must move with the predefined maximum velocity V_{max}. The duration of rushing is determined by the two different RUSH messages. Evidently a STOP message stops a node.

Once the coordinator is elected, it sends a START message to all other nodes in the network. After each node receives the START message the network starts moving. Henceforth, the movement algorithm is as follows:

Step 1: The coordinator listens to the HELLO messages from all the other nodes at a period of T/4. On missing HELLO message from some nodes, it assumes that those nodes have moved out of the shortest communication range from it.

Step 2: On the assumption that the nodes have moved ahead, the coordinator first stops those nodes, sends all other nodes the RUSH1 message and rushes along with the well-connected nodes for a time interval of T/2.

Step 3: If the coordinator receives the next HELLO message from the nodes those were stopped, it sends a START message to all the nodes and starts normal movement. On the other hand if next HELLO is not received either from all or from the some of the stopped nodes, coordinator detects that those nodes are not ahead but have been left behind. So it sends a RUSH2 message to each of them and sends STOP message to all other well-connected nodes. The coordinator itself also stops. The nodes that receive the RUSH2 message rushes with the predefined maximum velocity V_{max} for a time interval of T.

Step 4: After the above mentioned two steps, the nodes those had moved out from the shortest range of communication from the coordinator would surely come back within the shortest range of communication if no emergency situation has crept in (proved in *Lemma 2* in section 2.1.2).

Step 5: If at this stage, the Coordinator does not receive HELLO message from some of the nodes, then it declares an emergency situation (may be an accident) and plans accordingly.

The flowchart of the proposed algorithm is shown in *figure 2*.

2.1.2 Lemmas

Lemma 1: Mid-Range Selection

The radius of the mid range of communication should be half of that of the longest communication range for maintaining neighborhood criterion.

Proof: We can say that two nodes are neighbor to each other only when they are within the longest communication range from each other, that is, when they can exchange data packets freely among themselves, without routing. Now, the extreme position of any two nodes, provided that they maintain the stability criterion, that is, they are within the mid range from the coordinator, is when they are in the diametrically opposite directions with the coordinator at the centre, and are located just at the circumference of the mid range circle. But, as per our algorithm, the nodes must remain neighboring ones at this position too. So, the diametrical distance of the mid range circle must be equal to or less than the longest-range radius. For maximum mid range diameter, we take the mid range radius to be half of that of the longest range. This proves the lemma.

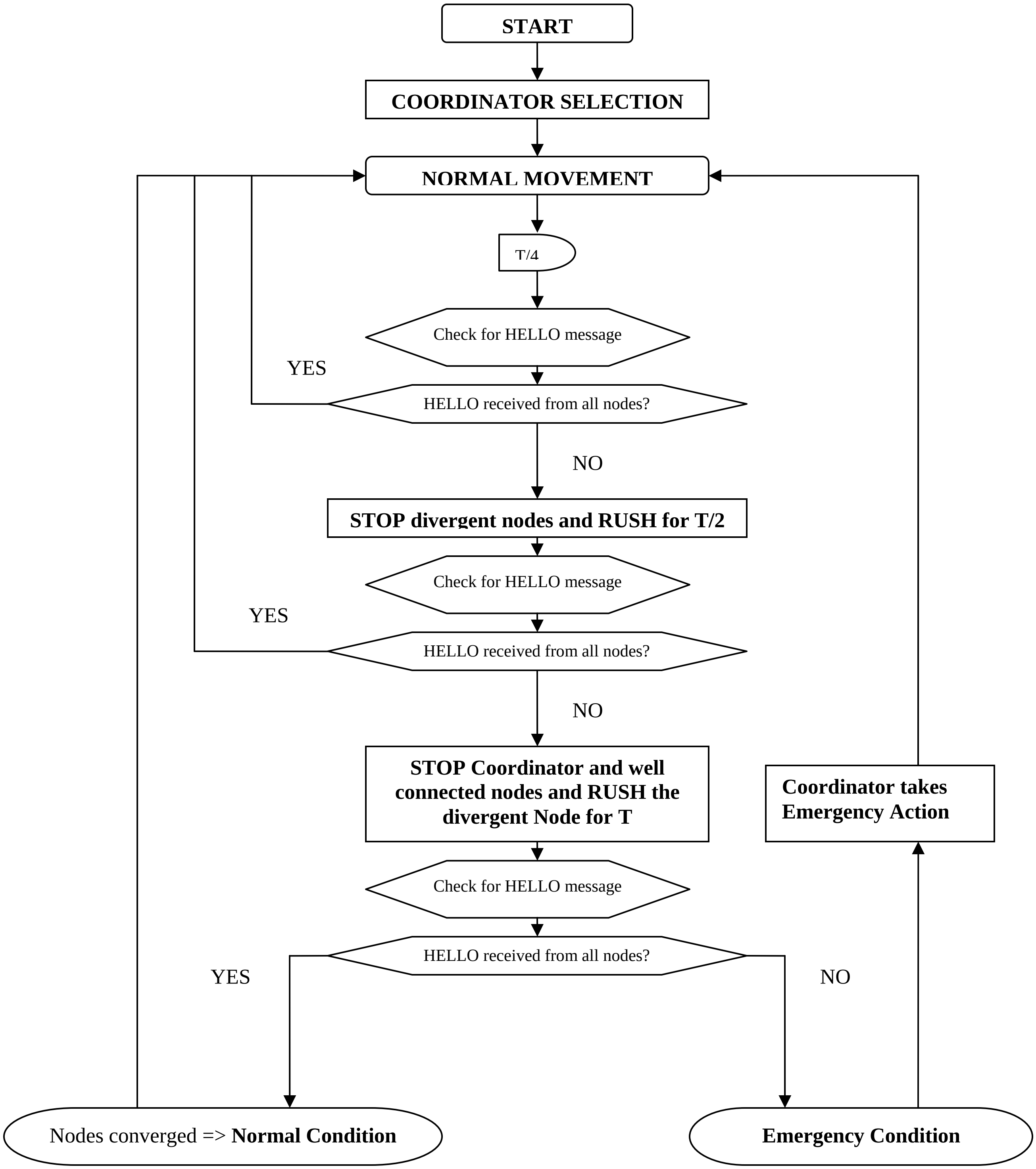

Figure 2: Flowchart of the Movement Algorithm

Lemma 2: Achieving Convergence

In case of any node going outside the shortest range of communication with respect to the coordinator, this proposed algorithm makes it converge within the zone in no more than a time interval of 3T/2.

Proof: As we have stated the maximum time of convergence as 3T/2, we will take the marginally worst cases to prove our lemma. Let us suppose that when the last HELLO message was received from the node, it was at the edge of the shortest-range circle, ahead of the coordinator. In the worst case, let the velocity of the node was V_{max} while the coordinator was static. Then, after the period T/4, the node will move away further by a distance X/4 and the HELLO message is not received for this position. Now, the coordinator commands the node to stop and rushes with all the well-connected nodes towards this node, with rushing velocity V_{max}, for a time T/2. Hence, the coordinator covers a distance of X/2 and surely catches up with the divergent node. So, the total time needed for convergence is T/2, when the divergent node is ahead of the coordinator.

On the other hand, let us suppose that when the last HELLO message was received from the node, it was at the edge of the shortest-range circle, behind the coordinator. In the worst case, let the node was static while the coordinator was moving with the maximum velocity V_{max}. Then, after the period T/4, the node will move away by a distance X/4 and the HELLO message is not received for this position. Now, the coordinator commands the node to stop and rushes with all the well-connected nodes away from this node, with rushing velocity V_{max}, for a time T/2. Hence, the coordinator covers a distance of X/2 and leaves behind the divergent node by a total distance of X/4 + X/2 = 3X/4. Again, the coordinator does not receive the HELLO message, and it commands the divergent node to rush with V_{max} for a time interval of T while remaining static itself along with all the well-connected nodes. Hence, the trailing node covers a distance of X in this time T and surely comes back into the shortest zone. So, the total time needed for convergence is T/2 + T = 3T/2.

As we have considered the worst possible situations on both the ends, we can state that the total time required for the convergence of a node is always less than or equal to 3T/2. This proves the lemma.

Lemma 3: Maintaining Convergence

Once a divergent node is converged with the help of this algorithm, it is ensured that the particular node will not diverge again for a successive time interval of T/2.

Proof: As shown in the Lemma 1, it is seen that in the worst-case scenario, when a node was primarily ahead of the coordinator and diverges, it comes back to a position within (and not on) the shortest zone circle after convergence. Again, when the node is primarily behind the coordinator and diverges, it also comes back to a position within (and not on) the circle after convergence.

We can clearly see from the cases above that the distances of the positions (after convergence) from the edge of the circle are given by - Case Ahead: X/2 – X/4 = X/4 and Case Behind: X – (X/2 + X/4) = X/4.

So, even if the worst-case scenario prevails and the relative velocity between the Coordinator and the node is V_{max}, then the node will take a time interval of T/4 to reach the edge of the circle and another T/4 to diverge again. Hence, after the convergence of a node by this algorithm, it is ensured that the node does not diverge again for a successive time interval of T/4 + T/4 = T/2. This proves the lemma.

Lemma 4: Stable Zone

If a node is within the zone of stability as defined before, it will either be stable or can be made stable easily after divergence.

Proof: Let us take the route of contradiction by assuming the whole circular region to be the zone of stability. In such a case, if we consider a node on the circumference of the circle for which the direction of motion is tangential to the region, then we will find that it has a strong tendency for divergence. That node will have just one point in the stable zone and if it is deviated by even a very small amount, the algorithm will fail to bring it back to that very point. We define this problem as Meta-Stability.

Now, as per the definition of the zone of stability in our algorithm, the node with the tangential velocity is provided with a band of length X/2 instead of just a point. Hence, in the worst case, if the relative velocity of the node with respect to the coordinator is V_{max}, then the node on the band will move to a position outside the zone and become unstable. In the process of converging the node, the distance between the initial and the final node positions will be X/4 (proved in *Lemma 3* in section 2.1.2). Hence, having the band of length X/2 at our disposal, we can surely bring back the node to a stable point on the band with the help of our algorithm. This proves the lemma.

2.2 Hardware

The overview of the network is shown below. We will be building the network consisting of five nodes those will be communicating among themselves. The network will be a protocol-specific network using our proposed algorithm for retaining mutual connections between the nodes throughout their movement.

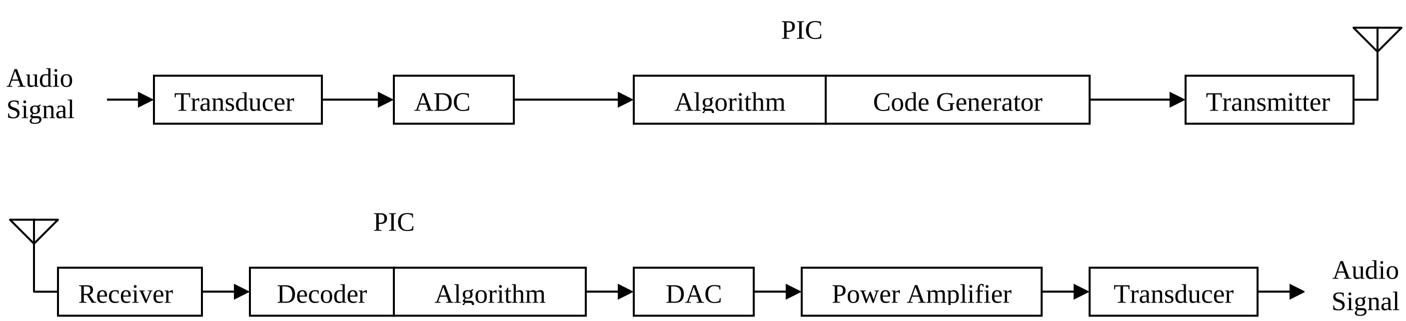

Figure 3: The Block Diagram of a Mobile Node

Each mobile node for the ad hoc network will be structured using a micro-controller as the basic processor, which will be interfaced with the trans-receiver modules. The components we are going to use for implementing such a node are:

1. PIC 16F877 micro-controller as the processor
2. The Analog to Digital (ADC) and Digital to Analog (DAC) chips
3. Dual Tone Multi Frequency (DTMF) generator IC - UM91214B and Keypad
4. Audio transducers like Microphone and Speaker
5. Power amplifier

The basic structure of each node of the MANET is shown in the above figure. At first, the audio signal to be transmitted is converted to analog electrical signal by means of the transducer. This signal is digitized using the ADC and fed to the PIC microcontroller. The microcontroller generates the code required to send according to the coding logic and passes it onto the transmitter. The transmitter performs FSK on the digital waveform and transmits it using Frequency Modulation technique. In the receiver part of the node, the received signal is demodulated and the digital waveform is sent to the PIC microcontroller. After decoding the signal, the microcontroller responds to the message according to the proposed algorithm and feeds the signal to the DAC. The converted analog signal is amplified and audio signal is generated through the transducer (generally a speaker).

3. Project Flow: Modules

Different modules of the project are discussed below:

3.1 Protocol Design

As this project is concerned with the implementation of a protocol-specific MANET, the module of primary importance is the protocol designing part. We have already completed this module and have presented our algorithm, the self-adaptive topology management scheme, in the 'Materials and Methods' section of this synopsis.

3.2 Software Coding and Protocol Simulation

Before implementing our algorithm onto the real hardware network, we have simulated it through software coding. The coding of the algorithm is done in C programming language and the simulation platform is MS-DOS. We have finished this module too. The simulation result is shown below:

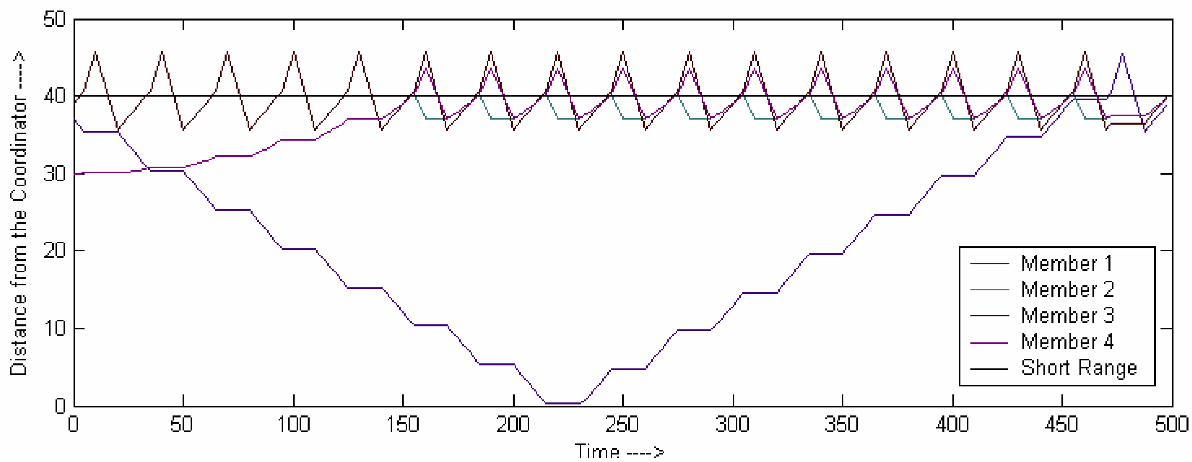

Figure 4: Simulation result

In the simulation result, the distances of the four member nodes from the coordinator are depicted against time scale. It can be seen that the members can move with their preferred random velocities when they are within the shortest zone margin, but the movement coordinator controls their movements and stabilizes the network whenever any member goes out of this range. It is also projected that the maximum time to stabilize the network is 3T/2 = 15 units in this case, which verifies the claim of the proposed algorithm. Again, the claim of constant connectivity between the nodes is also verified as no node goes outside the Mid Range of radius 50 units. Hence, this simulation result depicts the effectiveness of our algorithm.

3.3 Hardware Design and Implementation

The hardware design is based on our algorithm itself, and hence the network will be a protocol specific one. The mobile nodes, as mentioned in the Hardware Materials portion previously, will be implemented with the help of PIC micro-controllers as the basic processor along with trans-receiver modules interfaced with it.

3.4 Network Testing

The complete network, once prepared, will be tested by implementing the proposed algorithm onto it. The final testing of the network will be carried out in practical mountaineering applications.

4. Discussions

So far, in our project, ***we have completed the first two phases***, that is, have finished the first two modules as discussed above. We have already formulated the algorithm on which the MANET will operate. We have also simulated the algorithm on a software platform and have obtained encouraging results. The simulation results are provided in the previous section. The last three phases of hardware design, implementation and testing are yet to be done.

5. Conclusion: Results Expected

- At the successful completion of the project, it is expected that we will have a ***protocol-specific Mobile Ad-hoc Network*** which will support our proposed scheme which is specifically suited for applications like mountaineering, rescue operation, battlefield and also in other fields where all nodes are moving in the same direction.

- Precise ***methodology for designing the MANET*** will also be developed as the output of the project.

- We also intend to extend the range of our MANET from this protocol-specific network to a common platform, which can be used as a backbone for the performance comparison of various routing protocols, resulting in the ***generation of a more efficient and robust routing protocol for MANET***. This study will also point out the advantages and disadvantages of different protocols.

- It is also expected that the system will be used in ***practical application oriented fields*** like - for maintaining communication within a group of mountaineers in the inhospitable terrains.

6. Acknowledgement

We would like to thank Surjya S. Ray for his contribution to the proper development of the new protocol. We would also like to acknowledge the valuable suggestions of Seetharam Narasimhan and Sourav Banerjee at the time of hardware design.

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