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Enhancing the Connectedness in Ad–hoc Mesh Networks using the Terranet Technology

Obeidat I., Bsoul M., Khasawneh A., Kilani Y.

***Abstract*—**This paper simulates the ad-hoc mesh network in rural areas, where such networks receive great attention due to their cost, since installing the infrastructure for regular networks in these areas is not possible due to the high cost. The distance between the communicating nodes is the most obstacles that the ad-hoc mesh network will face. For example, in Terranet technology, two nodes can communicate if they are only one kilometer far from each other. However, if the distance between them is more than one kilometer, then each node in the ad-hoc mesh networks has to act as a router that forwards the data it receives to other nodes. In this paper, we try to find the critical number of nodes which makes the network fully connected in a particular area, and then propose a method to enhance the intermediate node to accept to be a router to forward the data from the sender to the receiver. Much work was done on technological changes on peer to peer networks, but the focus of this paper will be on another feature which is to find the minimum number of nodes needed for a particular area to be fully connected and then to enhance the users to switch on their phones and accept to work as a router for other nodes. Our method raises the successful calls to 81.5% out of 100% attempt calls.

***Keywords*—**Adjacency matrix, Ad-hoc mesh network, Connectedness, Terranet technology

I. INTRODUCTION

PEER to peer networks are an excellent option in areas where the traditional base stations are impossible to install due to many reasons. One of them is the highly cost in rural areas in which the users are very limited, and commercially perspective none of the mobile companies will invest millions of dollars in such area. Another reason is that when using a peer to peer network in battlefield and disaster recovery, each node can talk to another node totally in a decentralized manner. For instance, in Terranet, if two persons own two Terranet phones and they switch on their phones, they can initialize a peer to peer network and they can communicate for free since they do not have to centralize their call to a base station. Therefore, TerraNet designs a proprietary ad-hoc mesh network mobile platform which alleviates the need of cell towers and radio base stations. Much work was done on technological changes on peer to peer networks, that is why the focus of this paper will be on another feature which is to find the minimum number of nodes needed for a particular area to make it fully connected and then to encourage the users to switch on their phones, since a call for more than one kilometer needs an intermediate phone to route it to its final destination. Such a problem will not come to pass in a regular network because all calls must go through the base station.

Obeidat I., Bsoul M., Khasawneh A. and Kilani Y. are with Faculty of Prince Al-Hussein Bin Abdallah II for Information Technology, Hashemite University, P.O. Box 150459, Zarqa 13115, Jordan. E-mail: imsobeidat @hu.edu.jo

It is important to mention that after finding the appropriate number of users, these users should cooperate in routing the calls of other users, while taking into consideration the limited power of their phones. Some users prefer to save their batteries to make calls especially with the limited resources in rural areas. For example, in east Jordan (Aljafar), the user needs to travel a long distance in order to recharge its battery, and thus the user might prefer to switch off his phone to save the phone power, or the user who has a technical skill might prevent its phone to act as a router for other users. In these cases, the network will crash and the connectivity will be lost. A peer to peer network is mostly similar to MANETS and VANETS so the next paragraphs will discuss these two kinds.

II. MOBILE AD-HOC NETWORKS

A MANET is a self –configuring mobile wireless network using no infrastructure [1] [2]. In MANET networks, each mobile is free to move in any direction, and therefore the links to other devices will change frequently. Each device must forward the data which is not related to it and behaves as a router. The confront in MANET networks is to continually maintain the information required to correctly route traffic . MANET networks can work by themselves or can be connected to the internet.

MANETS are wireless networks that have a routable networking environment on top of a link layer ad hoc network. MANETS employ the ad-hoc mode of IEEE 802.11 standard (Wi-Fi) and are primarily used for data packets. On the other hand, Peer to Peer networks can be used for data packets and voice communications. MANETS commonly used for military purposes and sometimes can be used for disaster assistance; while Peer to Peer Networks can be used for more purposes.

III. VEHICULAR AD-HOC NETWORKS

A vehicular Ad-Hoc Networks (VANET) is a network that uses the cars as nodes to create mobile networks. In such networks, every car will act as a wireless router allowing cars that far about 100 meters of each other to connect. The application of these networks can be mainly used for police and fire-fighters to maintain security, as on car fall out of the signal range another car join in.

VANETS are similar to MANETS, but they differ in not moving at random direction. They tend to move in a controlled manner, and most vehicles are restricted in their motion [3].

The rest of this paper is organized as follows. Section 2 will address the literature review. Section 3 describes the network structure. Section 4 presents the ranking method. Section 5 discusses the simulation results. Section 6 concludes the paper and describes future directions.

IV. LITERATURE REVIEW

The Indian Institute of management project [4] is very close to our work, but they assume that the network in the tested

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area is fully connected. Furthermore, they use a rating based scheme to encourage the user participation in ad-hoc mobile mesh networks, and they assume a network of N nodes in which each node may be on or off at a given time. Their system runs in time slots and each node either stays on or off for the whole time slots. In Terminodes project [5], it assumed a pure decentralized use of the tamper proof hardware. It is also assumed that the tamper-proof at each node keeps track of the “nuggets” or virtual currency, and the sender loads a packet of nuggets before sending it. Each node will be paid a nugget for routing the data, and each of these nodes in the network will generate a packet continuously and that packet cannot be buffered, thus it has to be sent right away or dropped. But in reality this assumption is not valid because the user cannot use his phone continuously. This project also does not take into account the peak and the lag time and the user may delay unimportant calls. The buffering is not considered in this project. Analyzing the Impact of Mobility on the performance of routing protocols for Ad-hoc Networks [6], they use the random waypoint in their simulation, and their framework aims to calculate the impact of different mobility models on the performance of MANET routing protocols. They suggest some protocols to capture mobility characteristics, including spatial, temporal and the land limitations, but the use of the random waypoint is not applicable in our research and may lead to lose some important mobility characteristics.

V. Network Structure

A. System Stage 1

To find how many nodes needed to form the ad-hoc mesh networks, asymmetric adjacency matrix n×n was used. The matrix works as follows: if node i and node jare only one kilometer far from each other then number one is placed in the matrix and zero otherwise. The matrix was first created using random numbers compared with a given probability. We use two methods to find the distance between two nodes.

The first method is Dijkstra’s algorithm which finds the shortest path from node i to every other node. If the distance between nodes is more than one kilometer, then the communications between node i and node j need to be routed by the closest node to i.

The second method to find the distance between two nodes is the triangle method which says that the distance between nodes a and b must be shorter than the distances between nodes a and c and nodes b and c (see Figure 1).

The graph or the matrix was formed several times using random numbers and by using the depth first search we can know if the graph is fully or partially connected.

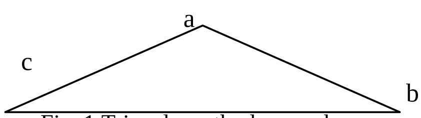

Fig. 1 Triangle method example

To simulate the random motion of the users, the network was formed more than a hundred times and then we took the average of the connectedness and that of course led to find the minimum number of users needed to make a certain area fully connected.

We did our simulation on rural area in Jordan called AlJafar (part of the north east) which has an area of about 40 kilometers (see Figure 2). That part needs about 120 nodes to be fully connected.

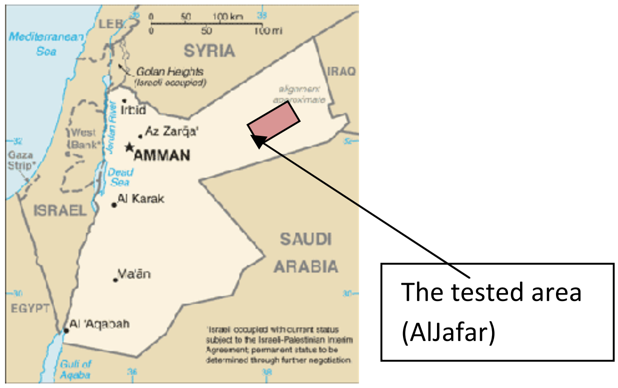

Fig. 2 Geographical area of the tested part of Jordan

B. System Stage 2

We proposed an ad-hoc mesh network representing the Terranet technology, where the tested area has the nodes it needs to be fully connected, but the problem occurred when two nodes want to communicate with each other and they are far than one kilometer from each other. In this case, they need an intermediate node to act as a relay between them. Because the handheld needs to be charged and the power supply is far away, some of the customers switch their phones off and therefore they will not act as a relays. Our method will deal with this situation by giving ranks to each node in the network, in order to encourage them to act as relays in case someone in the network needs them to transfer its data or voice to the nearest node. As in real situation, the users can switch on or off their phones depending on their needs. In rural areas, the need to switch off the phones even rise more in the sense that the users will switch on the phone to communicate and switch it off to save power.

C. Ranking Method

In the beginning of the simulation we assumed that each node in the network has 50% chance to communicate (see figure 4), that depends on the distance between the communicating nodes and the status (that can be ON or OFF) of the intermediate nodes between the two communicating nodes.

We divided the nodes into three kinds:

1) Nodes that are ON all the time. The users in this case will have their phones on all the time and they always act as routers for other calls.

2) Nodes that are OFF all the time. The users in this case will keep their phones off except if they want to send or receive calls.

3) Nodes that can be ON or OFF. The users in this case keep their phones off for various reasons until their rank will prevent them from doing any call. In this case, they will keep their phones on to reach the rank that permits them to send and receive calls.

Our method gives the same ranking for all the three types at the beginning of the simulation. Then, the ranking is increased as the node acts as an intermediate node. For instance, if the node transfers the communication of another node, then the ranking will be increased by one and the probability to have a successful call will rise too. The ranking of the intermediate node which refuses to act as intermediate node will also decreases by one each time it cancel the communication of another node, and that will decrease the probability of making a successful call.

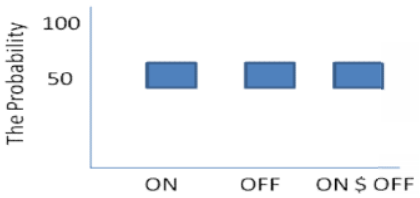

Fig. 5 The probability that each node has at the beginning of the simulation

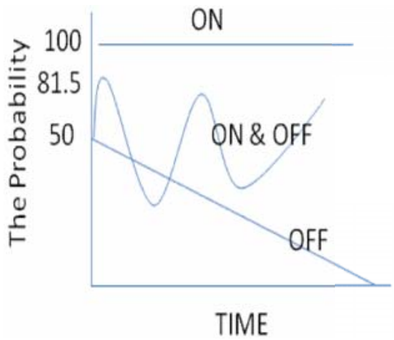

Fig. 4 The probability that each node has over time

VI. Results

As we divided the customers into three types, the OFF nodes as will send and receive no calls after a period of time, because their rank will become zero. The ON nodes will send and receive calls all the time and that because of having a high rank. The ON and OFF nodes in which we try to encourage to act as relays for other nodes by using the rank system, the percentage of successful calls reached up 81.5% of all the trail calls (see figure 5). This achieved percentage is considered a good result taking into account that the simulated environment is a rural area.

VII. Conclusion

In this paper, a new method for determining the number of nodes needed for making an area fully connected. This method aims to encourage the users to keep their phones on by giving each phone a rank. So, the phones with higher rank will have a better chance to make a call via intermediate nodes. This method achieved a better result than the other existing methods.

In future work, there are two main areas of consideration: considering more factors to calculate the rank for each phone, and undertaking further experimental investigations.

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