DISCOVERING THE MOST STABLE NODES IN MOBILE AD HOC NETWORKS

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DEDICATION

One of the merciful god great blesses upon humanity, is surrounding us with people who love and support us through our life.

Along the rough road, they have always been a true guidance, a sweet shine of light and a great support; to those who never gave up on me and helped me through my long trip I dedicate this thesis.

Foremost, I dedicate it to my venerable parents who helped me along this accomplishment, by these few words, I wish to express my great gratitude for their endless support and love, that surrounded me through out my life, they have been the solid ground that I leaned on during these years.

I would like also to dedicate this thesis to my sweet sisters, for their patience, support, inspiration and continuous encouragement.

To all of my relatives who followed up my progress, guided me and supported me.

At the end

Life without friends is nothing, through these lines, I would like to thank all of my friends, for the sake of all the hours that we shared together working and studying, and for making boring and hard work look more exciting and enjoyable.

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LIST OF ABBREVIATIONS

MANET	Mobile Ad hoc NETworks
GPS	Global Positioning System
GSBRA	Grid Stable Based Routing Algorithm
MSN	Most Stable Nodes
AODV	Ad hoc On-Demand Distance Vector

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ABSTRACT

Due to its flexibility and ease of formation, ad hoc wireless networks MANETs, is considered one of the recent promising technologies that are pervading in modern communication systems. Inspired of the importance of such technology, and after an intensive study for its nature, we aimed in this thesis to find a new protocol that is able to find the most stable nodes in MANETs. The idea behind such protocol is to improve the performance of the network, by narrowing the problem of its central management lacking.

Finding the most stable nodes in the MANETs, may help many other researchers to improve their protocols efficiency, such as: routing protocols, backbone building, data distribution and other protocols.
In order to find the most stable nodes, we studied the main properties that emphasize node stability which were the neighbors association and the logical coordination. Where in our thesis we preferred using the logical coordination, as it provides better vision in deciding the nodes stability. In the proposed logical coordinating, protocol we

suggested two different methods, then studied the difference in the results accuracy between them, and chose the most suitable method. After that we used the suggested protocol as a base in building our protocol, which aims to find the most stable nodes (MSN) in the area. The MSN finding protocol relied on a collection of location displacements measurement, and periodic updates exchanging to find the most stable nodes in the area.

Then, we analyzed the new protocol abilities to find the most stable nodes; by comparing the protocol results to real stability scenarios. Then we studied many factors that may affect the accuracy of the protocol, such as, the total stability measurement time, number of nodes in the area, periodic displacement updates, speed of nodes, speed of stable nodes and the displacement acceptable range.

Introduction and Literature review

1. Introduction and literature review

1.1 Introduction

Throughout the age of wireless networks history, two types of networks formed the main classification root, those were the infrastructure networks (which depended on access point or base stations), and the infrastructure less Ad hoc NETworks (MANETs), in which wireless mobile nodes can communicate with each other without utilizing any centralized management (Meghanathan, 2007).

When browsing through MANET's history, we can see that the main idea of using MANET was to eliminate the centralized management, this is achieved by allowing the nodes that constitutes MANET to play dual role; as a computing device and as router at the same time (Lim, Shin, Lee, Yoon, Ma, 2002), (Meghanathan, 2007).

Pure MANETs are constructed under infrastructure less topologies, where there is no central knowledge about the network topology, and nodes move without any supervision about their locations. Due to this dynamicity; a great deal of the scarce network resources are consumed by many MANET protocols, since they need to communicate very frequently. (Gerharz, Waal, Martini, James, 2003)

The idea of mixing between decentralization and centralization was proposed, under the denotation of clustering, in which moving nodes that form the network are divided into groups, and a cluster head is assigned for each group. Cluster heads were used to help in making routing decisions and reducing the route's discovery cost. Many research papers discussed clustering techniques and proposed more and more appropriate methods, in order to improve the network performance. (Wu, Song, Jiang, Xu, 2007)

Among many challenges in managing and designing MANET networks, route and path stability have an important impact on network performance. Researchers have been always seeking for the best ways, to construct routing algorithms that provide fastest, least cost, and most stable routes to send packets between source and destination. (Khetrapal, 2006) (Gerharz, Waal, Martini, James, 2003) (Cottin and Wack, 2009)

In this thesis, we aim to propose and test a new protocol, derived from deep understanding of the nature of MANETs, and browsing through many other researches. The protocol main idea is to find the most stable nodes in a network area, which will appeal many benefits that would in rich the performance of MANETs. Many other researches may use this protocol to support their new ideas in routing, database distributing, power management, clustering (Qadduora, Almobaideen, Omari, 2006) (kumar, Aseri, Patel, 2009) and many other ideas that may depend on the most stable nodes to be applied in the most appropriate way.

The rest of this thesis is organized as follows: in the next chapter we present a literature review for some other useful works related to our thesis idea, then in chapter three we provide some analysis for the stability vectors, propose a new logical coordination protocol, and study its abilities to coordinate the nodes logically. In chapter four we propose the MSN finding protocol and present its analysis, later we discuss the testing results of the MSN finding protocol and present them in chapter five, after that we summarize the thesis and discuss our conclusions in chapter six, at the end the future work are proposed in chapter seven.

1.2 Literature Review

We have studied many other thesis papers related to our concern, in this chapter we tend to summarize proposed ideas and protocols used by other authors and compare them with our work.

Our main focus, while studying through other related works was to find techniques that have studied the nodes stability, unfortunately the papers that study the nodes stability are limited, and some are using GPS systems. Other papers discussed node stability from other perspectives such as route stability, links stability, and neighbors' association.

At the beginning we studied some strategies to estimate links and paths stability, the strategies were discussed in Paper (Gerharz, Waal, Martini, James, 2003), and could be summarized as follows:

The first used approach to estimate the link stability is by selecting the oldest link in which oldest links are selected as the most stable links. This approach fits only on scenarios with high probability of residual lifetime such as, static scenarios and random-way point with long pause time. Unfortunately, this algorithm does not work if the residual lifetime is low, where the second strategy fits better, the second approach was designed to select the youngest link, and this approach relied on theory that the youngest link may remain in the very next future.

However, both of the previous approaches are inflexible, so the third approach was commonly used, which is to select the link with maximum expected residual lifetime, which form in somehow a hybrid between the previous two algorithms. (Gerharz, Waal, Martini, James, 2003)

(Wu, Song, Jiang, Xu, 2007), discusses clustering protocols; analyze the probability of cluster heads replacement, and their effect on the performance of the network, especially the delay that happens due to those changes. Then the authors propose an algorithm called “Grid Stable Based Routing Algorithm (GSBRA)”, which depend on dividing the network into small zones, then assign each area zone a primary grid head and a backup grid head, which would be the future primary head, if the current one moved.

The grid dividing algorithm use the global positioning system (GPS), to locate the nodes in the area, and the process of electing the primary grid head and the backup grid head is done, according to the frequency of changes in the node location. The most stable node is elected as a primary grid head, and the next most stable one is elected as a backup grid head.

The main idea of the model is to form more stable path using the primary grid head, and alternative path using the backup grid nodes. Path stability is evaluated using end to end reliability model, depending on the backup grid head, so if the first path was broken the second path will be used immediately, and that minimizes the path breakage delay, and increases the network performance.

The algorithm was tested and compared to the AODV and AODV-BR; the experimental results showed that (GSBRA) model achieved higher delivery ratio, route stability and least route load (Wu, Song, Jiang, Xu, 2007).

Another technique that studied cluster stability is suggested in (ER, Seah, 2004), where a new cluster forming algorithm is presented; based on d-hop mobility model(where d-hop refers to the multi hop model), in this paper, the relative mobility is estimated over time depending on the variation of distance between the nodes.

The distance estimation is calculated, by measuring strength of signal between two nodes, over a period of time, and if the variation in the strength between the two of them is negligible, they are considered to have the same moving pattern, and they are grouped together, this operation is repeated between all of the nodes, and at the end the nodes are clustered together according to their movement pattern (ER, Seah, 2004).

Unlike other clustering techniques, the cluster diameter in this paper is variable and depends on the nodes movement pattern stability, instead of having a fixed 2 hop count cluster diameter as usual.

The simulation results of this paper revealed that the model decreased the cluster head changes and the number of clusters in the network, it had also led to higher cluster stability (ER, Seah, 2004).

However, the idea of our thesis is to find most stable nodes in the area, and as mentioned before, nodes stability could be measured according to the location stability through time and neighbors association. But finding the node location in MANETs formed a big challenge.

We studied many papers that discussed the idea of figuring out nodes locations (unfortunately, most of these papers relied on the use of GPS), while other papers tried to figure it out through estimating logical locations of the nodes, in the following we summarize some of those papers.

The authors of the first paper propose, the idea of approximating nodes location using directional antennas, the paper discuss the possibility of using 2 reference nodes and signal arrival angle, each node uses the previous information to estimate its' logical location using well known mathematical formulas, the protocol choose 2 main reference nodes with directional antenna, to be used to estimate the locations of the direct nodes, then the protocol is cascaded to find m-hop neighbor nodes (where m-hop refers to multiple hop cluster head) (Roy, chatterjee, bandyopadhyaya, uede, etc. 2005).

In the second paper the authors (Cao, Abdelzaher, 2006) also propose another logical coordinating routing (LCR) protocol to be used in wireless sensor networks, the idea of the paper is to elect some nodes to be landmarks nodes, then calculate the hop counts between each node over the area and the landmarks, which will end with a hop count logical coordinates for each node, demonstrating its logical position according to each landmark in the area. The authors of this paper discussed and tested their protocol, and showed by experimental results that their protocol was able to improve the messages delivery ratio and the delivery overhead.

The authors of the third paper (Savvides, Han, Strivastava,2001) study the ability to estimate the location of nodes in MANET, and propose a new protocol, which they called AHLoS (ad-hoc localization System), that enables nodes to discover their own locations in the network area.

The protocol idea is to use few nodes supported by GPS system, (which were called beacon nodes), these nodes will be used to estimate surrounding nodes positions using some algebraic mathematical models, the other proposed that in order to enable a node to estimate its' location, it should have at least 3 beacon direct neighbors, within its transmission range, if so, the node will use the received signal power from each beacon node to form a triangle of transmission powers, which the node will use later to calculate its logical coordinates (Savvides, Han, Strivastava,2001).

Many other papers, studied the paths and routes stability and considered them as an important metric in improving networks performance, and because nodes stability plays a huge role in routes stability, we can see the importance of discovering the most stable nodes in the network.

Stability Analysis

2. Stability analysis

2.1 Introduction

Inspired by studying many related works, we found that the main concerning factors, when deciding node stability are the location stability in reference to other nodes in the same area (Cao, Abdelzaher, 2006) (Roy, chatterjee, bandyopadhyaya, uede, 2005), the node association to other neighboring nodes, and for how long neighbors remain connected to that node (Basu, Khan, Little, 2001) (ER, Seah, 2004). In this chapter we rely on existing protocols in order to propose an appropriate protocol which is able to decide node stability.

2.2 Neighboring stability

Many papers shared an understanding of nodes stability as a long term association with other neighbors, these papers made use of the neighbors association to decide the best routing path, and reduce the updates overhead (ER, Seah, 2004) (Basu, Khan, Little, 2001).

In our thesis we tend to use the neighbors association when deciding the reference nodes, as we will discuss the nodes logical coordinating abilities.

2.3 Location Stability

Tracing out the dynamic nature of MANETs, we found that it is lack to any central management restricts the ability to decide a node location, so we rather depend on calculating a logical coordination to the node instead of real coordination.

Some papers like (ER, Seah, 2004) (Wu, Song, Jiang, Xu, 2007) (Cao, Abdelzaher, 2006), relied on the neighboring nodes and the hop counts in routing protocols, to decide the logical coordination of the node, but due to the nature of the research, we cannot depend on the neighbors association because we need to find the stability according to the location displacement, so we prefer to find logical Cartesian coordinates for the nodes, that is why we referred to the idea proposed in (Roy, chatterjee, bandyopadhyaya, uede, etc. 2005).

The authors of the paper, discussed the ability to calculate the logical coordination of a node, depending on the existence of directional antennas and the exact angle of the received signal, however the drawback of this idea according to our needs, is that it depends on additional equipment, which are the directional antennas, while we want to depend on the minimum network specification, so we only made benefit from their idea of electing a certain node as main reference node, and giving it the logical coordination (0,0), then electing another node and giving it the coordinates *(x,0)*, where ***x*** presents the distance between the two nodes according to the measured power signal.

The authors of paper (Savvides, Han, Strivastava, 2001) also proposed some useful ideas, to estimate a node location, their estimation was based on the transmission power of 3 surrounding nodes, and the angles between them and where these angles were calculated based on well known mathematical formulas. Unfortunately their idea made use of few nodes supported with GPS system, to estimate the locations of other nodes, in our thesis we do not want to use any kind of GPS system, so we propose a new protocol, that uses a combination of the two previous protocols ideas and would need neither GPS system nor directional antennas.

2.3.1 The new Logical coordinating protocol

Our new protocol, present the mobiles area as 2D Cartesian plane, where the original point (0, 0) presents the logical location of the main original reference node (elected node according to a long history of association with other node), and the other direct neighboring node in the area will be elected as second original reference node, and will be assigned the logical coordinates (x,0) (Roy, chatterjee, bandyopadhyaya, uede, 2005), those two nodes will be the main reference nodes, and they will be used by the other direct neighboring nodes, when deciding their own logical coordination.

In general each node can use the signal power received from two distinct reference nodes forming 2 sides of a triangle (*rm* and *sm*) in Figure 1, while the third side *rs* present the signal power sent from the second reference node toward the first reference node, now we have three transmission powers forming a logical triangle with three known sides lengths (identified by the transmission powers). In all of the calculations the assumption that there is no noise in the area between the three nodes, which may reduce the accuracy of the distance calculation.

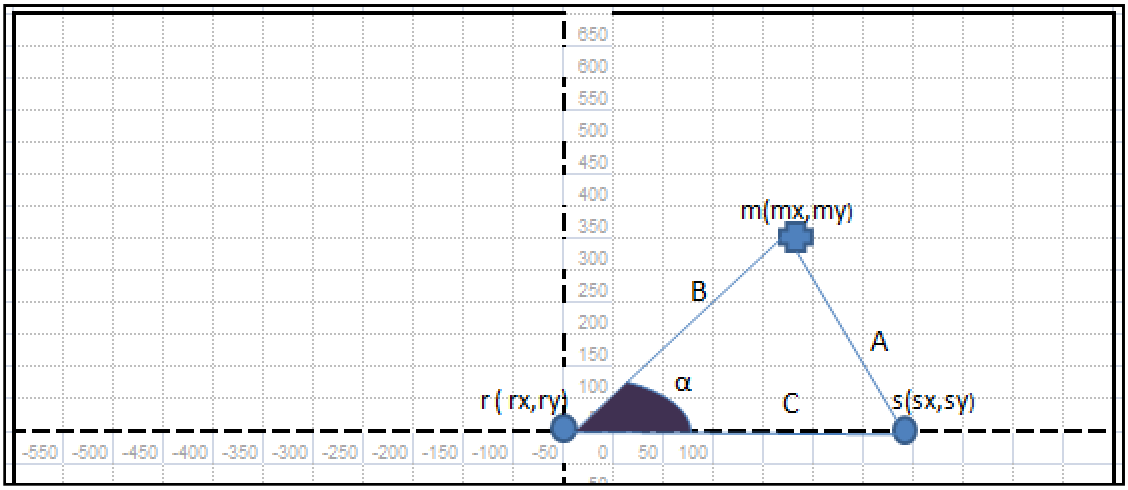


Figure 1. Finding Logical Coordination for m node

Figure 1, shows three nodes on (x, y) plane, where nodes r and s present the two reference nodes, while node m presents any node within their transmission range, A, B and C present the estimated distance between each two nodes according to the transmission power exchanged, and α presents the angle between our target node and one of the reference nodes, this angle will be used when the logical coordination of node m is estimated.

If we suppose that the previous three nodes ***s, r*** and ***m*** are placed in the transmission range of each other, and assuming that each one of them can estimate the distance that separates it from the other node (using the transmission power measurements), we can form the transmission powers triangle *(RMS).*

Logical coordinating protocol

Original Reference Node Direct neighbors coordinating

Figure 2 displays a chart for the algorithm that will be used at the begging of the direct neighbors coordinating procedure, as a start, one node is chosen as original reference node, this node will be assigned the logical coordinates (0, 0). Then another direct neighbor node will be chosen as the second original reference node, and will be assigned (x, 0) coordinates, both nodes are assumed to be on the same y-axis level which equals 0, while second original reference *x* coordinate will be the (distance from original node), now we have two reference nodes with known logical coordinates, the next step is to assign the logical coordinates for direct neighbors of those 2 reference nodes using formulas (1-5).

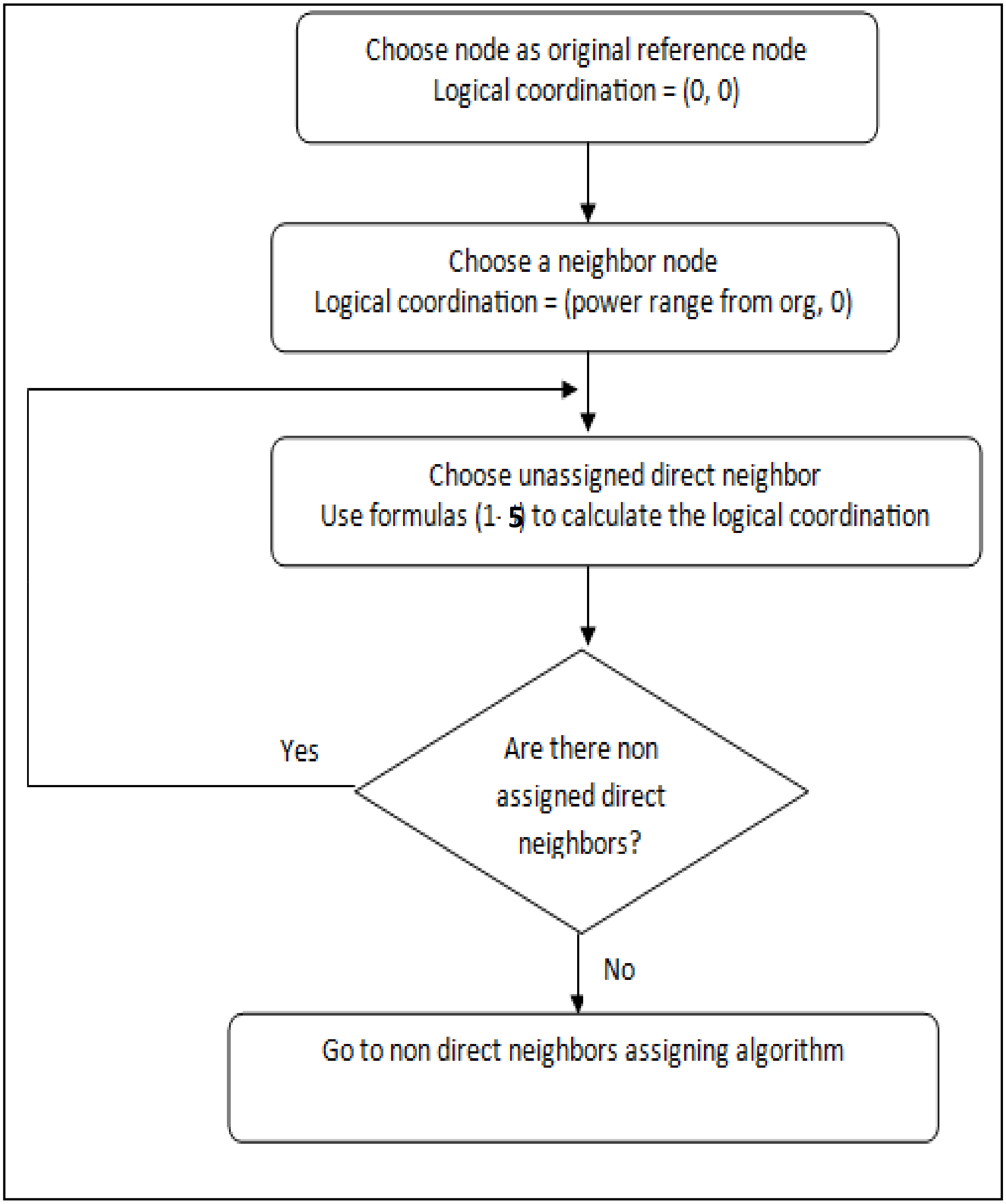


Figure 2. Finding direct neighbors coordination algorithm

Cosine law: (Lee, 1997) (Beyer, 1987) (Savvides, Han, Strivastava, 2001)

$A^2 = B^2 + C^2 - 2.B.C. \cos(\alpha)$ …………………………… (1)

From the previous equation (1) (Lee, 1997) (Beyer, 1987) (Savvides, Han, Strivastava, 2001)

$\cos \alpha = (A^2 + B^2 - C^2) / 2.A.B$ ………………….……….. (2)

From (2) we can find the angle α (Torrence, Follet, 1999)

$\alpha = A\cos(\alpha)$ ………….……………… (3)

Then to find m_x and m_y, we can use the following equation (Torrence, Follet, 1999)

$m_x = r_x + A.\cos(\alpha)$ ……….…..………… (4)

$m_y = r_y + A.\sin(\alpha)$ ……………….……… (5)

Signal Propagation problem

Though we can calculate the logical coordinates of nodes using their signal transmission power, but it is common sense, that the transmitted signal of any node propagate in a circular way around the node, and that means that a neighbor node could be anywhere in the domain (0 - 2π), the problem is that although the previous formulas can definitely find the logical coordinates of a certain node, but it can only estimate the logical coordination in a domain (0 – π), unfortunately it is unable to give the logical coordinates in a (0- 2π) domain, because formula(2) depends on the length of the triangle sides only and it cannot determine whether the node is in (0- π) domain or in (π- 2π) domain.

Figure 3 shows the problem scenario, suppose we have the nodes *m* and *m1*, where both nodes share the same distances from the reference nodes (A = A1, B = B1 and C= C), node *m1* is positioned in (π - 2π) domain, while m is positioned in (0- π) domain, in this case the previous algorithm is unable to tell whether the coordinates of *m1* are (m_{x1}, m_{y1}) or (m_x, m_y), so when applying the algorithm, both *m* and *m1* will be assigned the same logical coordinates, (m_x, m_y).

In order to solve this problem, we added a third reference node *T*, to enable us to determine the logical coordination for m, accurately. After finding the logical coordination of *m*, we can calculate the distance between *m* and *T*, using logical coordination, then calculate the distance between them using the signal transmission power, if they were relatively equal, then we will assume that the node is in the right domain (0-π), otherwise it will be on the other side of the Cartesian plane, so we will reverse *y* value to be –*y*.

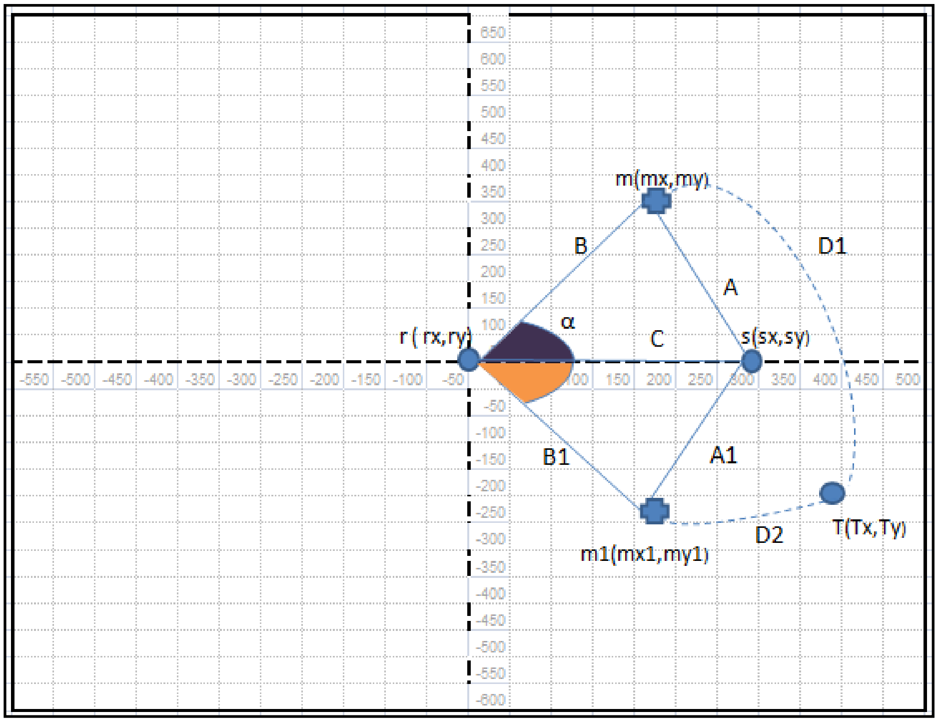


Figure 3. Finding logical coordinates in (0-2π) domain

Original reference node indirect neighbors

The next step in the protocol, is to calculate the logical location for the non direct neighbor nodes, (in reference to the original nodes), it will be difficult to calculate the transmission range, between non direct neighbor node and the original two reference nodes, so we will depend on finding other nodes to be reference nodes (Roy, chatterjee, bandyopadhyaya, uede, 2005).

If a node could not reach the transmission power of the original nodes, it will search for other nodes that have been already assigned with logical coordinates, and then it will use them as reference nodes to get its own logical coordinates.

Figure 4 presents the previous scenario, where node *m* could not reach the transmission range of the original reference nodes *(org r, org s)*, so it will search for other neighboring nodes, that have been assigned logical coordinates, supposedly they are nodes (*r* and *s*), in this scenario we cannot use the formulas (2,3,4,5) directly, because formula 4 and 5, assumes that the two reference nodes r and s are on the same y axis, while as shown in Figure 4 nodes *r* and *s* are not on the same axis, so using formulas 4 and 5, will certainly lead to inaccurate coordinating results.

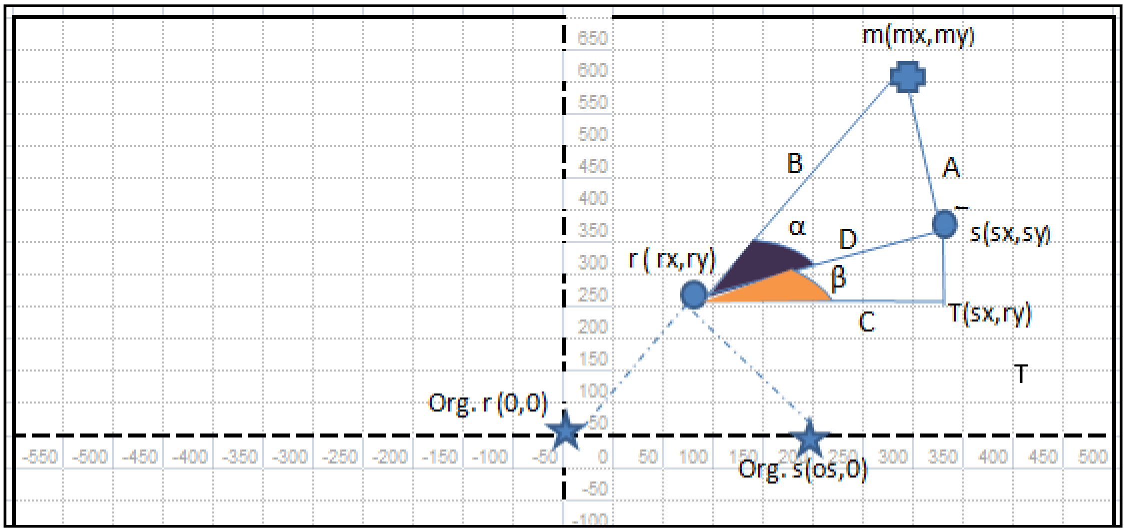


Figure 4. Non Direct nieghbors logical coordinates

To solve this problem, we will add another hypothetical point with the coordinates (s_x, r_y), that will draw another triangle (*SRT*), then we can use formulas (1-3) to find the value of the angle β as well as angle α, both angles (*α* and *β*) will be used later, to estimate the desired (mx, m_y) logical values as shown in formulas (6-11).

To find the distances D and Z we can use the distance theorem **(Torrence, Follet, 1999)**

$$D=\sqrt{(r_x-s_x)^2 + (r_y-r_y)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$Z=\sqrt{(s_x-s_x)^2 + (s_y-r_y)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Then we can find the Cosine value of angle β using formula 8:

$$Cos(\beta) = (Z^2 + C^2 - D^2) / 2ZC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$\gamma = (\beta + \alpha) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

the values of mx and my could be found using formulas (10 and 11)

$$m_x = r_x + B\cos(\gamma) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$m_y = r_y + B\sin(\gamma) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

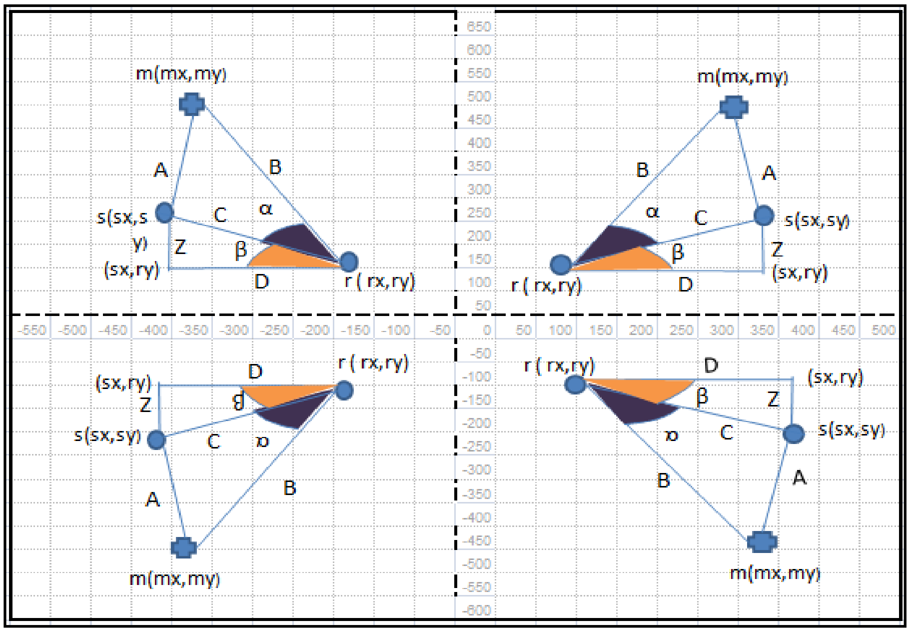


Figure 5. Various scenairos for node location

Figure 5 shows the various possible scenarios of *m* node locations on the Cartesian plane, each scenario may apply different formula in order to get its logical coordinates, after analyzing the different scenarios, we found that formulas (10 and 11) may not be the appropriate formulas to cover all possible scenarios, so we construct the appropriate formulas to be used on each case, which are formulas (12, 13).

Finding logical coordination over (0- 2π) (Torrence, Follet, 1999) (Lee ,1997) (Beyer, 1987)

$$\text{Logical } x = \begin{cases} r_x + BCos(\alpha+\beta), & r_x < s_x \\ r_x - BCos(\alpha+\beta), & r_x >= s_x \end{cases} \quad \ldots\ldots\ldots\ldots (12)$$

$$\text{Logical } y = \begin{cases} r_y + BSine(\alpha+\beta), & r_y > s_y \\ s_y - BSine(\alpha+\beta), & r_y <= s_y \end{cases} \quad \ldots\ldots\ldots\ldots (13)$$

As we mention before, each scenario should use its own formulas, for example if node m was in the domain (π- 3/2π) then we find that:

$rx > sx$, so the appropriate formula to find mx will be: $r_x - BCos(\alpha+\beta)$

$ry > sy$, so the appropriate formula to find my will be: $s_y - BSine(\alpha+\beta)$

Figure 6 summarizes the logical assignment algorithm, at the beginning each node search for the original reference node, if it did not find it, it will search for neighboring nodes that have been assigned logical coordinates, if it could find 2 nodes assigned with logical coordination, it will use them to calculate its' logical coordinates, once the node logical coordinates is calculated, it might be used by farther nodes to calculates their logical coordinates, the nodes that did not find logical coordinates will be considered as outer nodes, and will not be used in our stability consideration.

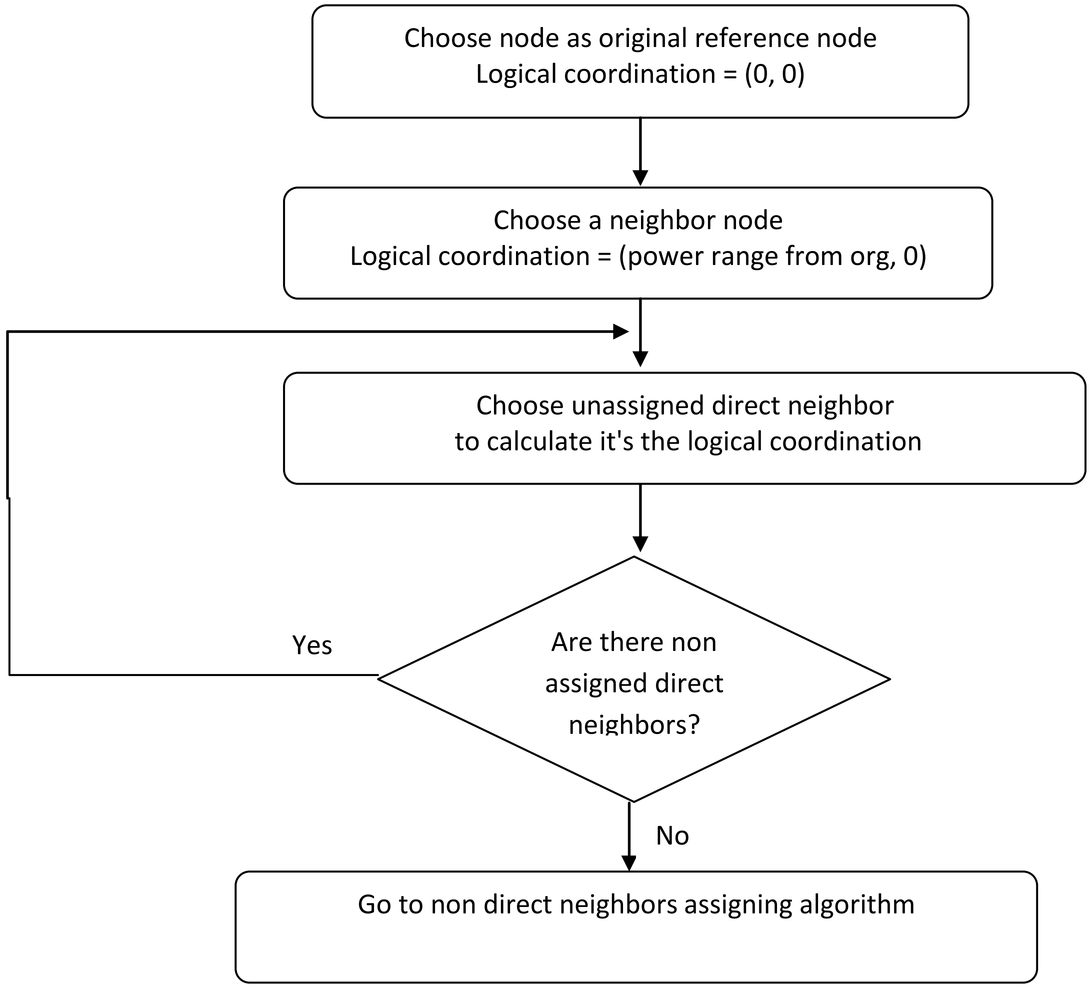


Figure 6. Finding indirect neighbors' chart

2.3.2 Number of reference nodes Vs accuracy

In this sub section, we discuss two methods to find the logical coordinates of a node, in the first method each node uses two reference nodes, in order to get its' logical coordination, while in the second method each node uses three reference nodes in order to calculate its' logical location. We will discuss both methods later in this sub section, and compare them from many perspectives.

Finding reference nodes methods

Method 1:

This method requires 2 reference nodes to assign logical coordinates to any node, using this method, each node searches for two surrounding nodes, which have already been assigned with logical coordinates, if the node is able to find 2 surrounding nodes, it will use the previous algorithm, shown in figure 6 to get its own logical coordinates.

Method 2:

This method required 3 reference nodes to assign logical coordinates instead of 2, the main idea of applying this method is to achieve more accurate results, however the third node in this method, is only used to assure the accuracy of the results, by deciding to which domain this node belong (0-π) or (π- 2π).

It is worth saying that the target node in this method, mainly depend on the existence of 2 reference nodes, to calculate its' logical coordinates, but if it was able to find third logically assigned node, it will use it to improve the accuracy of its' logical coordinates assignment, by determining the correct domain into which it belongs.

Methods comparison and discussion

It is obvious that depending on 3 reference nodes, will certainly increase the accuracy of the results, but on the other hand the probability of finding 3 reference nodes in the surrounding area is less than the probability of finding 2 reference nodes, in the following subsection we briefly document the probability of finding 2 reference nodes and the probability of finding 3 reference nodes, by recurring the probability formulas used in paper (Savvides, Han, Strivastava,2001), and provide a comparison relative to the number of nodes in the desired area.

Finding reference nodes probability

The number of nodes in a certain area plays a great role in finding the logical coordinates, because in order for a node to be able to calculate its logical coordinates it should have 2 or 3 reference nodes, and the probability of finding reference nodes increase when the number of nodes in the area increase. Now assuming the number of nodes in the area = N and the terrain size is T, the average transmission range is M and the number of required reference nodes is r.

The probability (Pl) for the target node to be within the transmission range of logically assigned node (Savvides, Han, Strivastava, 2001) is:

$$Pl = \pi M^2 / T^2 \qquad \text{……………………………………… (14)}$$

If we suppose that: (Savvides, Han, Strivastava, 2001)

$$\gamma = PlN \qquad \text{……………………………………… (15)}$$

Where γ present the result of multiplying Pl with N, then the probability of having the required number of reference nodes P(r) is: (Savvides, Han, Strivastava, 2001)

$$P(r) = 1 - \sum_{I=0}^{r-1} (\gamma^r / r!) e^{-\gamma} \qquad \text{…………………………………… (16)}$$

Table 1 displays the probability of finding 2 reference nodes against the probability of finding 3 reference nodes in a certain area, Assuming that the nodes are distributed uniformly in the area and T = 1000, M = 150, while the number of nodes = 20, 30, 40, 50, 60, 70 and 80.

Table 1. Probability of finding reference nodes

Number of nodes	Probability of finding 2 reference nodes	Probability of finding 3 reference nodes
20	0.562	0.292
30	0.774	0.537
40	0.89	0.726
50	0.949	0.849
60	0.977	0.921
70	0.99	0.96
80	0.995	0.98

As shown in Table 1, the probability of finding reference nodes increases while increasing the number of nodes in the area, and as expected, the probability of finding 2 reference nodes transcend the probability of finding 3 reference nodes. We have also developed a simulator, that calculates the logical coordination for some moving nodes in a network area, then we studied the accuracy of logical coordinates compared to the real coordinates of the nodes, the general used environmental settings in the simulation are summarized in Table 2 .

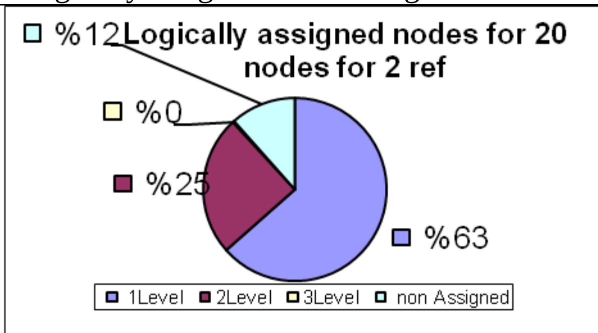
Simulation Specifications:

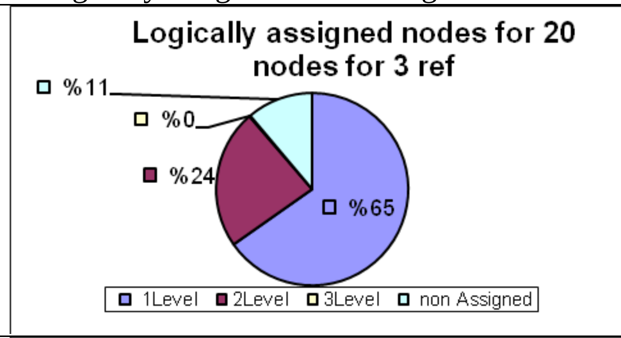
Table 2. Simulation enviromental parameters

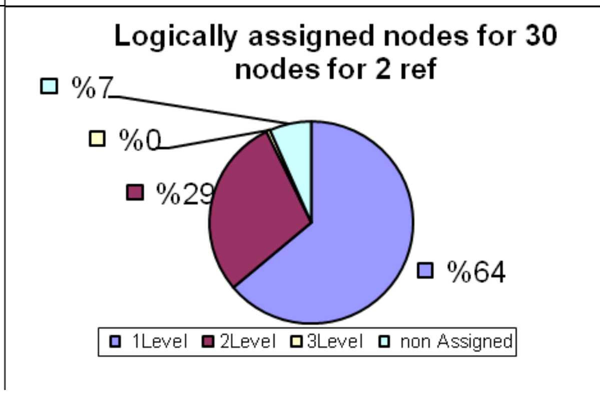
Environmental Variable	*Value*
Development Language	*C#*
Number of nodes	*20, 30, 40 and 50*
Nodes distribution	*Random*
Average nodes speeds	*(0-10) Meters/second*
Simulation run time	*50 seconds*
Average transmission range	*150 -170 Meter*
Terrain size	*900,900*

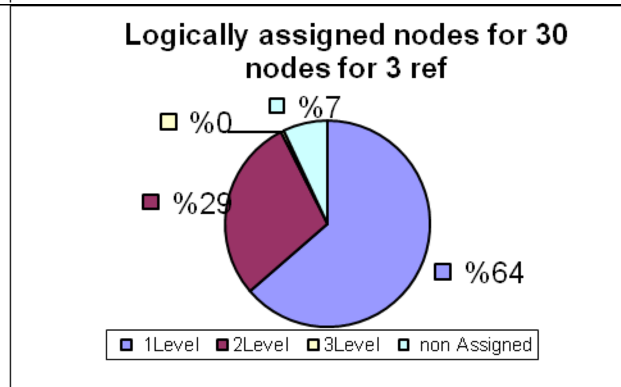
Figure 7 shows the experimental results of the simulation, each sub graph presents the average percentage of logical coordinates assignment, for the direct neighbor nodes presented in (level 1), second indirect nodes (level 2), third indirect nodes (level 3), and the percentage of un assigned nodes in the area, as the figures show, when the number of nodes increase, the percentage of unassigned nodes decrease; and that is due to the increased probability of finding reference nodes in the transmission range of each node, Figure 7 also shows that the difference in logical assignment when using 2 reference nodes and 3 reference nodes is negligible.

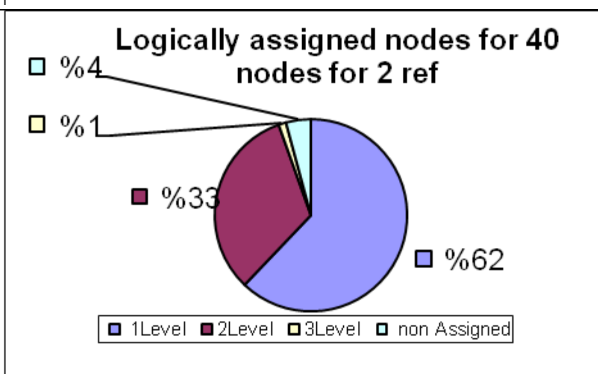
Logically assigned nodes using 2 references	Logically assigned nodes using 3 references

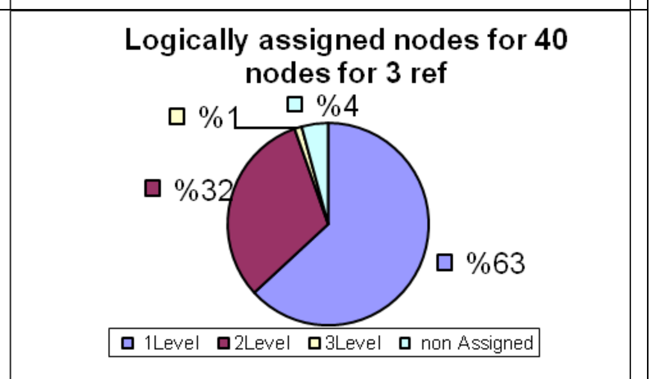


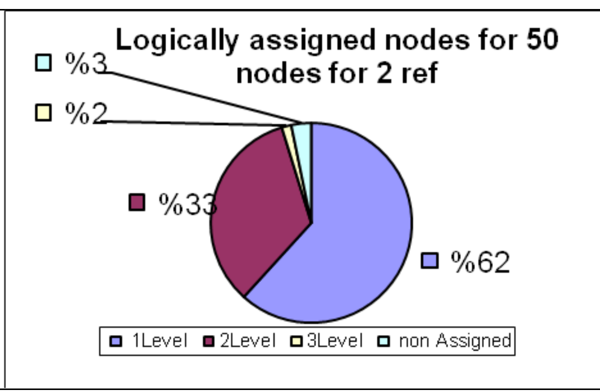












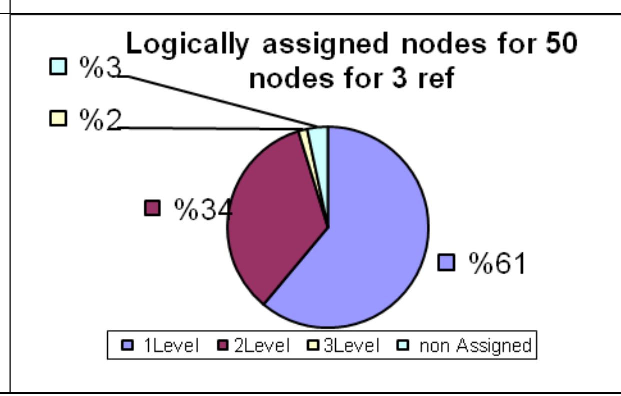


Figure 7: Nodes logical assignment using 2 and 3 reference nodes

However we also study the differences in the accuracy degree between using 2 reference nodes and 3 reference nodes, (Figure 8 and 9) show that using 3 reference nodes increase the accuracy of the results, the figures also reveal that the accuracy percentage when using 3 reference nodes, increase more and more, when the number of nodes increases, and that could be attributed to the cascaded false assignment through the neighboring levels in the area.

For example: if node A used two nodes (M, N) as reference nodes to calculate its' logical coordinates, and the node N is already assigned an incorrect logical coordinates, then certainly node A will calculate wrong logical coordinates, and that is why we highly recommend using 3 reference nodes instead of two, in order to avoid such cascaded false assignment.

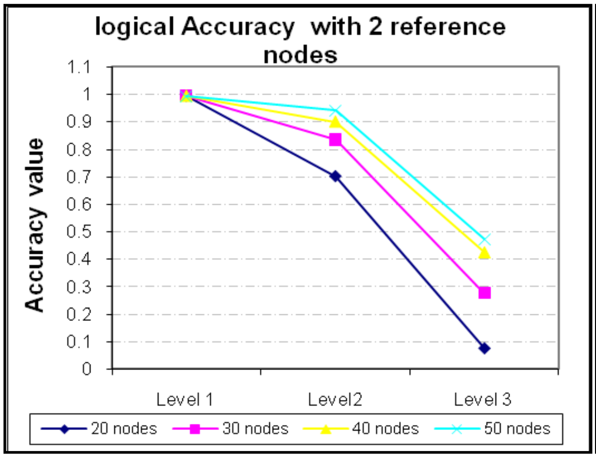


Figure 8. Accuracy percentage using 2 reference nodes

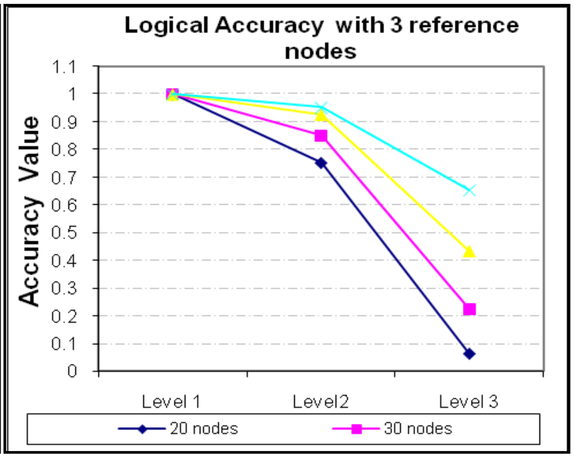


Figure 9. Accuracy percentage using 3 reference nodes

The ability to find the logical coordinates of nodes in the MANET area, provided a great assistance in figuring out nodes stability, in the following chapter we propose our stability deciding algorithm, and then we present the testing results and their discussion.

Finding Most Stable Nodes Approach

3. Finding most stable nodes approach

3.1 Introduction

From the previous stability analysis, we found that from our own perspectives, the location logical coordinating is the most appropriate way to decide the stability of nodes, since it depends on the displacement of the nodes location. However other stability parameters may be more appropriate for other researchers, but it depends on the nature of the research, and why does it need to find the most stable nodes.

In this chapter, we propose a protocol to decide the most stable nodes in an MANET area; the protocol will depend on the existence of logical coordinates for the nodes.

3.2 Finding Most Stable Nodes (MSN) protocol

As mentioned before, at the beginning of this protocol we need to decide which nodes to be the main reference node, and the second reference node. Here researchers may decide what is the most appropriate way to choose these two nodes; according to their needs and the network specifications, but we suggest using two nodes with a long historical neighborhood (association).

After deciding the main reference nodes, the coordinating algorithm should take its place, in assigning logical coordinates to the other nodes in the area; figure 10 summarizes the stability deciding protocol steps.

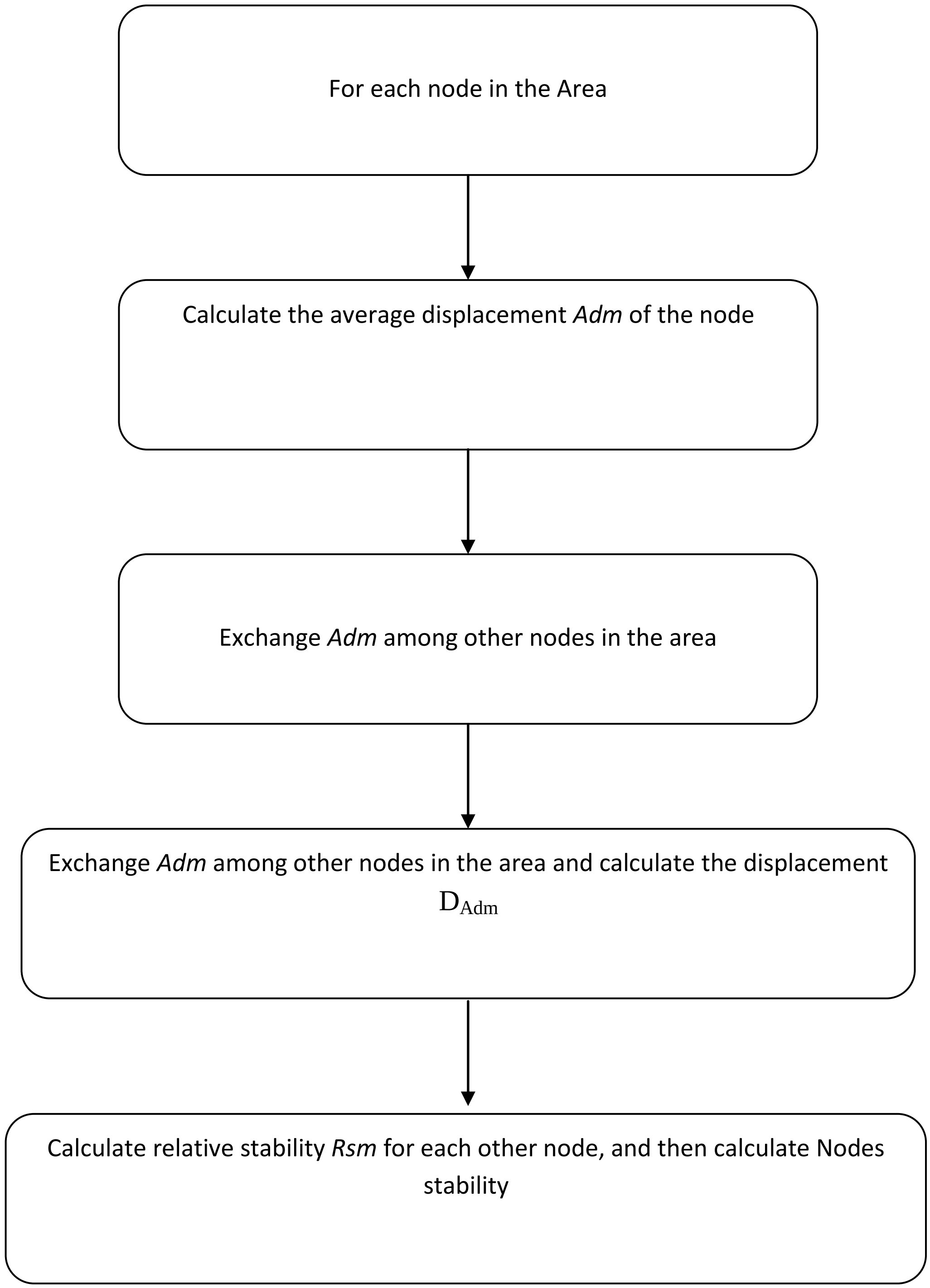


Figure 10. Finding Stability Flowchart

As shown in the figure, after applying the logical coordinating protocol, each node will calculate its average displacement periodically using formulas (17- 19), where *Adm* present the average displacement measurement.

$X_{Adm} = (X_{ts1} - X_{ts2}) / (ts_2 - ts_1)$ ……………………………….(17)

$Y_{Adm} = (Y_{ts1} - Y_{ts2}) / (ts_2 - ts_1)$ ……………………………….(18)

Where X_{Adm} is the average displacement in logical X coordination, ts_1 is the first time slot, ts_2 the second time slot, Y_{Adm} is the average displacement in logical Y coordination

$Adm = (X_{Adm}, Y_{Adm})$ ………………………………..(19)

Then the displacement of the node could be exchanged periodically among other nodes, and also here we leave choice to the researcher to choose the most appropriate exchanging protocol. Such as sending the updates periodically with the hello messages or they could be sent with the routing messages, they could be even sent with a new suggested protocol if the research requirement demands that.

Later, when any node in the area receive the displacement average of other node, it will calculate the difference between its average displacement and the other nodes average displacement using formulas (20 -22)

Calculating the displacement between nodes

$$Dx_{Adm} = (N1x_{Adm} - N2x_{Adm}) \quad \text{………………………………….. (20)}$$

$$Dy_{Adm} = (N1y_{Adm} - N2y_{Adm}) \quad \text{………………………………….. (21)}$$

$$D_{Adm} = \sqrt{(Dx_{Adm})^2 + (Dy_{Adm})^2} \quad \text{…………………………………..(22)}$$

If the value of D_{Adm} is within the acceptable range R, then N_1 relative stability vector toward N_2 will be increased as shown in formula (23)

Each node has a relative stability vector (Rsm) for each other node in the area:

$$N_1rsmN_2 = \begin{cases} N_{1\,Rsm}N_2 + 1 & , D_{Adm}N_2N_1 <= R \\ N_{1Rsm}N_2 & , D_{Adm}N_2N_1 > R \end{cases} \quad \text{…………. (23)}$$

After that, the stability vector relative to each node will increase or decrease with time, each node could calculate its stability vector periodically, which is the sum of the stability vector of all other nodes.

3.3 Finding most stable nodes Example

Example: Supposedly, there are two nodes *n* and *m* where node *m* stability vectors relative to the other nodes in the network are shown in Table 3, for example the relative stability vector between node m and node N1 = 0.23, while between m and node N2 = 0.9, etc. and node *n* has the stability vectors toward other nodes are shown in Table 4.

Table 3. Node m stability vectors

N1	0.23
N2	0.9
N3	0.2
N4	0.2
N5	-
N6	0.12
N7	0.3

Table 4. Node n stability vectors

N1	0.34
N2	-
N3	-
N4	0.23
N5	0.4
N6	0.23
N7	0.5

When the nodes calculate their stabilities the values will be:

Node m stability at t_1 = $(N_1+N_2+N_3+N_4+N_6+N_7)$ / Number of stable nodes

0.325 = (0.23+0.9+0.2+0.2+0.12+0.3) / 6

Node n stability at t_1 = $(N_1+N_4+N_5+N_6+N_7)$ / Number of stable nodes

0.34 = (0.43+0.23+0.4+0.23+0.5) / 5

With time each node in the area, will have list of relative stability vectors which could be calculated using formula (24), the node with the highest stability rate, will be a part of the most stable nodes in the area.

N stability = $\left(\sum_{i=0}^{m} Rsm\, N i\right) / m$ .... (24)

Then the list of stable nodes associated with this node could be found, and they will be the most stable nodes in the area. Figure 10 shows the (MSN) protocol flowchart, each node in the area will apply this protocol to end up with a list of most stable nodes relative to it. Also the most stable nodes in the area could be found by comparing the nodes' stability, and the node with the highest stability (N stability) vector, shall own the list of most stable nodes in the area.

Stability measurement example:

Figure 11 presents a sample for nodes movements in some area, nodes (B, M, L and Z) are moving randomly in the area, and each node of them calculate its average displacement periodically, using formulas (17-19)

For node B the average displacement will be:

$B\,x_{Adm} = (B_{x1} - B_{x2})$ and $By_{Adm} = (B_{y1} - B_{y2})$

then:

$B_{Adm} = (Bx_{Adm} , By_{Adm})$

Then node B will send its average displacement to the other nodes, and receive the average displacement of other nodes node B will calculate the displacement amount between itself and other nodes in the area. Let us suppose that the results are (DL_{Adm}, DZ_{Adm} and DM_{Adm}), for each of the previous values, if the difference was within the acceptable range R, then the node relative stability vector will increase.

In our example, nodes L and Z are almost moving same direction and within the acceptable difference range, as shown in Figure 11. So they will be considered relatively stable to node B, at the end each node will calculate its average stability and the node with the highest stability vector will be considered stable.

In Figure 11 nodes *B, Z* and *L* are almost moving in the same average direction of node B, and within the acceptable difference range, so for node B they could be considered stable. While on the other hand node M is moving to another direction, so it could not be considered relatively stable to node B, though node M may be relatively stable to another nodes in the area.

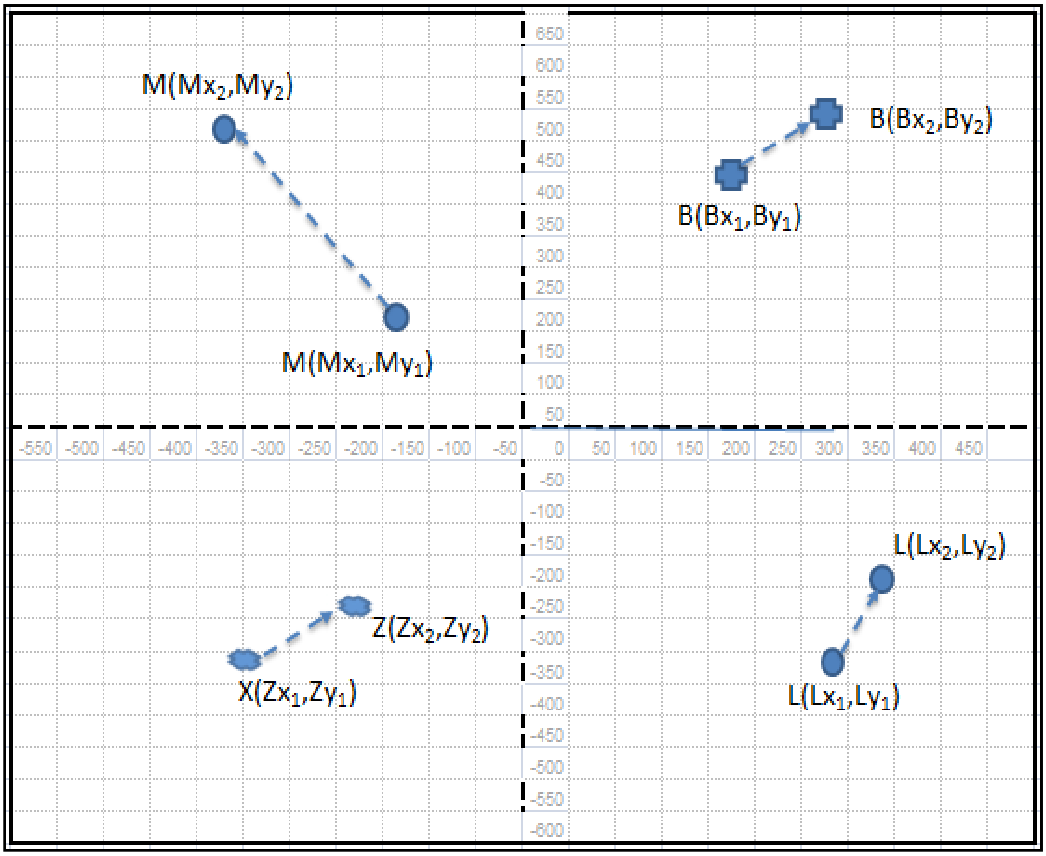


Figure 11. Nodes movement and stability measurment

The previous MSN protocol was applied on a group of nodes then its ability to discover the most stable nodes in the area was measured. The protocol results were compared to the real pre chosen stable nodes.

Results and Analysis

4. Results and analysis

4.1 Introduction

In order to study the performance and the accuracy of the proposed protocol, we developed the simulator used in (Almobaideen, Qaddoura, Sharieh, Alasir, 2007). The simulator applies a sample of moving nodes, in a pre defined area. The simulator suggests stability scenarios, and applies the MSN protocol on them, and then it compare the MSN finding protocol results, to the real stable nodes in the scenario.

In the following sub sections we present the results of our protocol accuracy; we studied the protocol ability to find the most stable nodes, under many environmental changes, which are:

- **Simulation Time:** in which we study the stability measurement duration time and its effect on the accuracy of finding MSN
- **Number of nodes in the area:** here we try to find the effect of the number of nodes in the area on the accuracy of finding MSN.
- **Periodic displacement update:** in which we study the relation between the frequency of sending the updates and the accuracy of finding MSN.
- **Average nodes speed:** here we study the effect of increasing the average speed of nodes in the area on the accuracy of finding MSN.
- **Average stable nodes speed:** this test emphasizes the effect of the average (in place movement) speed of the stable nodes on the accuracy of finding them.

- **Difference acceptable range:** which present the last factor that may affect the accuracy of the results; in this test we study the relation between the acceptable range, within which the nodes are considered stable, and the accuracy of the finding the MSN.

4.2 Testing Scenarios

The protocol ability to find the most stable nodes was tested using two scenarios. The first scenario presents a normal movement case (where some nodes are stable and the rest of the nodes move randomly in the area) and the other scenario present a hypothetical scenario, that aim to find the real ability of the protocol to find the most stable nodes in the area. The following subsections present the two scenarios and the accuracy of finding the most stable nodes associated with each of them.

4.2.1 First Scenario: Stable nodes and random movement

In the first scenario, the general movement style was random for most of the nodes in the area, except some nodes which were chosen to be the most stable nodes, and they were distributed among the area, the movement of those nodes was limited to 50 Meters radios area for each one, such scenario forms a good example for an area where some nodes are moving inside a limited area such as buildings and the other nodes are moving outside in random speeds and different directions.

Table 5, shows the common simulation environmental variables that were used when the first scenario was tested:

Table 5. First scenario stability simulation parameters

Environmental variable	*Value*
Development Language	*C#*
Number of nodes	*40*
Nodes distribution	*Random*
Non stable nodes speed	*(10-20) Meters/second*
Stable nodes speed	*(0,6) Meters/ second*
Simulation run time	*70 seconds*
Average transmission range	*150 -170 Meter*
Terrain size	*900,900*
Periodic update time	*5Seconds*
Difference acceptable range	*20 Meter*
Number of Runs for each measurement point	*30 times*

We have applied this scenario, and studied the previously mentioned factors effect on the accuracy of the suggested protocol. The problem of this scenario is that the random movement of nodes, in the area might lead to the formation of another group of stable nodes, which cannot guarantee that the chosen group of stable nodes is always the most stable group of nodes. So we suggested the second scenario, which tend to decrease the probability of stable nodes groups formation.

4.2.2 Second Scenario: Stable nodes and surrounding in range nodes movement

Figure 12 presents the second scenario, where there are some stable nodes (F, E, D and S) which are moving in limited area (the small solid circles). While the star shaped nodes move in the dashed circular area, surrounding node D. The triangular shaped nodes move within the dashed circular area surrounding node E, the cross shaped nodes move within the dashed circular area surrounding node S and the small circular nodes moving within the dashed circular area surrounding node F.

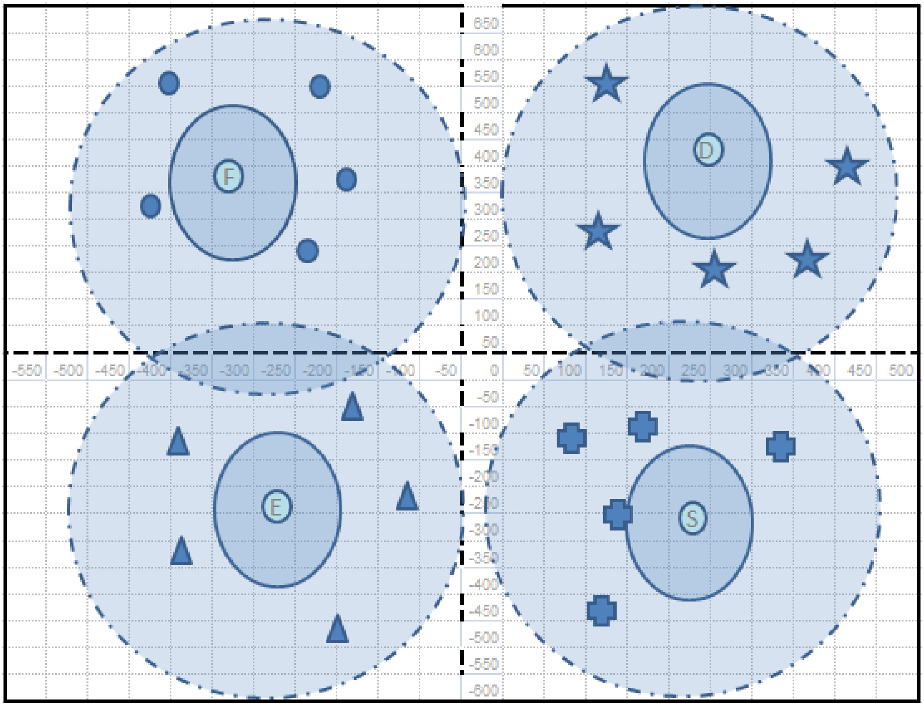


figure 12. Second Scenario of nodes movement

In this scenario triangular shaped nodes for example are considered neighbors to node F most of the time. While they may not be neighbors for each other all of the time, the same idea is also applied to the star, cross, and circular shaped nodes in their areas. A star node may also be neighbored to a cross, triangle or circular shaped node at any moment, However this relation is not supposed to last for too long, because they might move away from each other, so this scenario decrease the probability of finding other stable groups in the area.

The common used parameters in this scenario are show in Table 6:

Table 6. Second Scenario common used parameters

Environmental Variable	*Value*
Development Language	*C#*
Number of nodes	*40*
Nodes distribution	*Random*
Non stable nodes speed	*(10-20) Meters/second*
Stable nodes speed	*(0,6) Meters/ second*
Simulation run time	*70 seconds*
Average transmission range	*150 -170 Meter*
Terrain size	*900,900*
Periodic update time	*5 Seconds*
Difference acceptable range	*30 Meter*
Number of Runs for each measurement point	*30 times*
Inner stable nodes moving range	*30 Meters*
Surrounding nodes movement range	*200 Meter*

4.3 Testing Factors Affect on the accuracy of the MSN Finding

In this subsection, we have applied the previous testing factors, on the two scenarios and analyzed the protocol ability to find the most stable nodes in the area, under the changing values.

4.3.1 Simulation Time and Number of nodes

Simulation time

The MSN finding protocol depends on the historical stability of the nodes, so it needs time in order to decide the most stable in the area. Figure 13 shows the accuracy o finding the most stable nodes in the area relative to the simulation time, the results of the simulation shows that at the 10^{th} second the results accuracy did not exceed 10%, because the periodical updates was sent every 5 seconds, which mean that the results were extracted after two updates only, and that did not give the protocol enough time to decide the real stable nodes, but as shown in the figure the accuracy of the results kept increasing with time.

Figure 13.A present the first scenario where the nodes where moving randomly. The accuracy of the results was higher than the second scenario results. And that could be attributed due the difference in the movement form between the two scenarios: in the first scenario the random movement of the nodes, increased the probability of finding the most stable nodes at simulation time equal 10 seconds, because the non stable nodes, might have moved away from each other, but in the second scenario the circular movement of the nodes gave them the chance to stay neighbors for a longer time, but with time they moved away from each other, leaving the space for real stable nodes to be discovered and considered more stable.

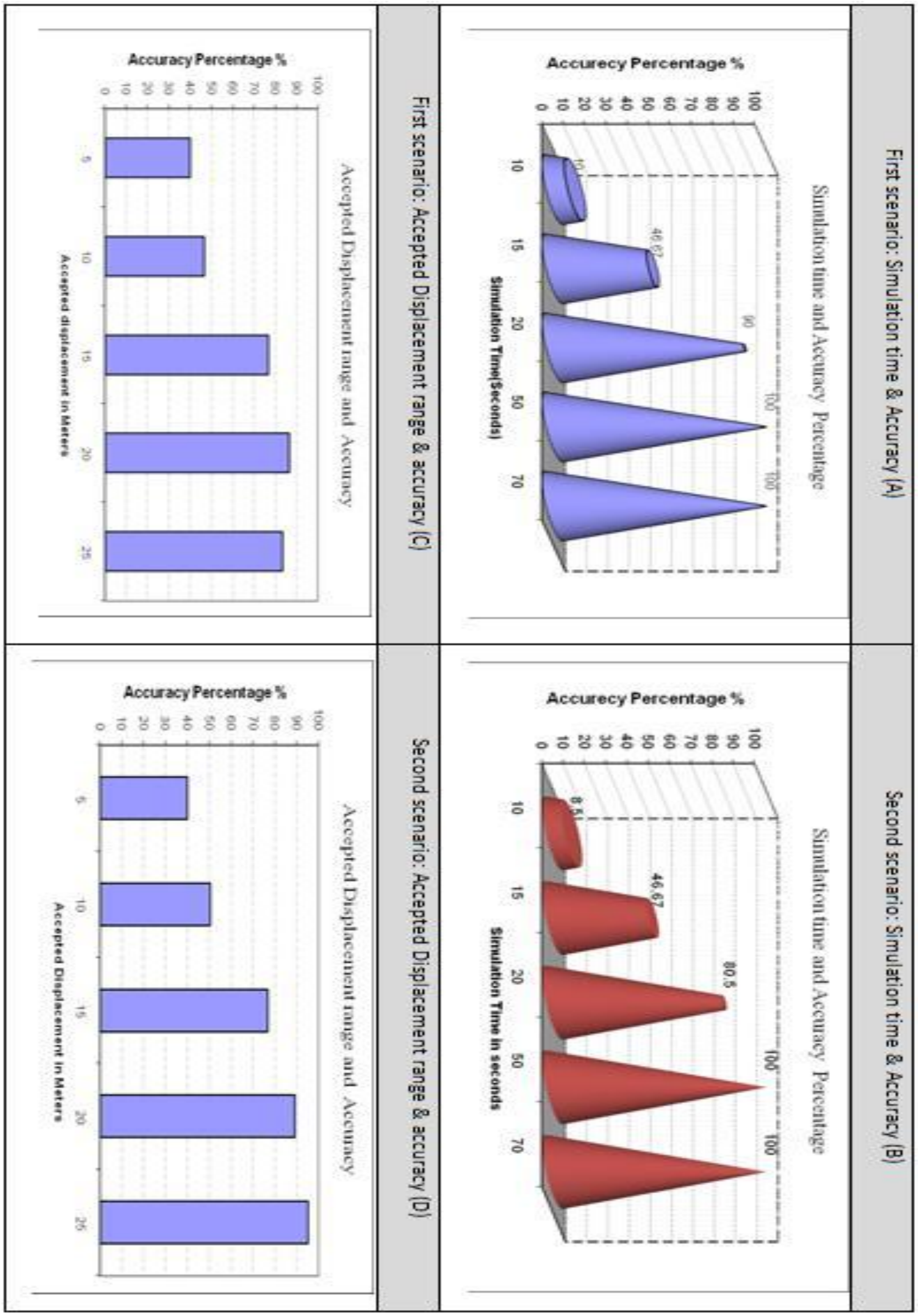


Figure 13: Simulation Time and Accepted Displacement

Periodic displacement update

Sending the periodical updates for each node displacement, affect the performance of the network by increasing the overhead of message transmission. But as mentioned earlier the researcher may choose the suitable transmission strategy according to his needs. Figure 13 shows the effect of increasing the number of periodic updates sent per unit of time, on the accuracy of the MSN finding protocol. Both scenarios revealed a decreased ability in finding the most stable nodes, when the number of sent update with a limited time decrease, however in the second scenario, Figure 13.D, the chosen stable nodes remain stable during the simulation time, but the other nodes are moving so often away from each other, and they cannot stay neighbors for a long time, which increased the accuracy of the results compared to the first scenario, shown in Figure 13.C.

4.3.2 Average speed for both stable and non stable nodes

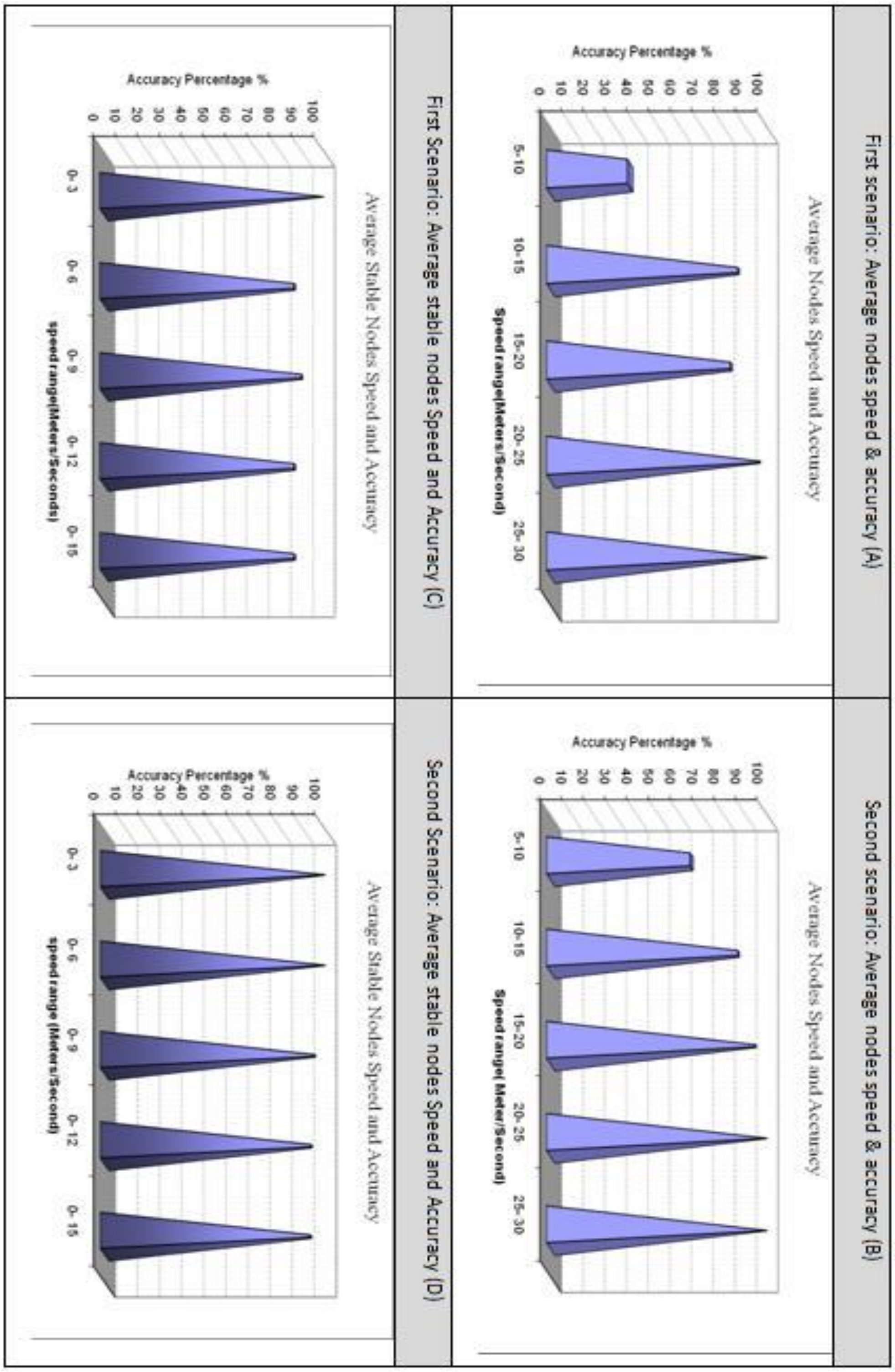


Figure 14. Average speed for stable and non stable nodes

Average nodes speed and Average Stable nodes speed

Another factor that plays an important role, in deciding the nodes stability, is the average movement speed of the surrounding nodes. It will be much easier to figure out which are the stable nodes among higher speed moving nodes, than slowly moving nodes because when all the nodes are moving slowly it will be hard to decide the most stable nodes among them, unless the stability measurement is activated for a long time, which will give the MSN finding protocol the ability to decide which are real the stable nodes

The random movement of the nodes in first scenario, shown in Figure 14.A, increased the accuracy of finding the most stable nodes when the speed of the number of surrounding nodes increased. At speed (5-10) M/s the nodes were moving almost at the same speed as the stable nodes, which made it difficult for the protocol to decide the real stable group of nodes among the whole number of nodes, but with the increased speed of the surrounding nodes, the stable nodes was found much easier.

The ability of finding the most stable group of nodes increased more under the second scenario, because the neighborhood relation between non stable nodes were broken faster due to their circular movement.

On the other hand if we increased the average speed of stable nodes more, the ability of finding the most stable nodes decreased, as shown in Figure 14.C because the protocol considered them less stable that they really are, due to the same reasons discussed before.

4.3.3 Number of nodes and the number of periodic updates

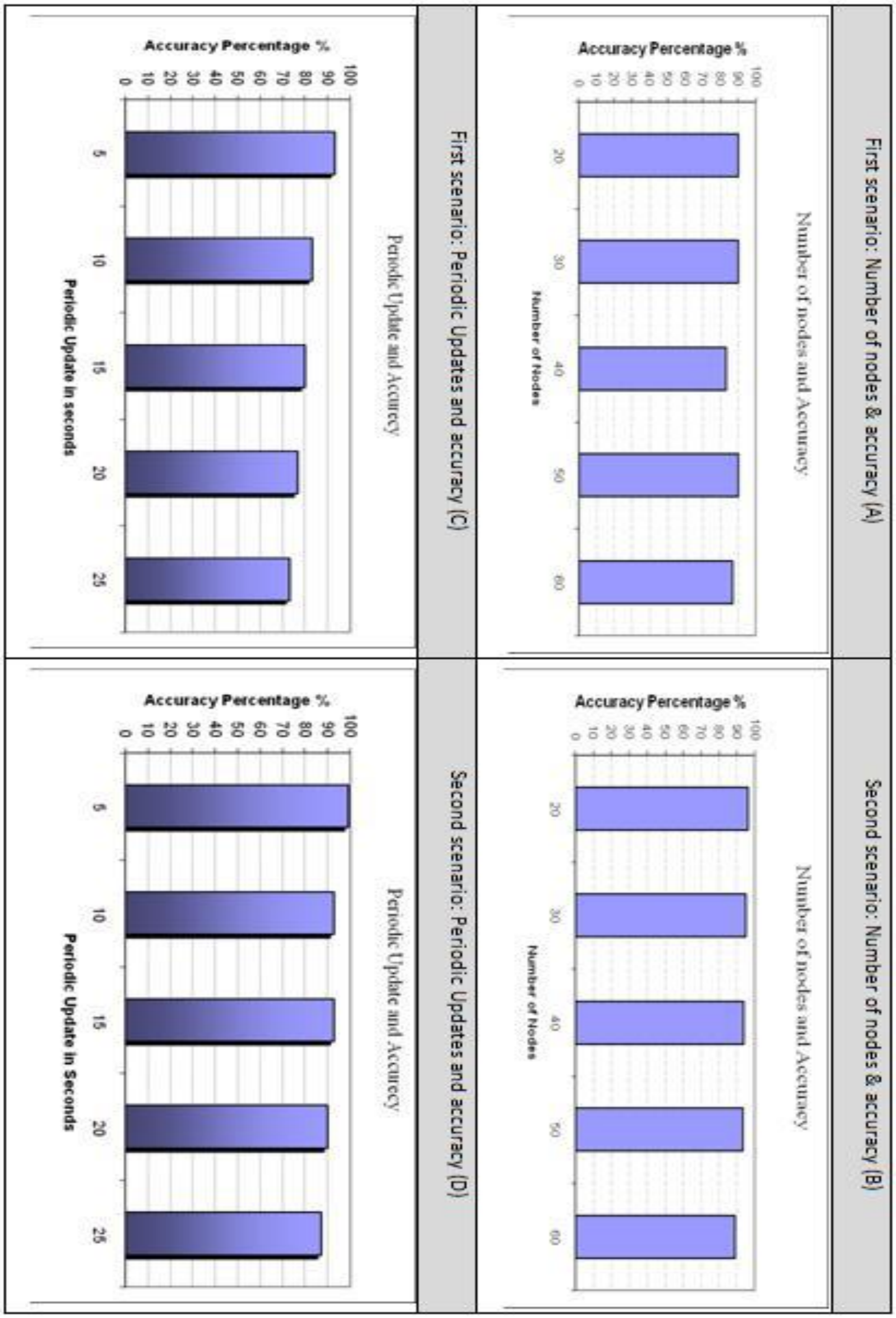


Figure 15. Number of nodes and periodic updates

Number of nodes in the area

Another factor that may affect the MSN finding protocol is the number of nodes in the simulation area, Figure 15 shows the accuracy of the MSN finding protocol results, tested using the first scenario. The random movement of the nodes increased the probability of forming another stable group of nodes which might have been considered more stable than the chosen group that is why the results of the testing scenario did not reveal any obvious relation between the number of nodes and the accuracy of the results.

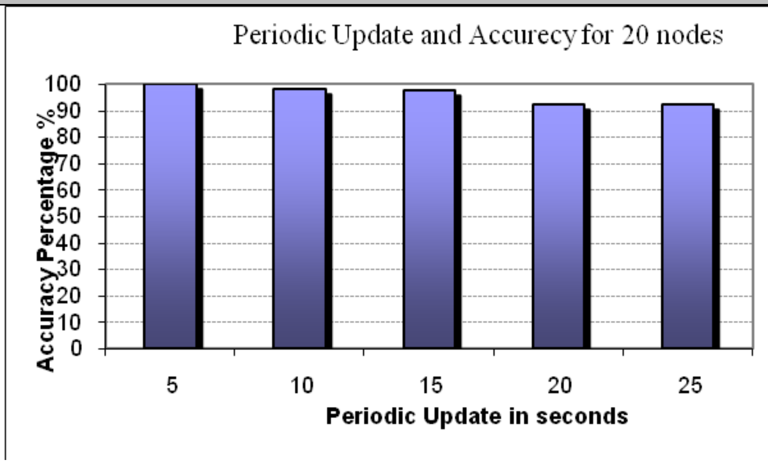
The nature of nodes movement, in the second scenario, keeps the nodes moving in a circular away around the stable nodes, when the number of nodes increase more and more nodes will move in a limited area, and that may lead to another stable nodes group formation, which might be considered more stable in the MSN finding protocol, so the accuracy of the results decreased when the number of nodes increased in the area, however the accuracy percentage did not decrease very much even when the number of nodes reached 60 nodes in the area.

Number of periodic updates

Sending the periodical updates for each node displacement, affect the performance of the network by increasing the overhead of message transmission. But as mentioned earlier the researcher may choose the suitable transmission strategy according to his needs. Figure 15.C shows the effect of increasing the number of periodic updates sent per unit of time, on the accuracy of the MSN finding protocol. Both scenarios revealed a decreased ability in finding the most stable nodes, when the number of sent update within a period of time decrease, however in the second scenario, Figure 15.D, the chosen stable nodes remain stable during the simulation time, but the other nodes are moving so often away from each other, and they cannot stay neighbors for a long time, which increased the accuracy of the results compared to the first scenario.

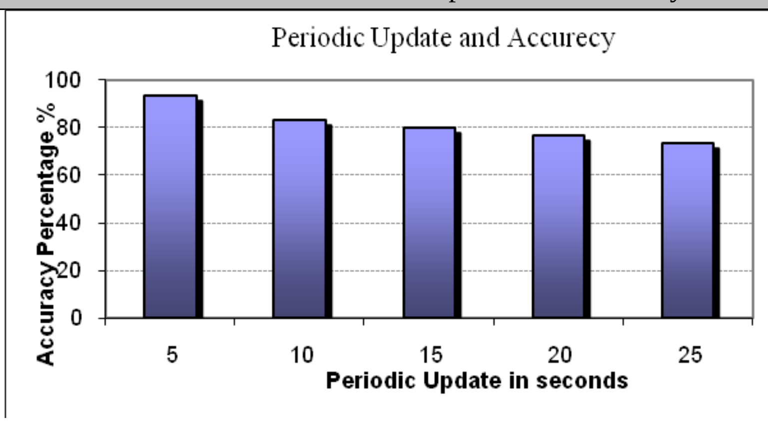
The number of periodic updates under the first scenario was also tested when the number of nodes in the area increases. The tests were applied using 20, 40 and 60 nodes moving within a limited area which equals to (900 X 900) meters, the testing results revealed that the accuracy of MSN finding protocol decrease when the number of nodes increase in the area, especially when the number of updates decrease, as shown in figure 16, the figure discusses the results of each test.

Periodic Updates and accuracy for 20 nodes



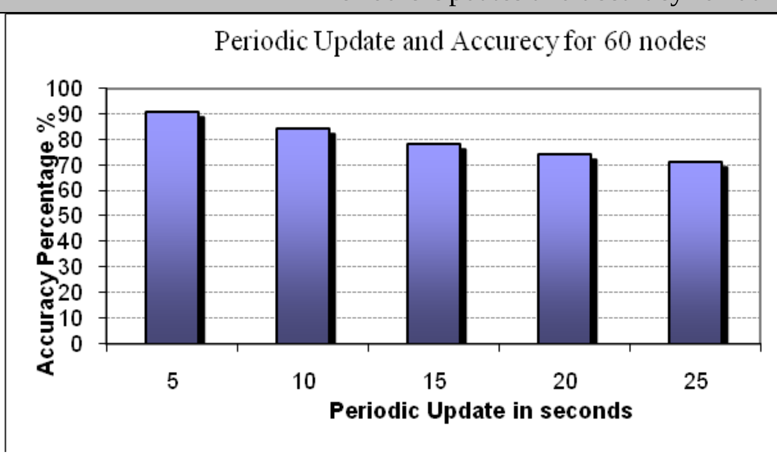
The first scenario present the results accuracy when running the simulation using 20 nodes, the low number of nodes, allowed the protocol to discover the most stable nodes easily because the number of the rest of nodes is small and they move faster than the stable nodes.

Periodic Updates and accuracy for 40 nodes



The second scenario presents the results accuracy when running the simulation using 40 nodes, when the number of nodes increased the probability of forming more stable nodes groups increased which decreased the accuracy of the results

Periodic Updates and accuracy for 60 nodes



The last testing scenario used 60 nodes, which increased the probability of forming more stable groups if we considered that in the three scenarios (20,40 and 60) the terrain size was limited, so the probability that moving nodes become neighbours is more likely in this scenario

Figure 16. Accuracy and periodic updates when the number of nodes increase

The results of the simulation revealed the ability of MSN finding protocol. In the first scenario the random movement of nodes made it hard to decide whether the protocol was un able to find the real group of stable nodes or there was another group of nodes which has been formed during the simulation, due to the nodes random movement, while in the second scenario the circular movement of nodes, made the test more reliable, because it decreased the ability to form long terms of stable nodes, other than the chosen ones.

Summary and Conclusions

5. Summary and Conclusions

In this thesis we suggest a new protocol, to find the most stable nodes in an MANET area. From our perspectives we found that in order to discover such nodes, we need to locate the nodes in the area. But the lack of infrastructure made it difficult to give real coordinates to the nodes in the area, so we went through many other related protocols, which tried to locate the nodes. Unfortunately we found that most of these protocols relied on some other helping techniques such as GPS systems and directional antennas.

So we suggested a new protocol to find the logical coordination of the nodes in the area. In this protocol we studied two coordinating methods, the first one required two direct reference nodes, in order to assign each node a logical coordination, while the other method required the existence of at least two direct reference nodes while if there was a third node it will be used to ensure the accuracy of the logical coordination assignment. In the research we discussed the accuracy of using each method, and then we chose the second method to be the base of the MSN finding protocol as it was able achieves more accuracy in the logical coordination assignment.

After locating the nodes in the area, we proposed the MSN finding protocol, which depended on calculating the average displacement of the nodes in the area, which will be periodically exchanged between the nodes in the area. The protocol enabled each node to find the most stable nodes relative to it, where this type of information could be used by the nodes in many aspects such as finding the best route, the most stable route, electing cluster head, and many other benefits.

The other facility the protocol provided is to predict the most stable group of nodes, in the area; those nodes could be used as a backbone for the network or could be elected as cluster heads.

At the end the protocol ability to find the most stable nodes in the area was tested, by suggesting some stability scenarios, where the stable nodes are pre known, and the results of the protocol were compared to the real chosen stable nodes.

We tested the MSN finding protocol accuracy over many affecting factors, such as the total stability discovery time. The results revealed that the accuracy of the protocol increase with time, because the stability measurement protocol relied on the historical average stability of each nodes, so with time it become more obvious which are the most stable nodes among the moving nodes.

The second factor was the number of nodes in the area, which formed an inverse relation, the more the number of nodes, the less the accuracy of the results. However the accuracy percentage decreased in the second scenario so slowly in a percent that did not exceed 3%. We assume that the reason of the decreased percentage in accuracy was because the probability of forming relative stable nodes groups in the area increase when the number of the nodes increases and those groups might be more stable that the pre chosen group.

The third factor was the number of periodic displacement updates during the simulation time. The results of this test showed that the smaller the updates exchanging intervals, the higher the accuracy percentage. In our test when the updates exchanging were done every 5 seconds, the accuracy of finding the most stable nodes reached 99.9%.

The fourth factor was the speed of unstable nodes in the area, where the results revealed that the faster the nodes are, the more accurate the results are. The testing results also showed that when the average difference between the stable nodes speed and the other nodes speed reached 14% the algorithm was able to find the most stable nodes perfectly. The fifth factor was the inverse of the fourth one. In the fifth test we studied the effect of increasing the stable nodes speed on the accuracy of the results, and here the results also showed that when the difference in speed between the stable nodes and the none stable nodes reached 14% the protocol was able to find the stable nodes perfectly. While when the stable nodes were moving in the same average speed of the non stable nodes the accuracy of the results was 90%.

The last factor we studied was the effect of the acceptable range of displacement between each two nodes. Where we assume that it is a very important factor, when deciding the degree of required stability; the less the acceptable range the less the ability of the protocol to decide which are the most stable nodes. Where in the other hand we found that when the acceptable range reached 25 meter the protocol achieved a higher ability in deciding the most stable nodes, and that was because the range of stable nodes movement was a radius equal to 30 meters.

REFERENCES

Almobaideen, Wesam Qaddoura, Emad Sharieh, Ahmad and Alasir, Shatha **(2007)**," **Distance Granularity Effect on MANET's Simulation**", 4th International Conference: Sciences of Electronic, Technologies of Information and Telecommunications, IEEE (France), pages: 201-207.

Basu Prithwish Khan, Naved and Little. Thomas **(2001)** "A Mobility Based Metric for Clustering in Mobile Ad Hoc Networks", **Proceedings of the 21st International Conference on Distributed Computing Systems Workshops** (ICDCSW .01), pages: 413 - 418.

Beyer, W. H **(1987)**." **CRC Standard Mathematical Tables",** 28th ed. Boca Raton, FL: CRC Press, pages: 148-149.

Cottin, Nathanael and Wack, Maxime **(2009)** "**Dynamic Registration and discovery of Location-Based Services Using Spatial Registries",** Proceedings of the 3rd workshop on Agent-oriented software engineering challenges for ubiquitous and pervasive computing, pages 33-38

Cao Qing and Abdelzaher Tarek **(2006), "Scalable Logical Coordinates Framework for Routing in Wireless Sensor Networks",** ACM Transactions on Sensor Networks, Vol. 2 (4) pages: 557 - 593

Er, I.I. and Seah, W.K **(2004)** "**Mobility-based d-Hop Clustering Algorithm for Mobile Ad Hoc Networks",** Vol. 4, page: 2359- 2364

Gerharz, Michael de Waal, Christian Martini, Peter and James, Paul **(2003)** "**Strategies for Finding Stable Paths in Mobile Wireless Ad Hoc Networks"**, Proceedings of the 28th Annual IEEE International Conference on Local Computer Networks (LCN'03) pages: 0742-1303.

Kumar, D. Aseri, T. and Patel, R. **(2009)**, "**EECHE: Energy-Efficient Cluster Head Election Protocol for Heterogeneous Wireless Sensor Networks**", Proceedings of the International Conference on Advances in Computing, Communication and Control, Pages 75-80

Khetrapal Ankur, (2006) "**Routing techniques for Mobile Ad Hoc Networks Classification and Qualitative/Quantitative Analysis**", (ICWN' 06), proceedings of the 2006 international conference on wireless networks, pages: 251-257

Lim, Geunhwi Shin, Kwangwook Lee, Seunghak Yoon H. and Soo, Ma Joong, **(2002)** "**Link Stability and Route Lifetime in Ad-hoc Wireless Networks**", (ICPPW'02) Proceedings of the International Conference on Parallel Processing Workshops, pages: 1530-2016

Meghanathan Natarajan **(2007)**," **Stability and Hop Count of Node-Disjoint and Link-Disjoint Multi-Path Routes in Ad Hoc Networks**", Third IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob 2007) pages: 42-42.

Qaddoura, Emad AlMobaideen Wesam, and Omari Ahmad, (2006) "**Distributed Clusterhead Architecture for Mobile Ad Hoc Networks,** Journal of Computer Science Vol. 2 (7), Pages: 583-588.

Roy, Siuli Chatterjee, Sanjay Bandyopadhyay, Somprakash, Ueda, Tetsuro Iwai, Hisato and Obana, Sadao **(2005)**, **"Neighborhood Tracking and Location Estimation of Nodes in Ad hoc Networks Using Directional Antenna: ATestbed Implementation",** Ad Hoc Networks Research & Applications Group WirelessCom, Accepted in WirelessCom.

Savvides A., Han C. and Strivastava B. **(2001)**, **"Dynamic fine grained localization in ad-hoc networks of sensors"**, Proceedings of the 5th International Conference on Mobile Computing and Networking, Mobicom, Rome, Italy, July 2001 pages: 166-179.

Soc, Math. Ed, Ser **(1997)**, "**The Law of Cosines in a Tetrahedron**". B: Pure Appl. Math. 4, pages: 1- 6.

Torrence Eve and Follett Bruce, **(1999) The Student's Introduction to Mathematica** Cambridge University Press. ISBN 0521594618.

Wu, Zhengyu Song, Hantao Jiang, Shaofeng and Xu**,** Xiaomei **(2007)** "**Grid-based Stable Backup Routing Algorithm in MANETs",** International Conference on Multimedia and Ubiquitous Engineering (MUE'07), pages: 680 - 685.

اكتشاف أكثر الأجهزة اللاسلكية استقرارا في الشبكات اللاسلكية العشوائية

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ملخص

نظراَ لسهولة إنشائها و مرونتها تعد الشبكات اللاسلكية العشوائية إحدى التقنيات الواعدة و الآخذة بالانتشار وسط أنظمة الاتصال الحديثة. بعد دراسة مكثفة لطبيعة هذه الشبكات و أهميتها، هدِفنا في هذه الرسالة لإيجاد بروتوكول قادر على اكتشاف و تحديد أكثر الأجهزة اللاسلكية استقرارا في مكانه.
الفكرة الأساسية من إيجاد هذا البروتوكول هو تحسين أداء الشبكات اللاسلكية العشوائية عن طريق تقليل المشاكل الناتجة عن عدم وجود إدارة مركزية فيها.
إن إيجاد أكثر الأجهزة اللاسلكية استقرارا يمكن أن يساعد الباحثين في تحسين أداء البرتوكولات التي يقومون بطرحها، مثل تصميم بروتوكولات التوجيه، بناء الشبكات العنقودية و توزيع قواعد البيانات و المزيد من البروتوكولات الأخرى.بهدف إيجاد أكثر الأجهزة استقرارا قمنا بدراسة الخصائص و الصفات الأساسية التي يتم على أساسها تحديد مستوى الاستقرار للأجهزة، حيث وجدنا أن أكثر الخصائص استخداما هي مدة الارتباط بين الأجهزة و المواقع المنطقية لها. في هذه الرسالة فضلنا استخدام المواقع المنطقية حيث أنها توفر رؤية أفضل في تحديد أكثر الأجهزة استقرارا.
في بروتوكول حساب المواقع المنطقية المطروح قمنا باقتراح طريقتين لحساب المواقع ثم دراسة مدى صحة البيانات الناتجة عن استخدام كلتا الطريقتين، من ثم اختيار الطريقة الأنسب. بعد ذلك قمنا باقتراح البروتوكول المسئول عن اكتشاف أكثر الأجهزة استقرارا في المنطقة المطلوبة. هذا البروتوكول يعتمد بشكل أساسي على حساب المواقع المنطقية للأجهزة، ثم حساب مقدار التغير في المواقع و تبادل هذه المعلومات في ما بينها لحساب أكثر الأجهزة استقرارا.

لقد قمنا بعد ذلك بتحليل قدرة البروتوكول على إعطاء نتائج صحيحة عن طريق مقارنة مجموعة الأجهزة التي اختارها البروتوكول كأكثر الأجهزة استقرارا مع المجموعة الحقيقة من الأجهزة الأكثر استقرارا و التي تم اختيارها مسبقا بطريقة يدوية. أثناء اختبار قدرة البروتوكول على اكتشاف أكثر الأجهزة استقرارا تمت دراسة مجموعة من العوامل التي من شأنها التأثير على النتائج و منها: مدة التجربة، عدد الأجهزة في المنطقة، مقدار تبادل التحديثات لمواقع الأجهزة، سرعة الأجهزة العادية ، سرعة الأجهزة الأكثر استقرارا و نسبة الاختلاف في المواقع المسموح بها لاعتبار أي جهازين مستقرين.