ABSTRACT

CO-OPERATIVE LOCATION UPDATES FOR MOBILE NODES FOR CELLULAR NETWORKS

by
Samir Shah

In current pure cellular networks, each and every mobile node updates it's location to the particular base station separately following certain algorithms, say timer based, mobility based or both. For the next generation wireless networks, which we can consider as a highly dense network, such location update algorithms prove to be very costly in the terms of overall location update traffic to the base station and average battery usage by each mobile node for location updates due to large number of mobile nodes for particular base station area.

Instead of using such one-to-one link for location updates, this report describes a new algorithm called 'Co-operative Location Updates' - in which many mobile nodes give their location details to one neighboring node and that node gives information to the base station. In this way, the traffic congestion to the base station due to location updates can be reduced drastically and also at the same time the average battery power used by the mobiles for location updates can be increased. Finally the work is proved by showing view graphs in the results section.

CO-OPERATIVE LOCATION UPDATES FOR MOBILE NODES IN CELLULAR NETWORKS

by

Samir Shah

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Electrical Engineering

Department of Electrical and Computer Engineering

August 2003

APPROVAL PAGE

CO-OPERATIVE LOCATION UPDATES FOR MOBILE NODES FOR CELLULAR NETWORKS

Samir Shah

Dr. Sirin Tekinay, Thesis Advisor — Date
Associate Professor, Department Electrical and Computer Engineering, NJIT

Dr. Papavassiliou Symeon, Committee Member — Date
Assistant Professor, Department of Electrical and Computer Engineering, NJIT

Dr. Cem Saraydar, Committee Member — Date
Research Associate, Department of Electrical and Computer Engineering, NJIT

Blank Page

BIOGRAPHICAL SKETCH

Author: Samir K. Shah

Degree: Master of Science

Date: Spring 2003

Date of Birth:

Place of Birth:

Undergraduate and Graduate Education:

- Master of Science in Electrical Engineering
  New Jersey Institute of Technology, Newark, NJ, 2003

- Bachelor of Science in Electrical Engineering,
  Sardar Vallabhbhai Regional Engineering College, Surat, India, 2000

Major: Electrical Engineering

This thesis is dedicated to
my parents, brother and sisters for giving me love, encouragement and support

ACKNOWLEDGMENT

I would like to express my deepest appreciation to Dr.Sirin Tekinay, my research advisor, who provided valuable, and countless resources and insight. I would like to thank Dr.Symeon Papavassiliou and Dr.Cem Saraydar for giving their valuable time to judge my work as committee members in thesis defense. I am very much thankful to Mr.Woo-Jin Choi for giving constant assistance and direction even though he was busy in his own PhD research work. In addition I would like to express my deepest gratitude to all my friends who helped me in one way or the other through out this period.

TABLE OF CONTENTS

Chapter **Page**

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

In this chapter general concept of typical mobile communication system, such as cellular networks is discussed. An overview of mobile ad-hoc wireless system is followed by a short explanation of major challenges faced by current implementations of pure cellular networks. This discussion helps in understanding the core interest – location update algorithms - behind this research work.

1.2 Cellular Networks

A typical mobile communication system, cellular network, mainly consists of mobile stations, base stations and a central controller which is known as mobile switching center. Each mobile communicates via radio with one of the base stations, in most of the cases it is the nearest base station to the mobile, and may be handed off to any other base station during the duration of the call. Such hand over is required under many circumstances such as low receiving signal strength at the mobile station or a change in location area by a mobile station. The base station serves as a bridge between all the communicating mobiles in the cell and connects simultaneous mobile calls through telephone lines, satellite links, microwave links or any other means to the mobile switching centers (MSCs). The MSC coordinates the activities of all the base stations and connects the whole cellular communication system to the public switch telephone networks (PSTN). Figure 1.1 gives an overview about a typical cellular communication system.

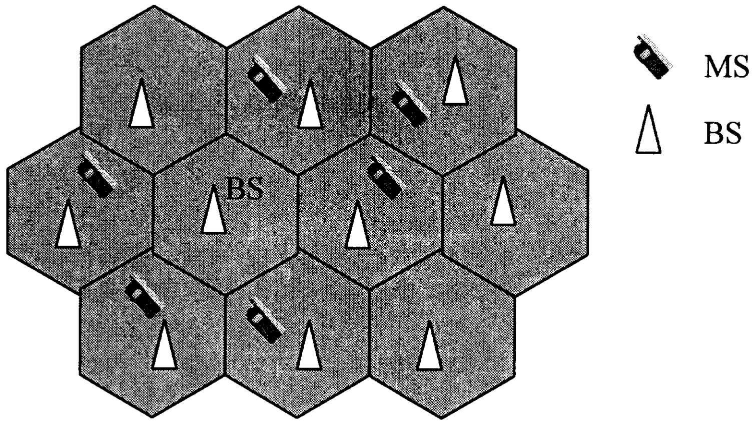

Figure 1.1 Typical Cellular Network.

Location registers also play important roles which are in the upper layer to the mobile switching centers. Location registers store location related information about each and every mobile in the network and provides this information to MSC when needed. Location registers get such information from each mobile time to time depending upon certain algorithms through base stations and mobile switching centers. Location update algorithms and its importance are discussed in detail in Chapter 2.

1.3 Mobile ad-hoc Networks

A mobile ad-hoc network is a collection of mobile nodes without having any backbone infrastructure such as base stations and mobile switching centers in cellular networks. Each and every mobile node is a router in itself and can route data packets from source to destination without taking help of any type of central command and control structure, read as base station and mobile switching center as in pure cellular system. In such ad-hoc network, a source mobile scans for its neighbors in a particular distance range. Depending upon certain routing algorithm it decides the next hop mobile node among a group of neighbors and hand over the information packet to that node. Now this new node becomes the source node. This procedure repeats until the packet reaches to the final destination node. In this way a source node takes help of its neighbors in reaching the destination node. Not exactly same but the similar principle is used in this research work to overcome the major problem faced by pure cellular networks – location updates for mobile nodes. Figure 1.2 gives an overview about such an ad-hoc network.

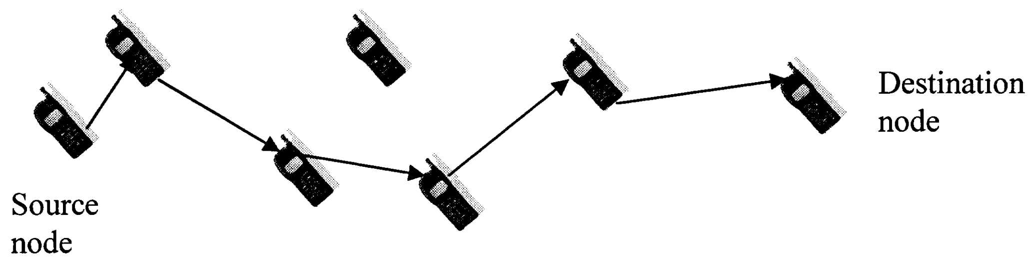

Figure 1.2 Ad-hoc Network Topology.

1.4 Major Challenge Faced by Next Generation Cellular Networks

A Next Generation cellular network means a network capable to track each and every mobile by its coordinates and provide location based services to the registered mobile users. Also such type of mobile tracking helps the emergency response team to respond quickly incase of user medical emergency. Hence to know the positions of each mobile node is very important for the base station or the mobile switching center.

To deliver an incoming call without significant time delay is also much more dependant on location updates information available to the central controller, MSC in cellular networks. When a new call arrives for a mobile node, the mobile switching center tries to locate the called mobile based on the latest location information available through the base stations. This procedure is called paging in cellular networks. Without having the knowledge of previous location of a called mobile or without having an algorithm to track its current position, it is very difficult to deliver the incoming call on time to the called mobile. The major challenge for highly dense cellular networks, which is a good assumption for next generation cellular networks, is to have a cost effective location update algorithm for mobiles. For the highly dense networks the current location update algorithms are proved to be very costly in terms of total signaling traffic towards the base stations due to location updates. In Chapter 2 various types of location update algorithms are discussed. And a very new approach for location update is proposed.

CHAPTER 2

LOCATION UPDATE ALGORITHMS IN CELLULAR NETWORKS

One of the fundamental problems in a cellular wireless network is the lack of efficient location update algorithm – especially for highly dense networks. A common location management procedure includes a three-step procedure: location updates, paging and mobile acknowledgement. In current implementation of location management procedures, the cellular network is divided into parts called as location areas. Each location area consists of multiple cells and each cell has a base station. Mobiles register their location information - to the nearest base station or to the base station from which they receive the strongest signal – when they move from one location area to another or due to some reason if the received signal strength reduces below the specified SNR ratio. The location register keeps track of latest mobile position – the last location update information given by mobile. When a call arrives, the cells in that particular location area are paged. The procedure is called paging. If mobile is not found in that particular location area, surrounding cells are paged or depending upon users past movement, the cells are selected. It is called sequential paging method. Incase the user is not found with the sequential paging, a blanket paging method is used in which the whole network is paged. Which method to be used is completely depend on the cellular service provider.

The frequency of location updates depends more on the size of the location area. With the smaller location areas, more updates occur as mobiles tend to cross location area boundary frequently. The paging and location update costs have a clear tradeoff. While location area is small, paging cost is less because a smaller area is required to be paged. If the location area size increases, location update cost decreases because mobiles tend to remain in the same location area while the paging cost increases because a larger are is required to be paged.

"Frequent location updates cause high power consumption at the mobile units and more load occurs in the wireless networks in terms of location management signaling" [1]. There are many different methods can be implemented for location updates. One of the common location management strategy used in existing systems is the location area scheme [2], [3], [4]. In this scheme, the network is partitioned into regions or location areas called LA with one region consisting of one or more cells as described above. Figure 2.1 illustrates such method.

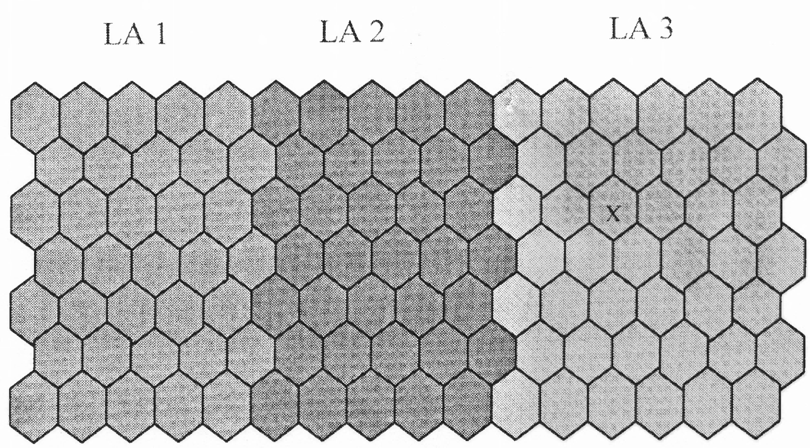

Figure 2.1 Location Area in Cellular Networks.

For above network, never-update strategy can be used within each region, with location updates performed only when the mobile moves out of the current location area. When a call arrives, only cells within current location area are paged and hence reducing the cost for paging. For example, when a call arrives for user X in figure 2.1, the surrounding cells are paged rather than entire network. Another method can also be used in which there a subset of cells in each location area is called as reporting cells. When a mobile enters in the region of these reporting cells, it has to perform a location update. Figure 2.2 illustrates such type of location update algorithm.

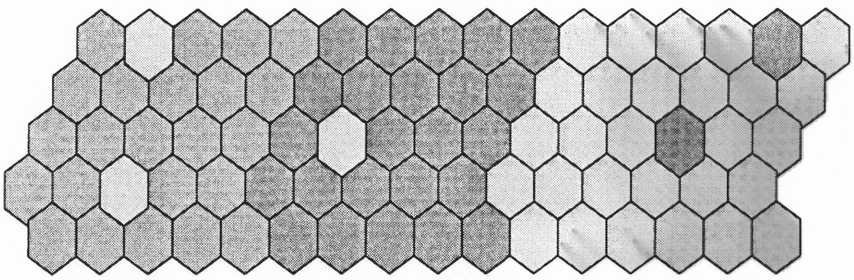

Figure 2.2 Reporting Cells in location area.

There are different schemes to decide when to update the location. These are discussed as follows.

Timer-based Location Update Scheme: In this scheme, a timer value is set in each and every mobile node [4]. The mobile provides a periodic update exactly once every t time units. This scheme is completely independent of user mobility or distance of the user from the base station. After the timer expires, user updates its current location information to the nearest base station. At the same time the timer resets to the previous value.

Distance-based Location Update Scheme: In this scheme, the user updates its location when it is m cells away from the cell when it updated last time. Such algorithm requires lot of complexity in terms of data required to be stored for each and every node in the network. There has to be a central control system which stores all the user information. HLR (Home Location Register) and VLR (Visitor Location Register) are very important part in such scheme. HLR maintains data of each node registered in home network. VLR maintains data for nodes which move out of the home location and hence provides roaming service when user gets incoming call or wants to make a call.

Mobility-based Location Update Scheme: In this scheme, the mobile provides an update when it crosses exactly m cell boundaries [2], [4]. This algorithm is completely independent of distance-based and timer-based methods. But the main disadvantage of this method is that whenever mobile crosses certain number of cell boundaries it has to update its location. But in real life, it is very difficult to distinguish physical boundaries of cells.

In all of the previous methods, the main aim is to inform base station about the presence of the mobile in its area. If the cell is highly congested, above methods create a lot of signaling overhead to the base station due to location update signals only. The proposed method – cooperative location update algorithm – reduces signaling traffic due to location updates to the base station drastically. The proposed algorithm is discussed in Chapter 3.

CHAPTER 3

CO-OPERATIVE LOCATION UPDATE ALGORITHM

3.1 Principle

The main principle of this algorithm is that a mobile takes help of its neighboring node while doing location update to the base station. In this algorithm, when a mobile, a Source Node – SN, is ready for location update, it searches for neighboring mobile nodes. If any of its Neighboring Nodes – NN - is also ready for location update, the source node collects the neighboring node details and then does location update to the respective base station for all nodes together. In this way, a huge signaling traffic to the base station due to location update can be reduced with highly dense network. Figure 3.1 describes this algorithm. If a source node does not find any neighbor nodes or if it finds neighbor nodes but if they are don't want location update, then the source node goes directly to the base station for its own location update.

Timer Based Location Update: A timer based approach is considered. All nodes are assigned particular timer value and when the timer becomes zero, it is ready for location update. When a nodes timer becomes zero, it looks for neighboring nodes If it has, say 2 neighbor nodes in its range, and one of the nodes has timer below some threshold value, Tsh, then that node will reply to the SN query. SN will collect the location related data from that neighbor node and will register the information to the base station. In this manner, a Source Node goes to the base station along with the information of other nodes. In this way the signaling to the base station can be reduced drastically. Also the average battery consumption and average energy consumption for the whole network due to location updates can be reduced.

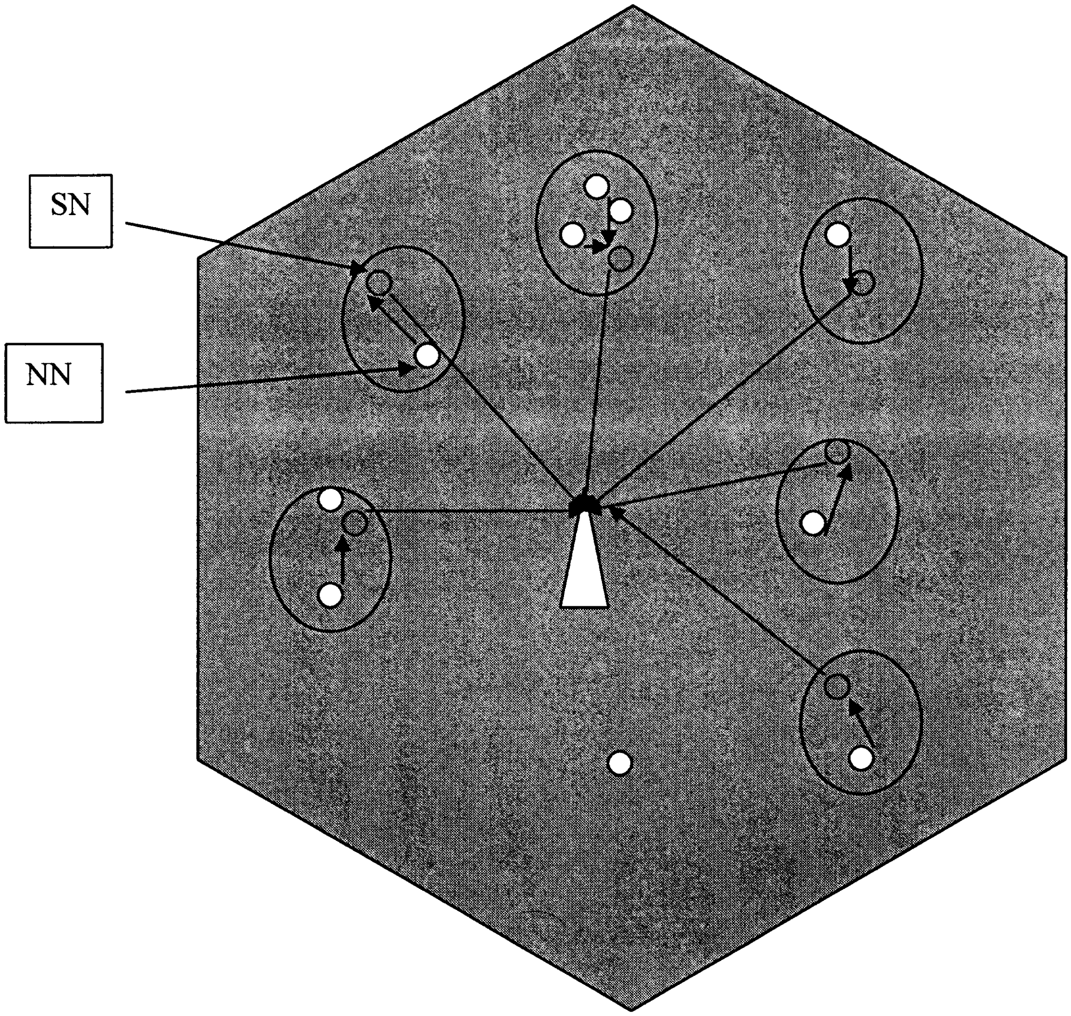

Figure 3.1 Co-operative Location Update Algorithm.

3.2 Simulation Scenario

The simulation is an applet in Java programming. Following are the different simulation scenarios.

The network: In simulation, a cellular network of 4 cells is considered. Numbers of cells are limited because of the simulation simplicity. The cell area is considered as rectangular rather than hexagonal area due to simplicity. The network size is 1 square km (1000 sq. met.)

Total Nodes: Total nodes for the whole network are considered as 30, 50, 100, and 150. Simulation is run for each case for multiple times.

Threshold Timer: Timer values considered are 10, 15, 20, and 30 seconds. The simulation is run for number of times for all these timer threshold values.

Node Range: Node Range is the range of the Source Node in which it looks for neighbors. Total 11 ranges have been considered for the simulation. These are 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, and 140 meters.

Mobility: Brownian Random Motion is considered for all the nodes. Among these nodes, 50% are vehicular mobile nodes with drift and 50% are pedestrian mobile nodes without drift. Whenever a mobile crosses the network boundary, it re-enters from the opposite direction of the adjacent cell. In this way, the network density remains constant for all the time during simulation.

3.3 Simulation Snapshots

Figure 3.2 is shows the snapshot of the network with 50 nodes. Base stations are considered in the center of all cells. Nodes are placed randomly in the whole network. In the figure, black color dots are base stations for each square base station area. Red color dots are randomly placed mobile nodes and moving randomly with Brownian motion. 50% nodes are moving with vehicular mobility with drift while 50% are pedestrian nodes without drift.

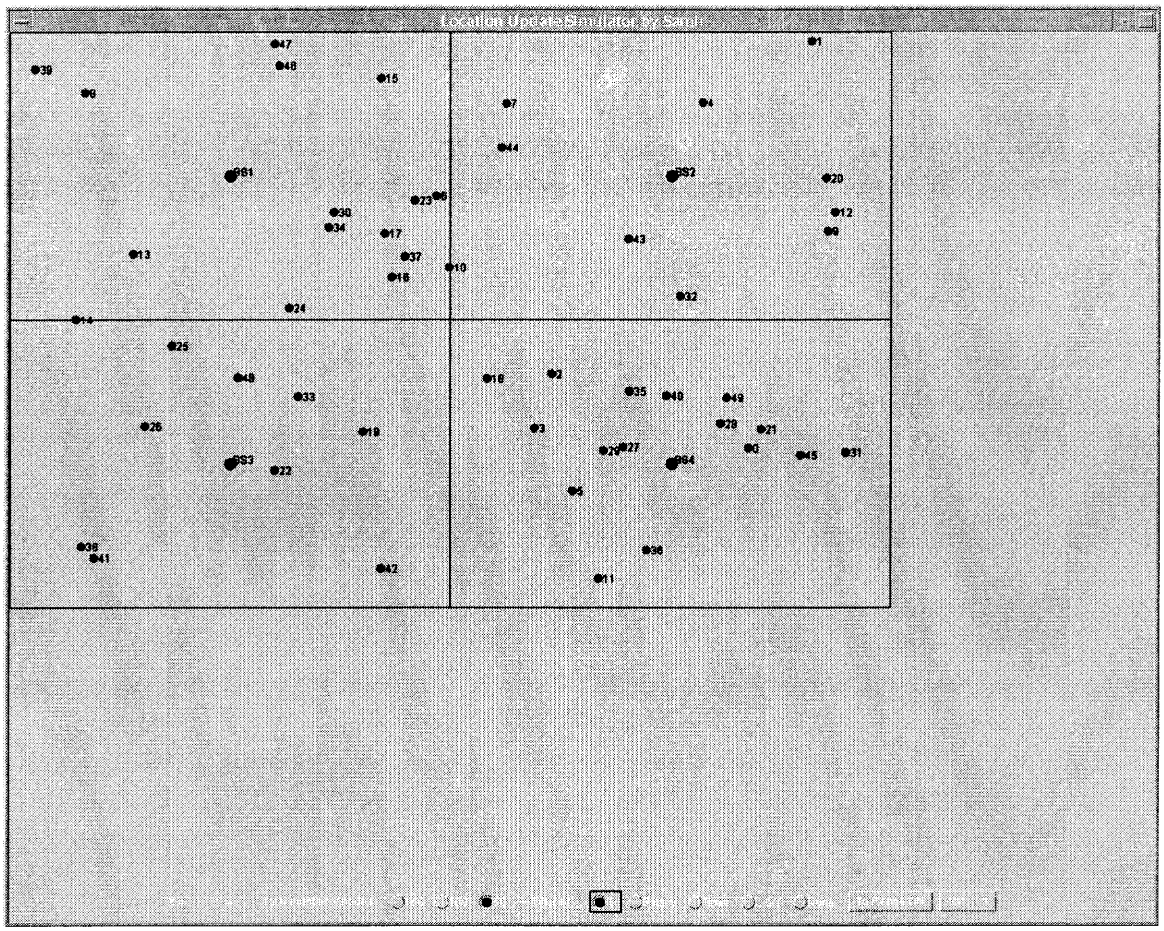

Figure 3.2 Network with 50 nodes.

Figure 3.3 shows the Simulation with pure cellular network algorithm. The snapshot is for the network of 150 nodes. Mobility is same as above case. All mobiles move with Brownian motion with 50% nodes following vehicular mobility while 50% are pedestrian mobiles. As it is pure cellular algorithm, each and every mobile updates directly to the base station without looking for neighbors. Black lines show the location update for the particular node to the base station in that area. The location update algorithm is based on purely timer based. Means, after a timer value becomes zero, the node does its location registration to the base station.

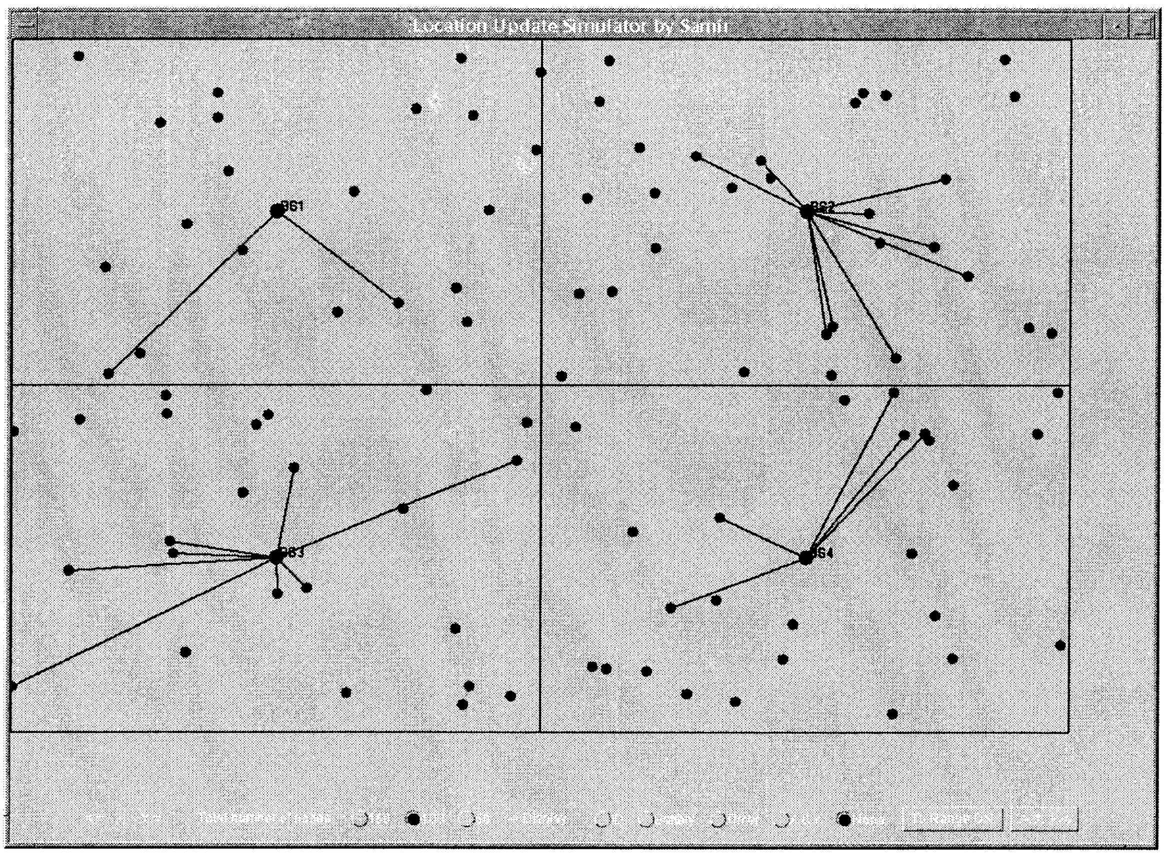

Figure 3.3 Pure Cellular case, N = 100 nodes.

Figure 3.4 shows the snapshot with total nodes in the area equal to 100 and range of each nodes is 100 meter. Before doing a location update, each node looks for its neighbor. This node is called as Source Node – SN. If it finds a neighbor which is called as Neighbor Node – NN, and if NN timer value is below the threshold value, it gives its location information to the SN and then SN registers all the information along with it's own to the base station. Threshold timer is 15 seconds in this case.

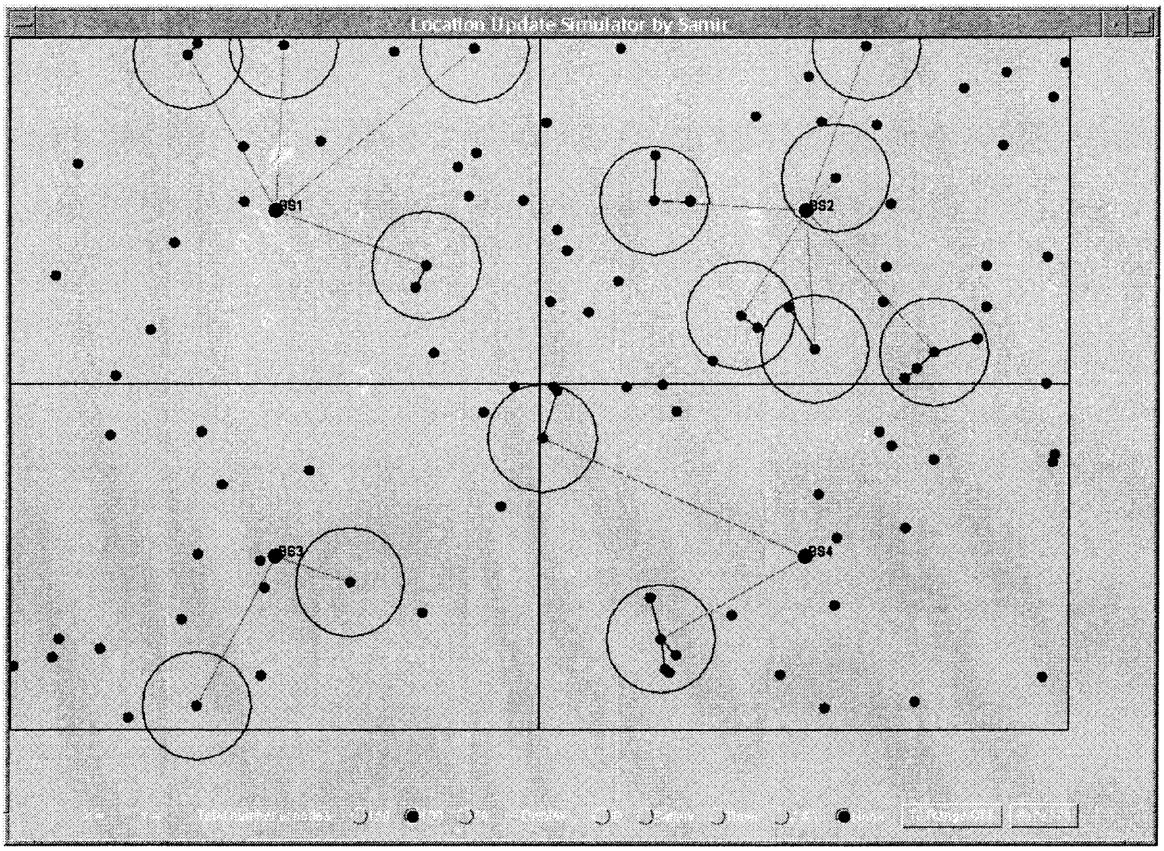

Figure 3.4 Co-operative location update algorithm, N = 100, R = 100 meters.

3.4 Energy Analysis

Energy consumption for pure cellular location updates and co-operative location updates can be compared using following analysis. In this analysis, a simple case in which a cluster of mobile nodes and only one time location update using both algorithms is considered.

If,

M = Transmitted Information ...bits
P = Power used for one transmission ...watts
k = Number of Transmission
R = Transmission Rate ...bits/seconds.
d_n = Distance from nth node to base station ...meters
d_{1n} = Distance from source node to nth neighboring node ...meters
Path loss exponent = 4

Then, energy required to transmit M bits is given by

$$E \propto M * P * k * R$$

If,

D = Actual Information bits and
L = Overhead bits

Then, energy consumption for both cases can be calculated as follows.

Case I: Pure Cellular Location Update Scheme

For n number of nodes and for one location update,

$$E \propto E_1 + E_2 + E_3 + \ldots + E_n$$
$$\Rightarrow E \propto (D+L)P_1 + (D+L)P_2 + (D+L)P_3 + \ldots + (D+L)P_n$$
$$\Rightarrow E \propto (D+L)\left[P_1 + P_2 + P_3 + \ldots + P_n\right]$$
$$\Rightarrow E \propto (D+L)\left[d_1^{\,4} + d_2^{\,4} + d_3^{\,4} + \ldots + d_n^{\,4}\right]$$

Hence,

$$E' \propto (D+L)\left[d_1^4+d_2^4+d_3^4+...+d_n^4\right]$$
$$E' \propto D\left[\left(1+\tfrac{L}{D}\right)\left(d_1^4+d_2^4+d_3^4+...+d_n^4\right)\right]$$

Case II: Co-operative Location Update Scheme

For n number of nodes in a cluster and for one location update,

$$E \propto E_1 + E_{12} + E_{13} + ... + E_{1n}$$
$$\Rightarrow E'' \propto (nD+L)P_1 + DP_{12} + DP_{13} + ... + DP_{1n}$$
$$\Rightarrow E'' \propto (nD+L)d_1^4 + Dd_{12}^4 + Dd_{13}^4 + ... + Dd_{1n}^4$$
$$\Rightarrow E'' \propto nDd_1^4 + Ld_1^4 + Dd_{12}^4 + Dd_{13}^4 + ... + Dd_{1n}^4$$
$$\Rightarrow E'' \propto D\left[\left(n+\tfrac{L}{D}\right)d_1^4 + d_{12}^4 + d_{13}^4 + ... + d_{1n}^4\right]$$

If the number of information bits transmitted and number of overhead bits are constant for both the cases
Then, $k = \frac{L}{D} = \text{constant}$

Hence,

$$E' \propto D\left[(1+k)\left(d_1^4+d_2^4+d_3^4+...+d_n^4\right)\right]$$
$$\Rightarrow E' = (1+k)\sum_{i=1}^{n} d_i^4$$

And

$$E'' \propto D\left[(n+k)d_1^4 + d_{12}^4 + d_{13}^4 + ... + d_{1n}^4\right]$$
$$\Rightarrow E'' = (n+k)d_1^4 + \sum_{i=2}^{n} d_{1i}^4$$

It is required to check the conditions for which the co-operative location update scheme performs better than the current pure cellular system. For it to perform better, the condition $E' - E'' > 0$ should be true.

Let,

$$E' - E'' = (1+k)\sum_{i=1}^{n} d_i^4 - (n+k)d_1^4 - \sum_{i=2}^{n} d_{1i}$$

$$\Rightarrow E' - E'' = -(n-1)d_1^4 + \sum_{i=2}^{n}\left[(1+k)d_i^4 - d_{1i}^4\right]$$

$$for\ R \ll d_1\ ,\ d_i^4 \simeq d_1^4$$

$$\Rightarrow E' - E'' = (n-1)(1+k)d_1^4 - \sum_{i=2}^{n} d_{1i}^4 - (n-1)d_1^4$$

$$\Rightarrow E' - E'' = (n-1)kd_1^4 - \sum_{i=2}^{n} d_{1i}^4$$

$$if\ kd_1^4 > R^4\ ,\ E' - E'' > 0$$

Hence, for $R \ll d$ and $kd_1^4 > R^4$, the co-operative location update scheme performs better than the conventional location update scheme in terms of energy consumption by all the nodes in a cluster for a single location update.

CHAPTER 4

SIMULATION RESULTS

Following are the view graphs for average location updates for each node. All the results are compared with the case when the range was OFF - Pure cellular case.

From Figure 4.1 and Figure 4.2, it is clear that using the modified location update algorithm, the average number of location updates for the network for constant battery life of a node can be increased. The following results are with the battery life of $10*10^6$ counts for each node.

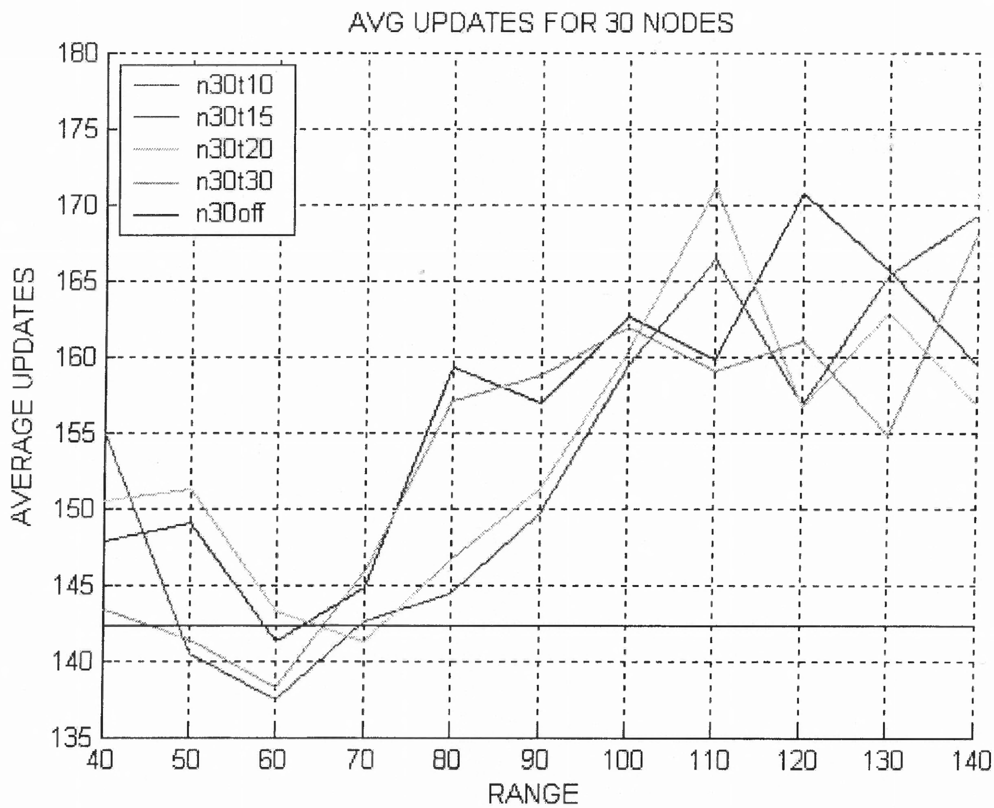

Figure 4.1 Average Location Updates, N = 30.

Figure 4.1 shows the average number of location updates by each node in case of total node density of 30 for the whole network and the range varies from 40 meters to 140 meters. The average number of location updates is shown with threshold timer values from 10, 15, 20, and 30 seconds. The black line in the graph shows the average number of location updates with the pure cellular case when each node updates separately to the base station. It is obvious that the modified algorithm performs much better than the current one in terms of number of location updates performed by a mobile node with constant battery power.

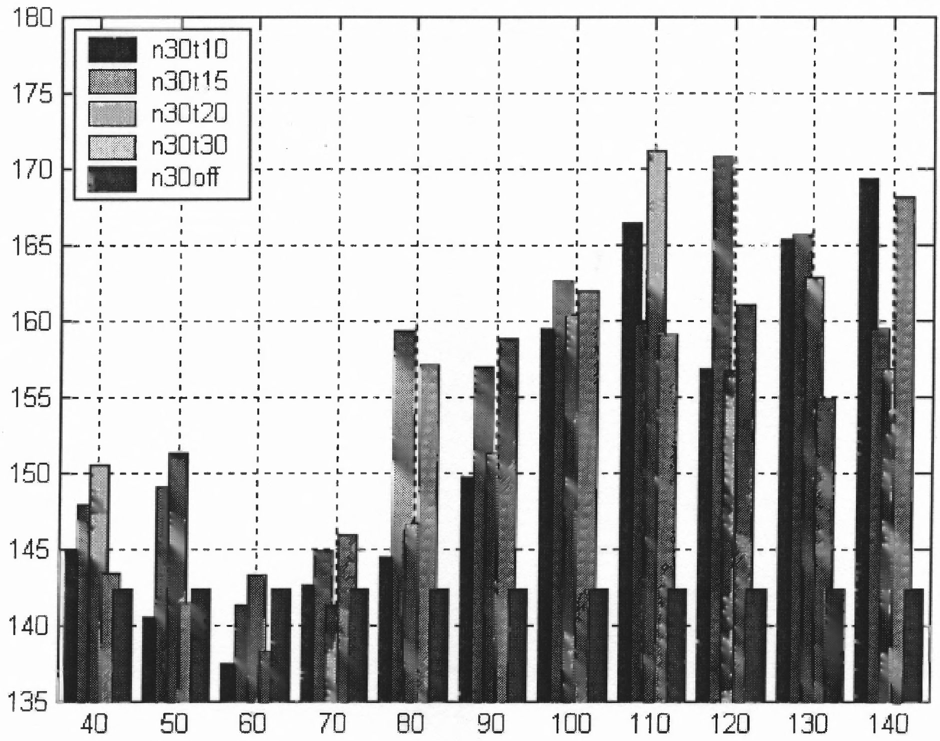

Figure 4.2 Average Location Updates, N = 30.

Figure 4.2 shows the average number of location updates as a bar graph. With the increase in range of a mobile, number of location updates performed by it increases with constant battery power.

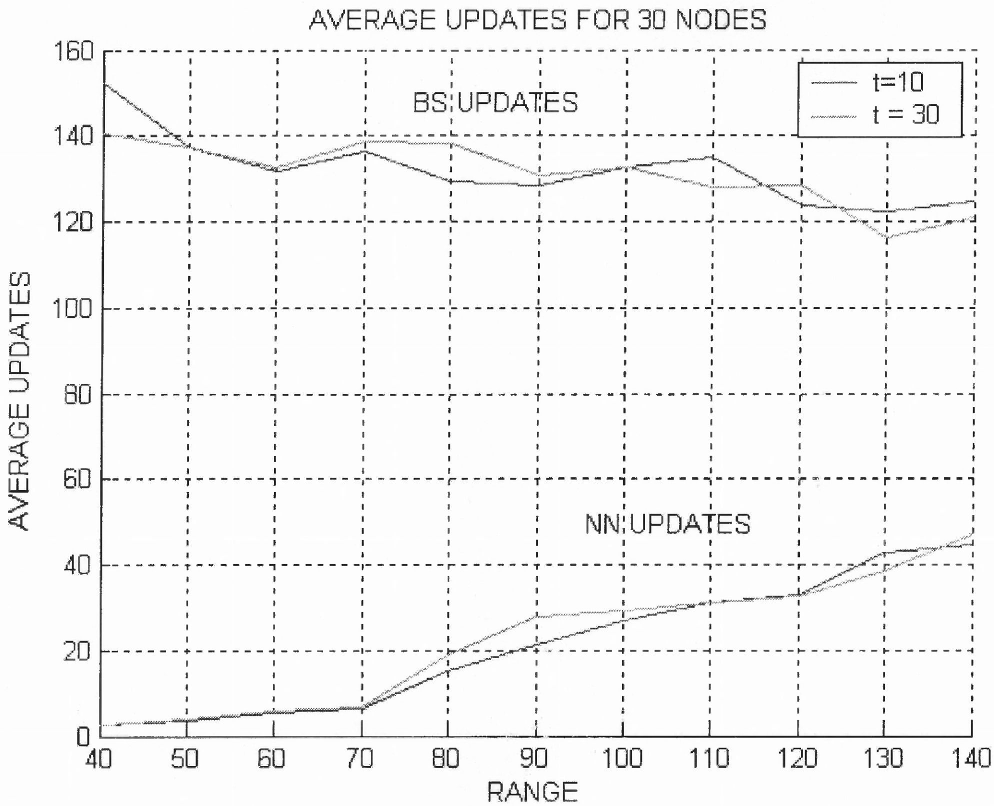

Figure 4.3 Average Location Updates by SN and NN, N = 30.

Figure 4.3 shows relation between the location updates by the source node – SN to the base station and the location updates by neighbor nodes –NN to the source nodes. In this case, only two extreme values for threshold timer, t = 10 seconds and t = 30 seconds are considered.

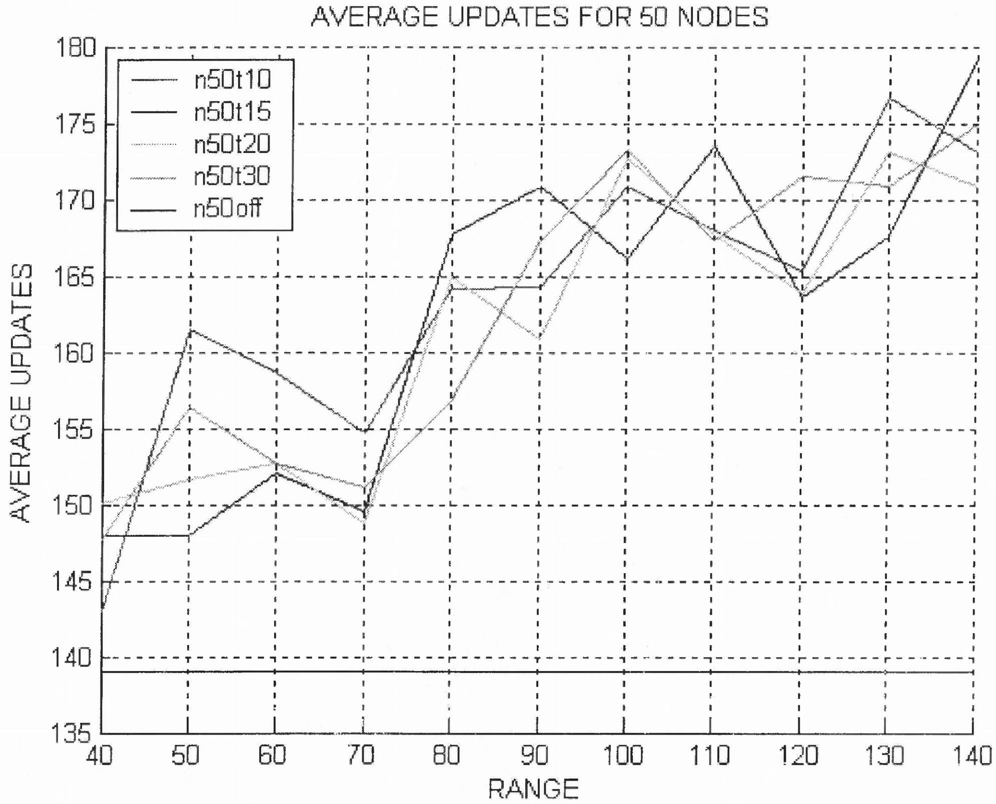

Figure 4.4 Average Location Updates, N = 50.

Figure 4.4 shows average number of location updates for total number of nodes equal to 50 for the whole network. Black line shows number of location updates when the range of a node was off means pure cellular case. Figure 4.5 shows the average number of location updates as a bar graph. Figure 5.6 shows the relation between number of updates towards base station and neighboring node updates.

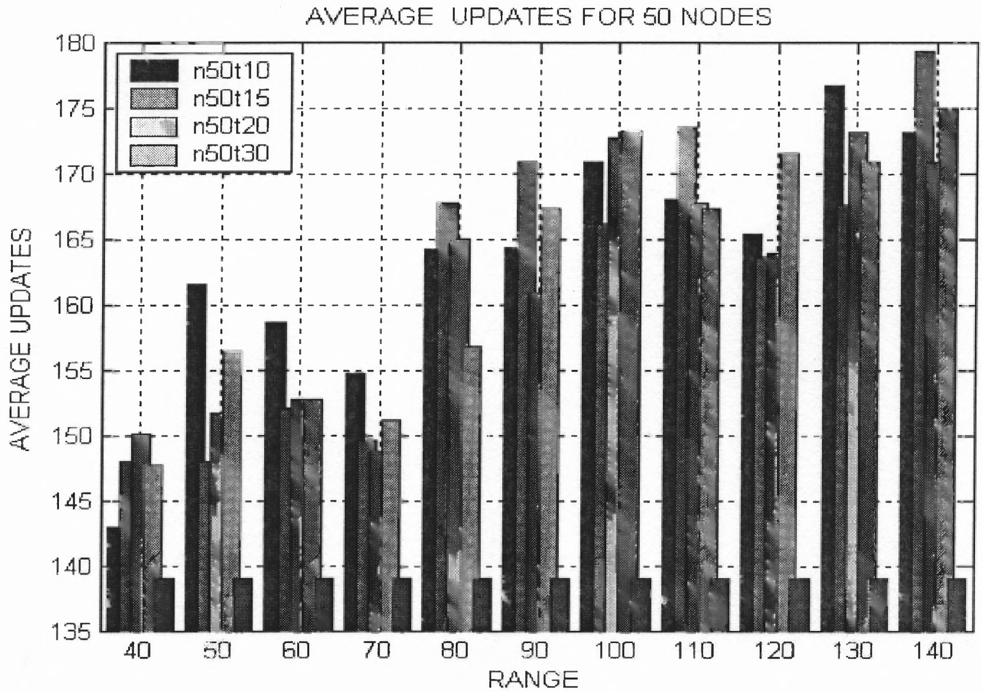

Figure 4.5 Average Number of Location Updates, N = 50.

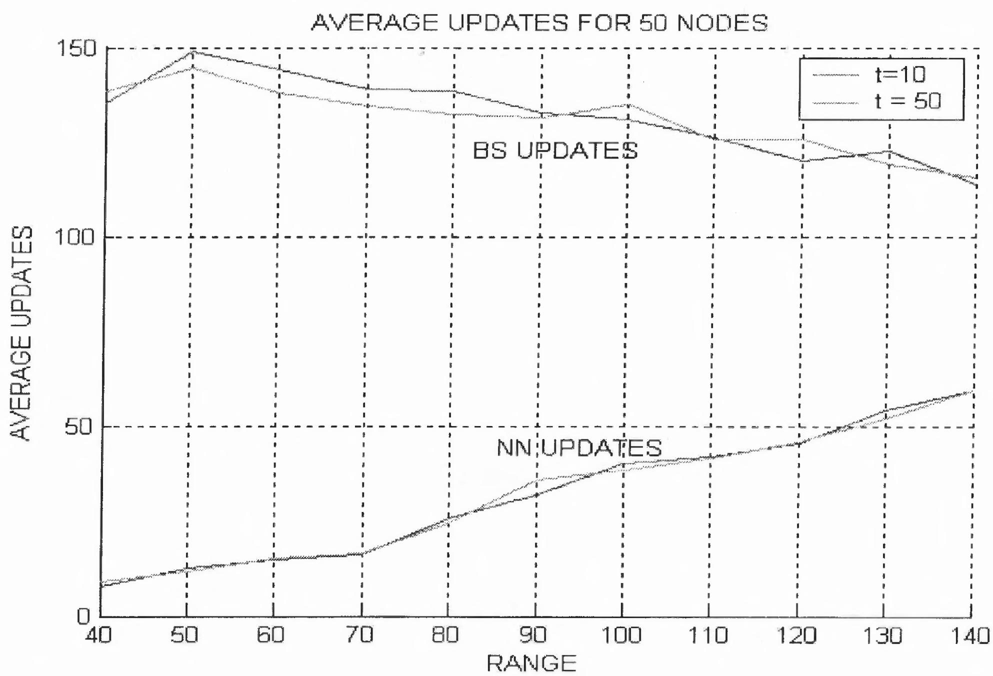

Figure 4.6 Average Number of Location Updates, N = 50.

Figure 4.7 shows the average number of updates for the 100 nodes case with different timer values. Range varies from 40 meters to 140 meters as in previous cases.

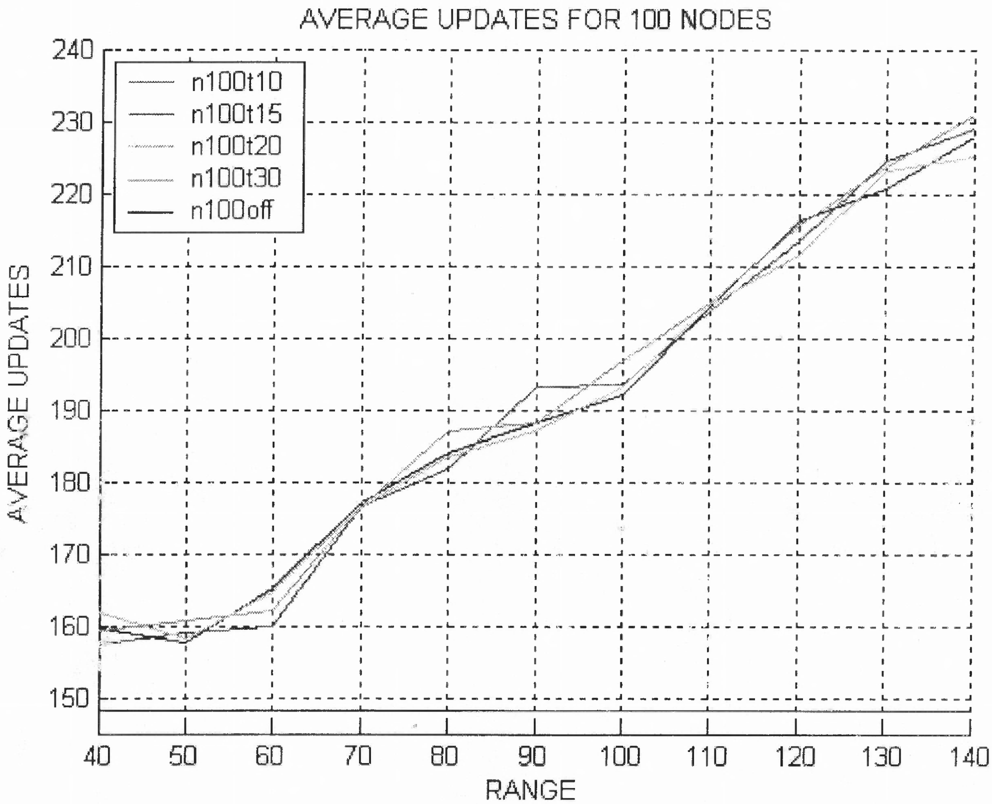

Figure 4.7 Average Location Updates, N = 100.

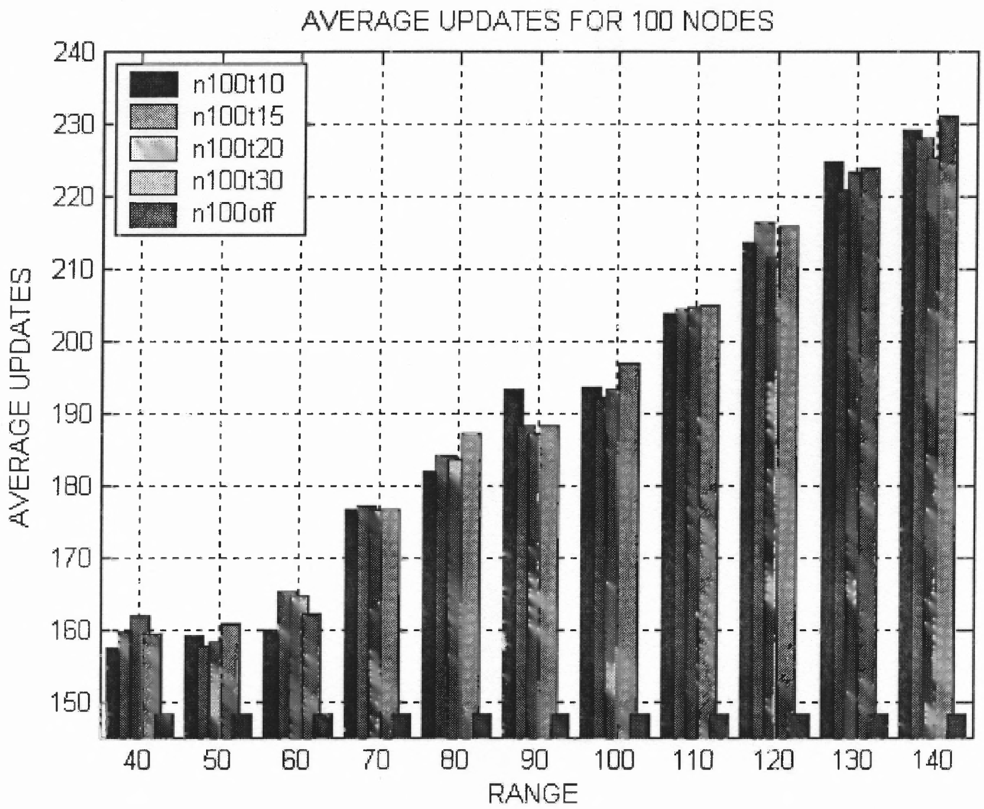

Figure 4.8 Average Location Updates, N = 100.

Figure 4.8 shows the average number of location updates with 100 nodes and the range varies from 40 meters to 140 meters. In this case, the number of updates increases in large number with the increase in range of each node. It is seen that this algorithm performs better with highly dense network.

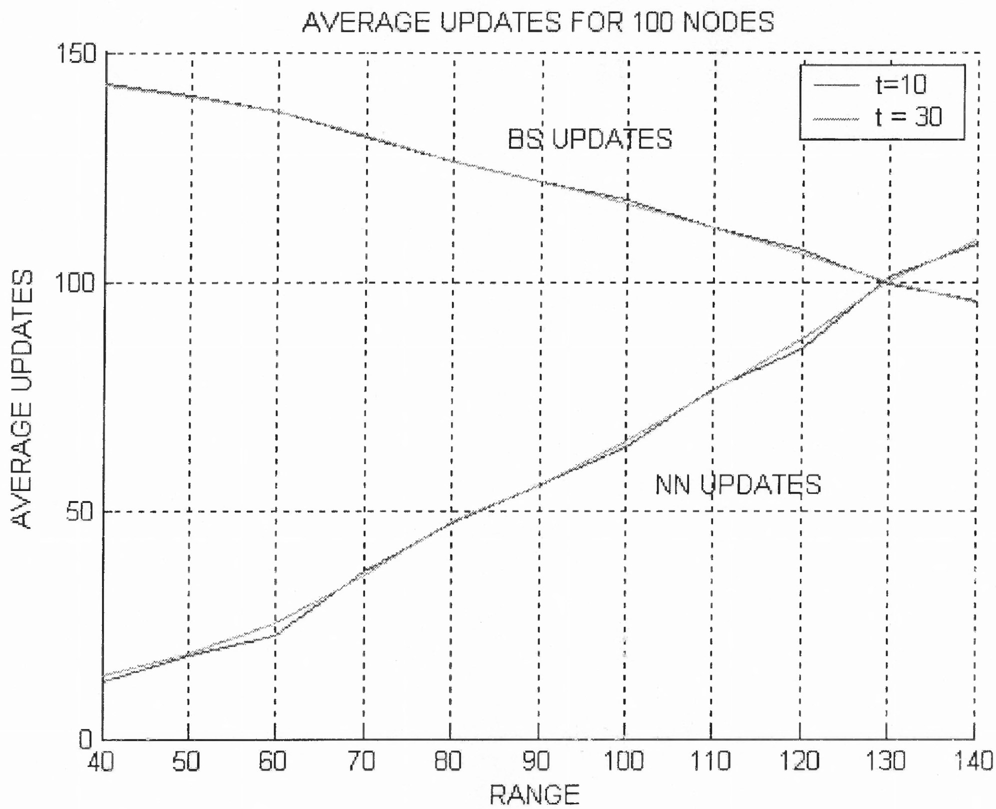

Figure 4.9 Average Location Updates, N = 100.

Figure 4.9 shows relation between base station updates and neighboring node updates with timer values of 10 and 30 seconds for 100 nodes. Figure 4.10, Figure 4.11, and Figure 4.12 are the results with total nodes equal to 150. From all the previous results, it is seen that using the co-operative location update algorithm, a node is able to perform more number of location updates compared with the current pure cellular location update algorithm with constant node battery power.

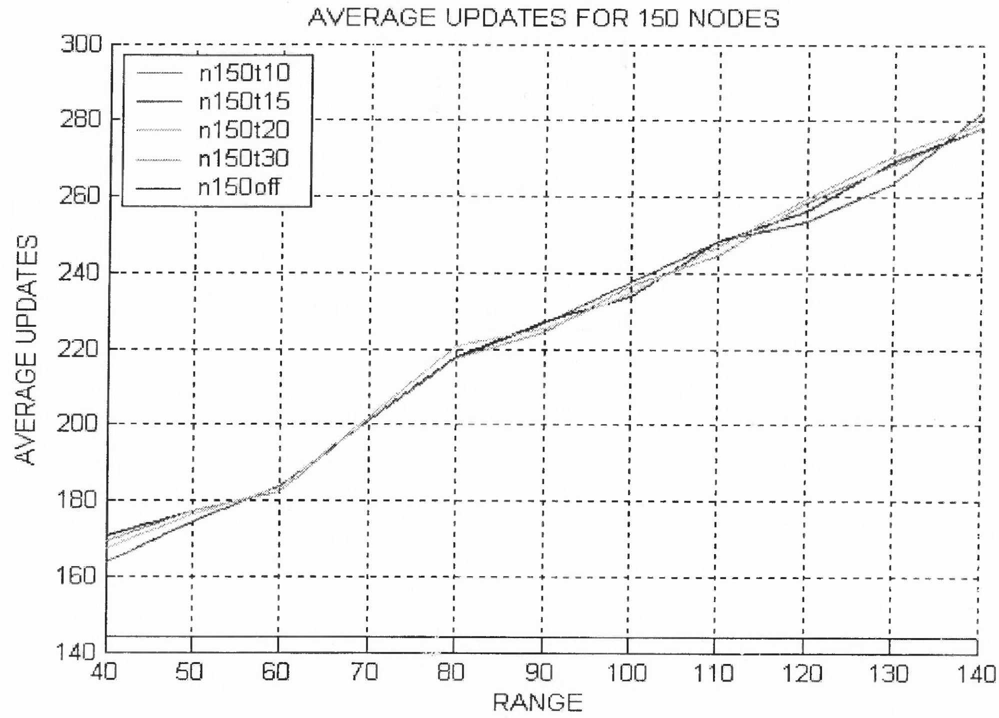

Figure 4.10 Average Location Updates, N = 150.

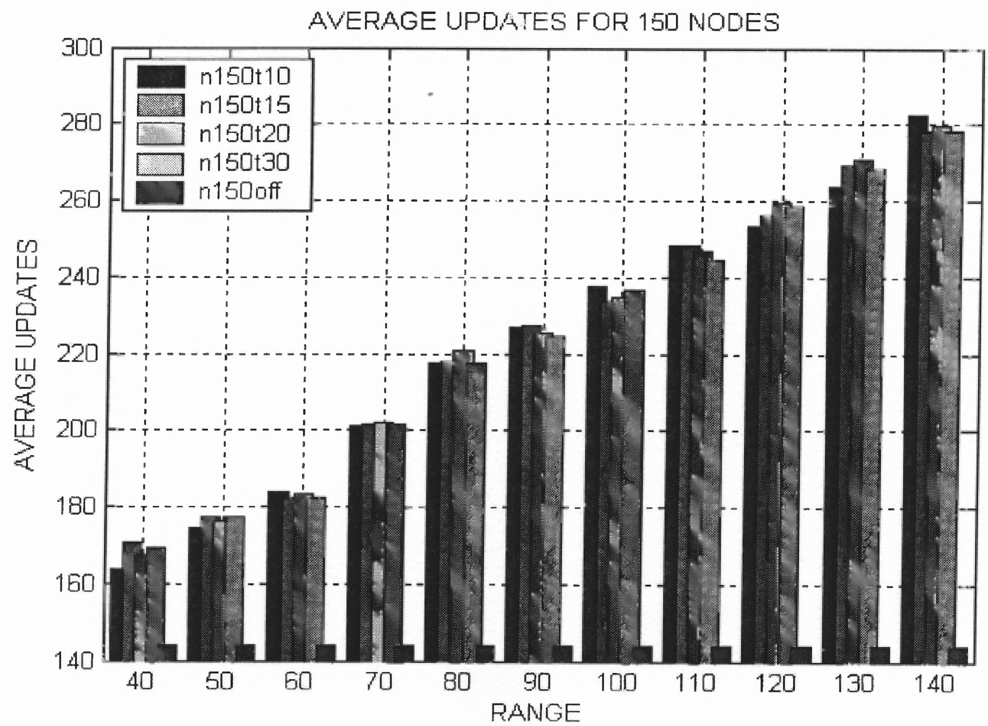

Figure 4.11 Average Location Updates, N = 150.

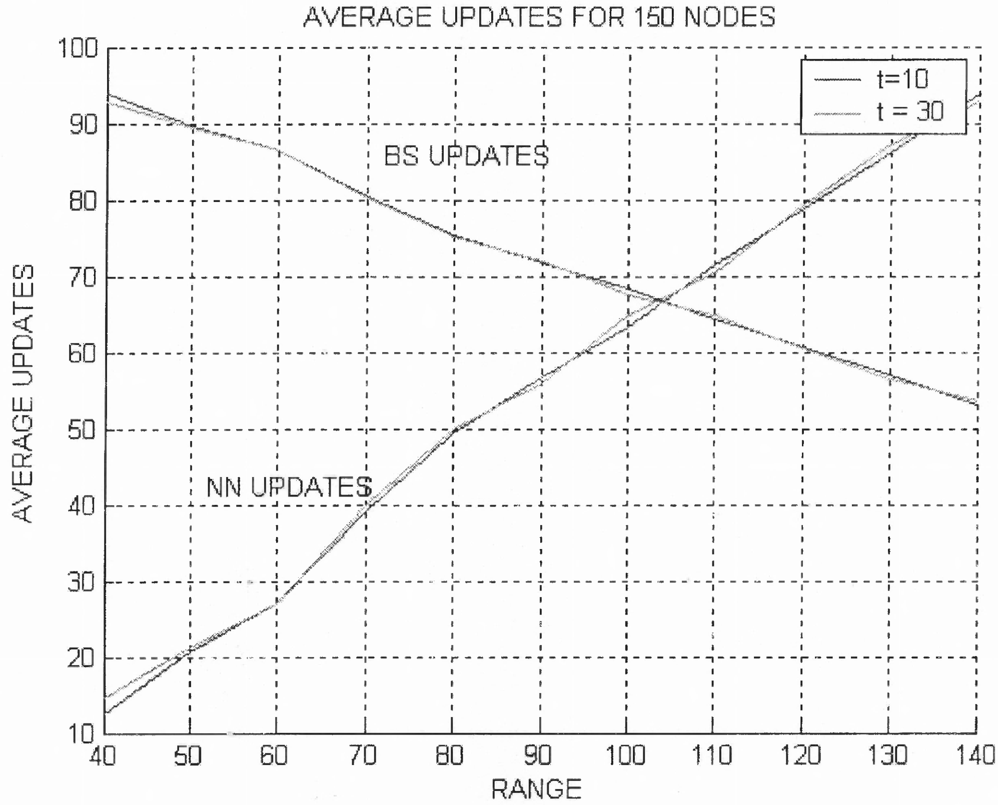

Figure 4.12 Average Location Updates, N = 150.

Figure 4.12 shows relation between BS updates by source nodes and NN updates by neighboring nodes when total number of nodes was 150. It is clear that with the range of about 105 meters, the neighboring node updates crosses the base station updates. Beyond this range, the signaling traffic towards base station due to location update decreases than the neighboring node location update traffic. In this case, the co-operative location update performs better than the pure cellular update scheme.

CHAPTER 5

CONCLUSION

From the previous view graphs, it is concluded that using the modified location update algorithm average number of location updates for given mobile node battery power is increased compared with the current algorithm in which each and every node updates directly to the base station. In other words, the battery power used for the location updates can be saved for fixed number of location updates using the co-operative location updates algorithm. Also with the co-operative location update algorithm, the signaling traffic to the base station due to location updates can be reduced. The average energy required by each node for location update can be reduced if $R = \quad d$ and $kd_1^4 > R^4$.

REFERENCES

1. Zohar, Naor and Hanoch, Levy (1998). Minimizing the Wireless Cost of Tracking Mobile Uers: An Adaptive Threshold Scheme. IEEE Communication Magazine.

2. Rose, Christopher (1995). Minimizing the Average Cost of Paging and Registration: A Timer-Based Method.

3. Wha, Sook Jeon. (2000). Performance of Improved Probabilistic Location Update Scheme for Cellular Mobile Networks.Vehicular Technology, IEEE Transactions on.

4. Rappaport, T. S. (1999). Wireless Communications – Principles & Practice. Prentice Hall, Inc.