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MCM: A New Mobility Coordination Model for WSN

Shantala Devi Patil
Computer Science & Engg,
REVA ITM,
Bangalore, India.

Vijayakumar B P
Information Science & Engg,
MS Ramaiah IT,
Bangalore, India.

***Abstract*— Many research works have been proposed to deal with the resource constraints in Wireless Sensor Networks. In order to optimally use the resources, researchers have come up with strategies and schemes enabling optimal use of resources, as the network is operated by tiny devices. Majority of the WSN application raise a need for nodes to be moving. Mobility of nodes is a solution to stabilize the network by reducing the isolation of nodes. Having heterogeneity in network is another way to optimize the usage of network resources. Mobility in WSN is introduced explicitly and therefore we can have more control over the nodes movement. In this paper, we aim to identify the benefits and challenges raised due to mobility of nodes. We propose a novel mobility coordination model that is more efficient than the existing techniques.**

Keywords—Mobility Model, Mobile Nodes.

I. Introduction

In the recent decade, research activities are focused on WSN as they are capable to integrate sensing along with communication and computation. At the inception of WSN, the nodes were assumed to be static and homogeneous in nature. But for most of the real world applications homogeneous, static scenario may not be suitable. Mobility of the nodes is a major requirement for most of the prevailing applications. In WSN, node mobility could be of a sensor node, sink/base station and mobile elements (with special functionality). Heterogeneity is another factor that can be introduced into the network to improve the performance. Heterogeneity could be associated with node, energy and links etc. Hence the next step would be to handle heterogeneity and mobility of nodes. The shift from static, homogeneous WSN environment to Mobile, heterogeneous WSN environment improves the network applicability and opens up new research challenges and opportunities. Mobility [1] in WSN is intentional and deliberate, hence allowing the movement of the nodes to be controlled and coordinated. Mobility is one such feature that has high impact on proper functioning of WSN and enhances capability of the network by handling multiple problems.

This paper makes following contributions, we first study the challenges associated with Mobile WSN. We design an algorithm that determines the nodes movement with location detection at any instance of time.

The subsequent sections give a detailed overview of challenges and advantages of having nodes mobility in II, in III we propose a new Mobility Coordination Model MCM for WSN nodes, followed by discussion on previously published research work in IV. Section V discusses the evaluation of the proposed Model. In VI we conclude the discussion.

II. Challenges and Advantages of Node Mobility

A. Challenges of Node Mobility

The whole perception of looking at WSN changes when mobility is introduced. Proper functioning of WSN is very difficult, when algorithms and schemes developed for static nodes are applied. Some of the problems associated with static WSN are 1) In WSN the nodes are initially deployed randomly through aircrafts and such a distribution may create several disconnected island of nodes and does not guarantee complete connectivity among nodes. 2) The nodes being battery operated my die due to energy exhaustion creating holes in the network. The only option to replace the dead nodes to overcome disconnection is to deliberately move the nodes. Hence raising a need for mobility in nodes.

The introduction of mobility in turn introduces to some challenges that have to be considered when developing new algorithms and schemes. In the table 1 we summarize the challenges in comparison to static WSN.

B. Advantages of Mobile WSN over Static WSN

The optimal deployment of network is achieved through mobility. Some of the advantages of Mobile WSN [2]: 1.Deals with the problem of scarcity of resources in WSN. 2. Makes network scalable. 3. Improves network performance and connectivity. 4. Increases Network Lifetime: since sensors can move they can connect the lost connection. 5. Increases Channel Capacity by creating multiple communication pathways. The capacity gain increases proportionally as the number of mobile nodes is increased. 6. Achieves Data Integrity and Fidelity by utilizing a mobile node to carry data to the destined node. 7. Target tracking and network coverage is enhanced.

III. PROPOSED SCHEME

In this section we discuss the issues associated with mobility model, understand a mobile WSN scenario and then discuss the New Mobility Coordination Model (MCM) in WSN.

A. Mobility Model

Modeling is referred to as imitation of the real world process, hence mobility models imitates the real movements and those movements are applied to the nodes. Mobility models represent the movement of nodes from one location to another within the deployed area.

In WSN mobility is deliberately introduced into the network and hence can be nodes can be tuned according the requirements of the network. The attributes associated with the mobile nodes are Location, Velocity, Acceleration, Angle of Deviation, and Direction of movement etc. mobility models can be simulated or analyzed. We try to emulate the mobility models to get an insight of their performance impact on WSN applications.

The mobility model should be adaptive and need to update as and when changes occur in the network environment. Several existing mobility models though they provide mobility, but they do localize the node as and when required. Hence raising a need to develop a comprehensive solution. In this section, we present a new mobility model based on coordinate geometry, which off course provides mobility with adaptive localization.

Attribute	Wireless Sensor Network		
	Static Nodes	*Mobile nodes*	*challenges*
Localization	Position of node is determined when network is initialized.	Position of the node keeps changing as time lapses. Hence localization of nodes have to done at regular intervals.	This requires a scheme that is able to localize the nodes adaptively.
Power Consumption	Consumption of power is less.	Due to mobility, power consumption of node is more.	Device schemes that will reduce the power consumption..
Topology	The routing tables are created at each node during initialization and do not change.	The routing tables keep changing as the neighborhood of nodes change due to mobility.	Develop schemes that update the Routing Tables at regular intervals.
Mobility	No mobility	The nodes, Base Station and Mobile Elements can be used to introduce mobility	Based on the type of node involved in mobility the schemes have to be developed.

TABLE I: *Comparison Of Static And Mobile WSN*

B. *A Mobile WSN Scenario*

The Mobile WSN environment is assumed to be a square area where numerous nodes are deployed randomly to perform sensing of environmental parameters as show in in Figure 1. Base Station which is having ample amount of energy is located somewhere outside the network. The Base Station is responsible for collecting the data from nodes and aggregating. The task of the node is to sense the environmental parameters and revert the same to the BS. Each node is equipped with a sensor to sense environmental parameters, transceiver for transmission and reception of data, a processor to process data, analog to digital converter to convert the sensed signals into digital signals, memory storage to store the data collected or exchanged and a battery for power requirement. For node mobility and location, the node must be equipped with a mobiliser and location finding system.

We propose a mobility model for flat topology and this is equally applicable to hierarchical topology. Each node in the network has energy, sensing capability, processing capability, communicating capability, some storage capacity, and mobility and location detection techniques.

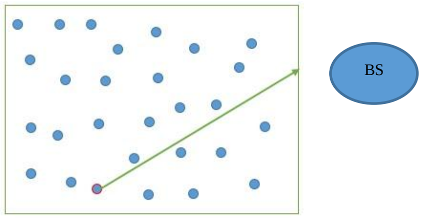

Figure 1: *A Mobile WSN Scenario, with a node moving towards boundary as an example.*

Assumptions:

- Nodes are in Quazi - State: a state where the nodes are static until initial setup of network and then they start moving in random directions in the network.
- The nodes know their initial location or they learn their location during the set-up phase.
- The nodes move in any direction and in any angle.
- The speed and the direction of the moving node do not change until it reaches the boundary of the network.

C. *Abbreviations and Notations Used*

WSN	Wireless Sensor Network
BS	Base Station
R	Right side of the network boundary
T	Top side of the network boundary
L	Left side of the network boundary
B	Bottom side of the network boundary
N	Node
DDA	Digital Differential Analyser

D. *The New Mobility Coordination Model (MCM)*

We propose a mobility model for individual nodes. The nodes are deployed in an area with coordinates (Xmin, Ymin) : represent the bottom left corner of the network boundary and (Xmax, Ymax): represents the top right corner of the network boundary. Every node is aware of the network coordinates. Let the initial position of node N be (Xo, Yo). In Figure 2, we observe the network area has 4 sides Left (L), Right(R), Top (T) and Bottom (B). Each of the side has following coordinates.

Left L: (Xmin, Ymin) to (Xmin,Ymax)
Right R: (Xmax, Ymin) to (Xmax,Ymax)
Top T: (Xmin, Ymax) to (Xmax,Ymax)
Bottom B: (Xmin, Ymin) to (Xmax, Ymin)

The node N at initial location (Xo, Yo) selects a point (X1,Y1) on any one of the sides of network boundary (LRTB). The node moves from initial location (Xo, Yo) towards (X1,Y1). For example, say the node selects side bottom B, then the Node N can take a value between X1=Xmin to Xmax and Y1=Ymin. If the node N selects side top T, then the Node N can take a value between X1=Xmin to Xmax and Y1=Ymax. If the node N selects side left L, then

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the Node N can take a value between X1=Xmin and Y1=Ymin to Ymax. And

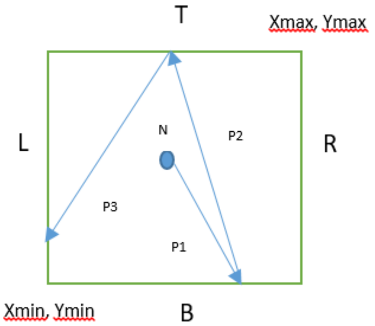

Figure 2: *Network Boundary with Node Mobility*

if the node N selects side right R, then the Node N can take a value between X1= Xmax and Y1=Ymin to Ymax.

Once the node reaches the boundary point (X1,Y1) the node then pauses for random amount of time and then repeats the same process of selecting any one boundary point for its subsequent movements. This is continued until the node is active. This procedure is applied to all the nodes to achieve mobility. For ease of understanding we consider the mobility of one node and can be extended to all nodes in the network.

Pseudocode for node mobility

```
1: The network coordinates are (Xmin, Ymin) and (Xmax, Ymax) and node N has coordinates (Xo,Yo), where Xo lies between (Xmin, Xmax) and Yo lies between (Ymin, Ymax).
2: Node N randomly Selects any one of the boundary side from (T,B,L,R).
        If
                N selects top T,
                X1=Xmin to Xmax and Y1=Ymax
        Else if
                N selects bottom B,
                X1=Xmin to Xmax and Y1=Ymin
        Else if
                N selects left L,
                X1=Xmin  and Y1=Ymin to Ymax
        Else
                N selects right R,
                X1=Xmax  and Y1=Ymin to Ymax
3: N moves from (Xo, Yo) to Selected (X1,Y1)
        Call(node_movement)
4: Node N, At Location (X1,Y1)
        sleep for Arbitrary time 't'
        rebounds towards network,
         repeat step 2.
5:End
```

The initial location of the node is (X0, Y0) and it moves towards (X1, Y1). This point is arbitrarily selected using step 2, where the node selects any point on one of the edges of the network. Once the node reached (X1, Y1), it sleeps for some arbitrary time and after the time lapses, the node uses the step 2 and reselects the next destination point. This method is an iterative procedure until the network is alive. The same procedure is applied to all the nodes of the network and the nodes movement does not influence the movement of other nodes.

The movement of nodes is based on DDA [12] line drawing algorithm, and is given in procedure node_movement.

Procedure for node_movement

```
Step 1: Let nodes Initial Position = (X0,Y0) and Final Position= (X1,Y1)
Step 2: Find the X displacement 'Δx' and Y displacement 'Δy' values
            Δx= X1-X0
            Δy=Y1-Y0
Step 3: Find slope 'm'
            m= Δy/Δx;
Step 4: Initially let Y=Y0,
            for all X values from X0 to X1
            Move node to Location (X, Round(Y)),
            Find Y ;    Y=Y0+m
Step 5: End
```

E. Path Tracing of Node N

From figure 2, for Node N, the path taken is (Xo,Yo) to (X1, Y1) represented by P1, and then the node sleeps for arbitrary time 't' before rebounding back towards the network from latest position (X1,Y1) to the next position on boundary (X2,Y2) using the pseudocode. This path is represented by P2 and the process continues until the node is active.

F. Localization of Node based on Digital Differential Analyzer Algorithm (DDA)

The description of DDA algorithm [12] can be found at the end of the paper. The localization of node is motivated by DDA a line drawing algorithm based on coordinate geometry. By modifying this algorithm we are not just able to provide movements to the node but also we can localize the node at any point of time. For this we assume that the node displacement Δx in terms of single units.

Pseudocode for Localizing Mobile Node

```
1: Initial Position of node is (Xo, Yo) and it moves towards say (X1,Y1).
            Total displacement for X is Δx=X1-Xo and
            Total displacement for Y is Δy=Y1-Yo and
2: find m= Δy/Δx;
3: At time t0,
    The node is at initial position (X0,Y0);
    For( i =  t0 time to tΔx ) where i=(0,1,2,…., Δx)
            Location (Xi,Yi) = (X0+ti,Y0+m*ti);
4: Node At Boundary Location (X1,Y1)
      Call (pseudocode for Node Mobility)
5: repeat step 1-4;
6: End.
```

The initial position of the node is (X0, Y0) and the destination point is (X1, Y1) before the node goes to sleep. The time taken by the node to reach the destination point from the initial point is Δx=X1-X0. The slope m can be given as $\Delta y/\Delta x$. At time t0, the node is at (X0, Y0). At time t1, the node is at location (X0+1, Y0+m) and at time t2, the location of node is (X0+2, Y0+2m) and at time $t\Delta x$, location is (X1,Y1).

IV. EVLUATION OF THE MCM

Let the coordinates of network Xmin=0, Ymin=0, Xmax=100,Ymax=100. The initial location of the node is (X0,Y0) =(50,50). According to the node mobility procedure, say the node selects B – then the value of X1 lies between Xmin and Xmax and Y1 is Ymin. Let's assume X1=75, a value within Xmin and Xmax range and Y1=0. The node moves from the initial point to the selected point. On reaching this location the node sleeps for random amount of time and then rebounds back into the network by selecting the next destination point.

The localization can be done as follows: the endpoints of node are (50,50) and (75,0). The time taken by the node to move to the destination location is Δx=X1-X0=25.

The node at time t0, is at (X0,Y0) = (50,50).
The node at time t1, is at (X0+1,Y0+m)=(51,48).
:
:
The node at time tΔx, is (X0+Δx,Y0+m*Δx)=(75,0) which is the destination location of the node.

V. PREVIOUS PUBLISHED WORK

Many Mobility models are published as research work. Based on functionality, Mobility models can be classified into Individual Mobility Model: Movement pattern for each node is calculated, Group Mobility Model: Movement patterns for group of nodes. Correlation Based Mobility Model: Mobility model for group of related nodes w.r.t energy, Location etc, Non-recurrent Mobility Model: Mobility model with nodes random movement with no trace back, Models based on Temporal Information: Mobility models based on previous node movements, Models based on Spatial Information: Similar to correlation model, where mobility is for group on nodes related to each other through some attribute etc. Individual mobility model is the one where the nodes movement patterns are calculated. Some of the common mobility models are

- Random Walk Mobility Model: based on particle movement in physics called Brownian motion. There is no pause during the movement of nodes and they move randomly in any direction in the network.
- Random waypoint mobility: Each nodes selects a random destination and starts moving with a random speed ranging between minimum and maximum speed, after a pause for some fixed time. This behavior is repeated till the simulation ends,
- Smooth random mobility: This model is based on temporal information. The movement of nodes is with controlled speed that can be increased or decreased.
- Realistic random direction mobility: The node changes the speed and direction at regular intervals.
- Manhattan Mobility Model: Nodes in this model moves only in horizontal or vertical directions. Uses a probabilistic approach to decide movements at the intersections.
- Random Point group Mobility Model: This model is dependent on the spatial characteristic. The nodes here work cooperatively, each group of nodes is governed by a leader which dictates the mobility behavior of the entire group.
- Guass- Markov Mobility Model: Each node is preset with speed and the direction of movement and these values can be changed at regular intervals.
- TRACK Mobility Model [14]: this model is based on Connected Dominating Set property of network which is built from spanning tree. This method was extended to MTRACK Mobility Model.

Based on the published work we have proposed a novel mobility model that provides an optimal mobility for nodes and also takes into account the constraints of resource. In fact many of the mobility models just focused on movement patterns whereas in our work we focus on localization of node and also estimation of the nodes location at a particular instance of time.

VI. CONCLUSION

Many of the mobility models published dal only with the movement or motion of nodes and not with the localization of nodes. The complete performance of a mobile WSN depends on the choice of mobility model. In this paper, we discuss a novice Mobility coordination model for individual nodes of Wireless Sensor Networks by making an attempt to localize the nodes in movement. It is based on coordinate mathematics and Geometry. These concepts have been used to calculate the movement of nodes, path and location of a mobile node. The mobility of the nodes can be achieved at ease and localizing the position of the nodes is also simple. In future we plan to extend the scheme to Clustered Scenario in WSN.

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ABOUT THE AUTHORS

Shantala Devi Patil is pursuing Research in Computer Science and Engineering Department from VTU, Karnataka. Her research interests include Wireless Sensor Networks, Mobile Sensor Network and also security in Heterogeneous Wireless Sensor Networks.

VIJAY KUMAR B P Received the Ph. D degree in Electrical Communication Engg., Department from Indian Institute of Science, Bangalore. M.Tech degree in Computer Science and Technology from the University of Roorkee. He is currently a professor and HOD in MSRIT Karnataka, India, where he is involved in research and teaching UG and PG students, and his major area of research are Computational Intelligence applications in Mobile Wireless Sensor networks.

DIGITAL DFFERENTIAL ANALYZER ALGORTIHM

The DDA algorithm[12] is a Line drawing algorithm based on incremental scan line conversion. It is the fastest method to calculate the pixel positions of a line. It makes use of easy calculations to move from one step to another. The DDA requires that the endpoints of the line to be drawn are known. Based on the, at step i a point (xi,yi) on the line can be calculated. A line is sampled at regular unit intervals in one coordinate and the corresponding integer value is the nearest point on the line path.

- Start at the pixel for the left-hand endpoint x1.
- Step along the pixels horizontally until we reach the right-hand end of the line, x2 .
- For each pixel compute the corresponding y value.
- Round this value to the nearest integer to select the nearest pixel.