

# An Extended Topology for Zone-Based Location Aware Dynamic Sensor Networks

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**Abstract:** This paper presents a novel scheme for self configured dynamic sensor networks based on zones, where the sensor nodes are location aware. Location about which the sensors provide the information is always more important than identification of sensors. It is vital to deliver this information to sink involving minimum packet processing at intermediate nodes due to limited battery life and bandwidth. It is proved through simulations that this scheme ensures high success rate with minimal data flow even if sensor nodes are highly dynamic.

**Keywords:** Sensors, Geocasting, Global Positioning System, Location Based Multicast Algorithms, Zone, Flooding

## 1. INTRODUCTION

Sensor networks are an important ingredient of “anywhere and anytime” ubiquitous wireless next generation communication infrastructure. In this diversified yet integrated future network environments, sensor network has a role of reliable monitoring and control of variety of applications based on environmental sensing [1]. These applications range from medical and home security to machine diagnosis, chemical/biological detection and military applications.

Sensor network is a combination of nodes that are used to sense data from its environment and to send the aggregated data to its control node often called sink. Figure 1 shows a typical sensor network. The sink node communicates with the task manager via core network which can be Internet or Satellite [2]. Sensors are low cost, low power, and small in size. Due to small size the transmission power of a sensor is limited. The data transmitted by a node in the field may pass through multiple hops before reaching the sink. Many route discovery protocols (mostly inherited from Ad hoc networks) [3] have been suggested for maintaining routes from field sensors to the sink(s). Due to low memory, scarcity of available bandwidth and low power of the sensors, many researchers considered these separate route discovery [3] mechanisms undesirable.

Once sensors are deployed they remain unattended, hence all operations e.g. topology management, data management etc. should be automatic and should not require external assistance. In order to increase the network life time, the communication protocols need to be optimized for energy consumption. It means a node must be presented lowest possible data traffic to process.

In the absence of separate (may be Proactive or Reactive [3]) route discovery protocol, the propagation of data

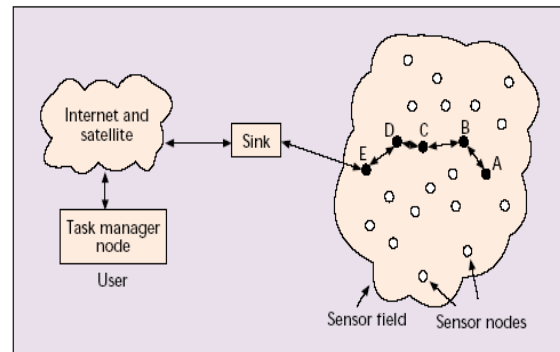


Figure 1: Typical Sensor Network [2]

packets towards the sink can best be controlled by equipping sensors with self awareness through GPS [4,5] coordinates. Sensors deployment is usually large in quantity and often we are interested in the location of sensors rather than the unique identification [6,7]. The scheme presented in this paper minimizes the traffic load (reducing the multihop nodes to minimum) from source sensor to the sink. The rest of the paper is described as follows. Section 2 discusses the background information for sensor networks. The motivation for the proposed scheme presented is discussed in Section 3. Section 4 discusses the proposed scheme called, ZOLA-DSN (Zone Based Location aware Dynamic Sensor Networks). Simulation results are provided in section 5. Conclusions and future work conclude the paper.

## 2. BACKGROUND INFORMATION

Most of the networks require unique identification of nodes within a network for the transmission of information between them. Global addressing has a very lengthy format e.g. it comprises of 128 bits in IPv6. The data packet generated by sensors is generally aggregated information to the sink. So it is unwise to send an address much larger than the actual message delivered [8]. Another option can be to use local addressing but it has its own problems [9,10]. Multiple schemes to achieve better functionality with the variations / alternatives of addressing [8,9,10] have been proposed. These schemes use identifier or label for sensors identification. Identifiers are generally generated in random. [9,10] discusses address free architectures that use randomly select probabilistically unique identifiers for each new transaction rather than using static addressing. But this method may create same identifier which may interfere with the neighboring generated identifier as this model achieves both local and spatial locality [9]. Moreover, in most of sensor networks we are interested in the location about which the sensors provide information rather than the identification of sensors. Location information

maintained at each sensor and sent along with the data packet can be a feasible alternative for global or local addresses. In this way sink would know the location of the sensor from which the data was sent and perform appropriate actions to address the situation at that location.

### 3. MOTIVATION FOR PROPOSED SCHEME

The aim of proposed scheme is to minimize the flow of packets in the network which ultimately reduces power consumption and hence maximize the battery life of a node. It also ensures efficient usage of available low bandwidth.

As separate routing strategy is undesirable in sensor networks, flooding can be an alternate choice but it needs serious modifications as unconditional flooding is always undesirable [11]. One attractive option to reduce flooding is to use location information based on Global Positioning System (GPS) [4,5] generally known as **geocasting** [13]. It is foreseeable that GPS will be available in almost every user terminal in near future, enabling geocasting as an attractive choice. For geocasting, we are using a modified version of Location-Based Multicast (LBM) algorithm. Original LBM algorithm is discussed in [11]. We are using zone based scheme where each zone is served by Zone Serving Node. Zones are like clusters or zones in adhoc mobile networks [10, 12]. We have modified LBM where only Zone Serving Nodes take part in forwarding process.

### 4. ZOLA-DSN (Proposed Scheme)

The proposed scheme is for mobile sensor networks, where each node is GPS (Global Positioning System) aware. LBM is a location based multicasting protocol. It is essentially identical to flooding data packets, with the modification that a node determines whether to forward a packet further via one of two schemes proposed [13]. We have modified 2<sup>nd</sup> scheme (which is more elaborate) to fulfill our requirement i.e. instead of multicasting we are unicasting towards sink. The working of 2<sup>nd</sup> scheme is as follows.

A node X receiving packet from node Y calculates its distance from the destination based on the coordinates of destination included in the data packet. Next it calculates the distance of Y (sender) from the destination. The data packet also contains the coordinate of source node. If the first distance is less by a specified factor, node X would broadcast the packet (as node X is closer to destination as compared to Y); otherwise the packet would be discarded (as node X is NOT closer to destination as compared to Y). The important point to note here is that there can be more than one nodes which can forward the data at one hop distance (all lying closer to destination as compared to sender). The aim of proposed scheme is to minimize the packet forwarding by reducing the number of forwarding nodes to one (in most of the cases). We have achieved this goal by dividing the geographic area into Zones and also deciding about a Zone Serving Node which is solely

responsible for the forwarding of packets. The Zone Serving Node would be the node in a zone closest to the center of the zone. Since all nodes are not forwarding the packets, it reduces the flooding in the network ultimately resulting in reduction in the power consumption.

‘Don’t Know’, ‘Yes’ and ‘No’ are three possibilities for a Zone Serving Node. In start there will be no Zone Serving Nodes and their status would be ‘Don’t Know’. With the passage of time as the data packets are processed by the sensor, the Zone Serving status of all sensors would be established as ‘Yes’ or ‘No’. The ‘Don’t Know’ is the default value to ensure the data forwarding process to initiate.

On receiving the packet, intermediate nodes first apply LBM (as explained) on the packet. If packet is not duplicated and LBM declares the node as optimal (near to destination when compared with source), the Zone Serving Node functionality is applied. Current node checks whether packet received is from same Zone or from another zone.

- Outside Zone: If the packet received is from another zone and the Zone Serving Node’s status is ‘Don’t Know’ or ‘Yes’, then the packet is transmitted; otherwise it is discarded.
- Current Zone: If the packet received is from the same zone, three possibilities exist.
  - If Zone Serving Node is set to ‘No’ and the distance of the source to the center of the zone is greater than the current node distance from center of zone, the Zone Serving Node is set to ‘Yes’ and the packet is transmitted.
  - If Zone Serving Node is set to ‘Don’t Know’, it is set to ‘Yes’ or ‘No’ based on the following conditions.
    - It is set to ‘Yes’ if the current node distance to center of the zone is less than the source distance from center of the zone.
    - It is set to ‘No’ if the current node distance to center of the zone is greater than the source node distance from the center of the zone. After setting the status of node, either it retransmits packet or discard it depending on the status just set.
  - If Zone Serving Node is set to ‘Yes’ and source distance to center of the zone is less than the distance of current node to the center of the zone, the Zone Serving Node is set to ‘No’. After setting the status of node, the packet would be discarded.

Zones are calculated in a manner that any extreme sensor of neighboring zones is completely within the range of sensor of current zone.

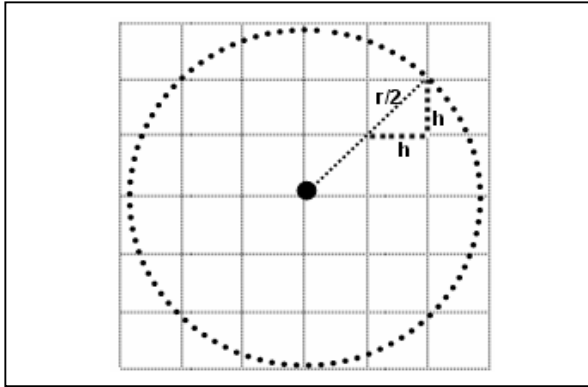


Figure 2. Transmission Range of a node

Figure 2 shows the transmission range of a sensor and the zones. Height / Width of a zone is represented by 'h' and 'r' shows the radius of transmission. The height of zone is calculated by equation 1.

$$h = \frac{r}{2\sqrt{2}} \quad \text{----- (1)}$$

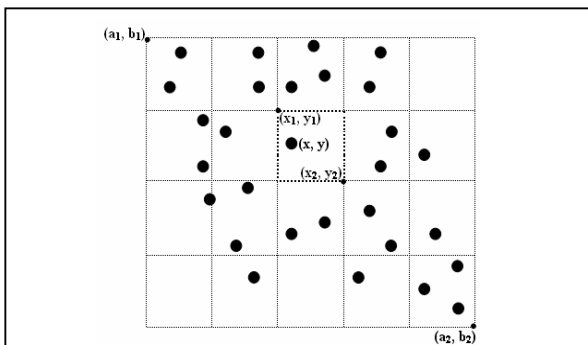


Figure 3. Deployed Area and zones

For a given deployed area coordinates we can calculate the number of zone within that area. In Figure 3, if we have coordinates as (a1, b1) and (a2, b2) then Equation 2 may be used to calculate the number of zones (n) for the deployed area.

$$n = nx * ny \quad \text{----- (2)}$$

$$\text{where } nx = \text{ceil} \left\{ \frac{\text{abs}(a2 - a1)}{h} \right\}$$

$$\text{and } ny = \text{ceil} \left\{ \frac{\text{abs}(b2 - b1)}{h} \right\}$$

Equations 3a and 3b calculate the distances (dC, dS) of current and source node from center of the zone respectively.



where (X, Y) is the center point of a zone and (CX, CY) are the coordinates of current node and (SX, SY) are the coordinates of the source node.

Center of a zone can be calculated by Equation 4.

$$X = \frac{X2 - X1}{2} \quad \text{----- (4)}$$

$$\text{and } Y = \frac{Y2 - Y1}{2}$$

where X1, X2, Y1 and Y2 are the zone boundaries, which are calculated by Equations 5a, 5b, 5c and 5d.

$$X1 = \left( \frac{X}{h} \right) * h \quad \text{----- (5 a)}$$

$$X2 = X1 + h \quad \text{----- (5 b)}$$

and

$$Y1 = \left( \frac{Y}{h} \right) * h \quad \text{----- (5 c)}$$

$$Y2 = Y1 + h \quad \text{----- (5 d)}$$

Where X and Y are the node coordinates and h is the height of the zone. A solved example based on the above equations is given in Appendix A.

## 5. SIMULATION ENVIRONMENT & RESULTS

Simulations are performed in OPNET 8.0[14]. The model we developed is a modified version of AODV (Adhoc on Demand Routing) Routing [15] model. The model for 3 different cases of 20, 35 and 50 sensor nodes has been simulated. The sensors are mobile and they are deployed with in the area of 1000 \* 500 meters. The coordinates of nodes in OPNET are considered as GPS coordinates. Zone size of 200 \* 200 meters is taken for simplicity. In start of the simulations all nodes are in 'Don't Know' status. The simulation Environment for 20 nodes is given in figure 4.

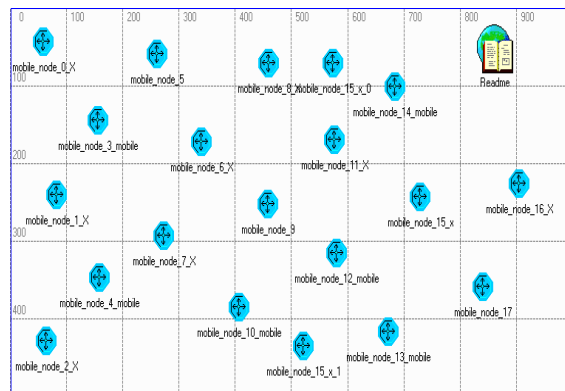


Figure 4. Simulation Environment- 20 nodes

For simplicity we have taken a single node to transmit data (node 17) for a single sink (node 0) while all other nodes are just forwarding the packets towards the sink. We have calculated and compared the result for simple flooding, LBM and ZOLA DSN schemes.

Figures 5, 6 and 7 show the comparison between three schemes for 20, 35 and 50 nodes.

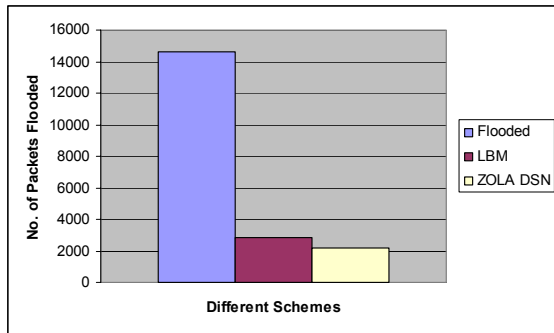


Figure 5. Comparison Environment for 20 Nodes Flooded, LBM and ZOLA DSN (L to R)

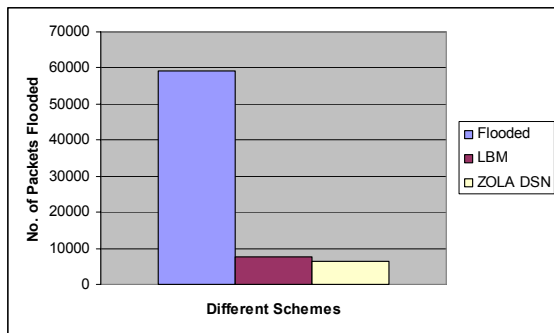


Figure 6. Comparison Environment for 35 Nodes Flooded, LBM and ZOLA DSN (L to R)

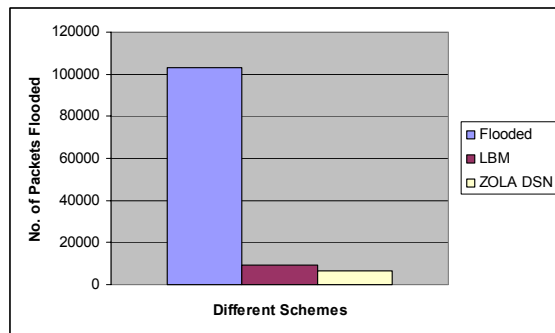


Figure 7. Comparison Environment for 50 Nodes Flooded, LBM and ZOLA DSN (L to R)

Table 1 summarizes the information presented in figures 5, 6 and 7 and the difference in flooding between the three schemes.

Table 1. Statistics of 3 Different Schemes

Scenario	20 Nodes	35 Nodes	50 Nodes
Flooded	14639	59066	103285
LBM	2829	7550	9446
ZOLA	2151	6415	6767
Difference b/w Flooded and ZOLA	12488	52651	96512
Difference b/w LBM and ZOLA	678	1135	2679

The difference in statistics shows clearly that ZOLA performs better than the other two schemes.

## 6. CONCLUSION AND FUTURE WORK

In this paper a novel scheme called ZOLA has been presented. It reduces the number of flooded packets as compared to LBM and Flooded schemes. The reduction in flooding ensures the reduction in power consumption and hence maximizes battery life of sensors. This scheme uses simple flooding rather than using any reactive or proactive algorithm for route discovery.

Future work will consist of a study of effect of zone size and density of nodes within a zone on flooding of packets.

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## APPENDIX A

### Example Calculations

Suppose we have 200 meter range (r) of a sensor node  
And the deployed area is 1000 meters \* 500 meters

The height 'h' of the zone is calculated as under

$$h = 200 / (2 * \text{Sqrt}(2)) = 90 \text{ meter approx.}$$

The number of zone may be calculated as under:

$$n = n_x * n_y$$

$$\text{where } n_x = \text{ceil}[(1000-0)/90] = 11$$

$$n_y = \text{ceil}[(500-0)/90] = 6$$

$$\text{Therefore } n = 11 * 6 = 66$$

A node at (30,50) may calculate the zone boundaries as follows to know about its current zone.

$$X1 = (30/90) * 90 = 0$$

$$X2 = (30/90) * 90 + 90 = 90$$

$$Y1 = (50/90) * 90 = 0$$

$$X2 = (50/90) * 90 + 90 = 90$$

So the height as well as width of a zone is 90 in this case and the start of zone is both 0 at height and width while end of zone is 90 at both height and width.

Another node having its co ordinates (110, 255), may have the following boundaries of the zone it resides in.

$$X1 = (110/90) * 90 = 1 * 90 = 90$$

$$X2 = (110/90) * 90 + 90 = 1 * 90 + 90 = 180$$

$$Y1 = (255/90) * 90 = 2 * 90 = 180$$

$$X2 = (255/90) * 90 = 2 * 90 + 90 = 270$$

This shows that the height and width are same again, but the start of zone in X range is from 90 and end of zone in X range is 180. Similarly the start of zone in Y range is 180 and the end of zone in Y range is 270.

Center of zone (X, Y) is calculated as follows by having the zone boundaries:

$$X = 90 - 0 / 2 = 45$$

$$Y = 90 - 0 / 2 = 45$$

Suppose a node receives the packet from a node having coordinates (30, 50). The coordinates of the receiving nodes are ((15, 65). As we have already calculated the center node (45, 45). We can calculate the dC and dS as under:

$$dC = \text{Sqrt}(((45-15) * (45-15)) + ((45-65) * (45-65)))$$

$$= 36.05$$

$$dS = \text{Sqrt}(((45-30) * (45-30)) + ((45-50) * (45-50)))$$

$$= 15.05$$

since 15.05 < 36.05 therefore source node will become the Zone Serving Node and the other will act as simple node.