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# A Novel Algorithm for Self Localized Packet Forwarding in Wireless Sensor Networks

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## *Abstract*

*Wireless sensor networks (WSNs) consist of sensor nodes that onward the sensed data in form of packets within the deployed network. Efficient packet forwarding is a key constraint in sensor networks and many demanding tasks in the network, together with redundancy estimation and sensor node localization depend principally on packet forwarding. Location based forwarding schemes have recently evolved as a promising solution for packet forwarding in WSNs, however, as the node density increases, the overhead incurred in terms of redundancy also increases considerably. With the motivation to develop a packet forwarding scheme that is tolerant to increase in node density and offers controlled redundancy a Self Localized Packet Forwarding Algorithm (SLPFA) is proposed in this paper.*

***Keywords:*** *gossip protocol, localization, node density, redundancy, WSNs*

## 1. Introduction

WSNs consists of spatially disseminated, independent sensors fabricated using thin film expertise for monitoring bodily or environmental state of affairs, such as moisture, temperature, sound, pressure, light, volatile organic compounds and many other phenomenon of interest over large sequential scales [1-3]. Packet forwarding is a common means for sensor nodes to efficiently share their information with each other. The packet distribution mechanism can be utilized to initialize the network arrangement for route detection between a given pair of senor nodes and could serve as an efficient method to localize sensor nodes. The simplest way of packet forwarding in WSNs is achieved by means of flooding protocol [4-5], under this protocol each sensor node resends the packet it receives for the first time. It is striking for its simplicity but causes high redundancy, packets collision, and bandwidth wastage [6], therefore a proficient packet forwarding scheme in WSNs is required to reduce the packet forwarding redundancy [7]. As an improvement to flooding, various probabilistic broadcast protocols have been projected [8, 9], the projected protocols shun the above cited troubles and provide substitute solutions to flooding. In addition, sensor network applications also require broadcast protocols to bear different degrees of reliability hence probabilistic protocols are more appropriate. One of the basic extensions to flooding is gossiping [10], where each sensor node forwards a packet in a probabilistic method. The extensions to gossiping protocols, [11-12] are largely static in nature and cannot adapt to the altering topology as well as changing application requirements. Therefore, static protocols require the network designer to conservatively pre configure the parameters, on a case by case basis, in order to allow for changes in the network topology (node density and number of duplicate forwarded packets). In this paper, we propose a Self Localized Packet Forwarding Algorithm (SLPFA) to control redundancy in WSNs. The proposed algorithm infuses the technique of gossip protocol for forwarding packets between the sensor nodes and routinely adapts to changing network topology with increasing node density. The simulation results highlight that SLPFA is light credence in view of the limited assets available with sensor nodes and works in a self localized manner. This paper is organized as follows:

Section 2 provides the description of gossip protocol and highlights few of its essential preliminaries in reference to WSNs. Section 3 presents the proposed SLPFA. The simulation model is described in Section 4 and Section 5 presents the results. Finally, Section 6 concludes the paper.

## 2. Gossip Protocol for WSNs

Location information of sensor nodes in WSNs is imperative since composed data has relevance only if the location from where it has been sensed is well known. Data collection and forwarding is based on common phenomena, so there is a high probability that this data has some redundancy. Gossip is a probability based protocol and its definition states that whenever a sensor node wishes to send a packet, it arbitrarily selects a neighboring sensor node, upon receiving the packet for the first time the neighboring sensor node repeats this process, if the same packet is received twice, it is discarded [13]. In order to achieve this, each sensor node has to keep track of packets it has already received. Besides supporting packet forwarding, gossip protocol also performs tasks to help inter process communication for information trade in networks. This section summarizes some vital preliminaries for the gossip protocol with orientation towards WSNs [14].

**2.1. Node Density:** The number of sensor nodes, *N* determines the level of confidence for the gossip protocol. Gossip protocol relies on the aspect that each sensor node can make its communication based on negotiations with neighboring sensor nodes. For a dense area *A*, sensor nodes are likely to receive more packets hence it might prove beneficial to hold the packets with very low probability. In some cases the area *A* might be very sparse, hence it might be beneficial to hold the packet with a probability, say P = 1, therefore the probability with which a sensor node holds the packets directly depends on the node density *D* of the sensor nodes deployed in the network. Sensor node density can be calculated using equation (2.1).

$$N = A\left(\frac{D}{r^2}\right) \tag{2.1}$$

**2.2. Node Degree:** The node degree Ń depends on the values of *A*, *N* and *R*; and it can be calculated using equation (2.2).

$$\acute{N} = N - 1\,\frac{\pi R^2}{A} \tag{2.2}$$

It is to be noted from equation (2.2) that Ń will always a variable parameter, since *A*, *N* and *R* cannot be always homogeneous in WSNs.

**2.3. Frequency of Received Packets:** Sensor nodes are understood to be adjacent if the distance between them is less than the defined transmission range. The sensor nodes if set to a very low probability of listening will pass on a packet only if there is a change, however they may send very few packets in special cases. Further, such a sensor node may or may not choose to listen depending upon the initial value of P. Thus a sensor node will gossip only if it receives a new packet else it continues to be in a passive state.

**2.4. Fan Out (*n*):** It is defined as a configuration parameter to count the number of sensor nodes selected as gossip targets, upon receiving a packet for the first time, the sensor node selects gossip targets to forward the packet. The trade off linked with this parameter lies between desired fault tolerance level and observed redundancy. High value of *n* guarantees fault tolerance but leads to an increase in the network redundancy.

**2.5. Relative Message Redundancy (RMR):** RMR measures the message overhead for a gossip protocol. It is calculated using equation (2.3).

$$\mathrm{RMR} = \frac{m}{n-1} - 1 \tag{2.3}$$

In equation (2.3) $m$ denotes the number of packets forwarded during a procedure. This metric is applicable if at least two sensor nodes receive the packet. Zero value of RMR denotes that there is exactly one packet exchange per sensor node and is clearly the optimal value. High value of RMR indicates a poor network usage and for gossip based packet forwarding the value of RMR should tends to $n - 1$.

**2.6. Maximum Rounds**: This is the maximum number of times a given gossip packet is retransmitted by the sensor nodes. Each packet is transmitted with originally a value zero, which is increased later on each time whenever a sensor node retransmits the packet. Sensor nodes will only retransmit a packet if its round value is smaller than the maximum rounds parameter.

## 3. SLPFA

SLPFA is intended for packet forwarding in high density WSNs because scalability is essential for sensor networks as they are composed of hundreds and thousands of sensor nodes. The localization of sensor nodes increases with the increase in sensor node density as each sensor node makes the decision to forward the packet according to the local information obtained from its neighboring sensor nodes. It is to be noted that SLPFA does not require any topology information hence the overhead remains small, besides this all sensor nodes are static and have the same characteristics (identical communication and sensing range). The locations of deployed sensor node are not known in any arbitrary coordinate system and the neighbors of a particular sensor node are determined on the basis of packet forwarding. Therefore the sensor nodes decide locally to forward the packets (helping like an active node) or to ignore the previously received packets. The packet forwarding will be redundant if a sensor node has already received the same packet at an earlier time. The major confront connected with this type of packet exchange lies in accurate estimation of redundant packet counts with varying number of sensor nodes within the network confined to the total number of forwarded packets. SLPFA is based on the assumption that the sensor nodes $N$ are deployed within a specified area $A$, are allowed to broadcast a message $m$, for an event $E_N$, intuitively with the increase in number of sensor nodes corresponding to a high density wireless sensor network. The steps of SLPFA are mentioned in Table 1.

**Table1. SLPFA**

```
1:  BEGIN
2:  define $A$, $N$ and $m$
3:  where $m$ and $N \subset A$
4:  Initialize $N = 50$ and $m = 1$,
5:  define $E_N$
6:  deploy $N$ such that $N \in A$
7:  Start
8:  packet forwarding
9:  forward initial packet, $m$
10: select neighbor sensor node as gossip targets, $n$
11: If neighbor sensor node receives packets for the first time, Go to step 9;
    Else go to step 14
12: End if
13: neighbor sensor node receives the packet twice, Then
14: discard packet forwarding;
    update, if $N$ abandons its attempt to re forward packet
15: repeat step 8 for $N$ = {100,150, 200, 250, 300, 350, 400, 450 and 500} with $m = 1$
16: Check redundant packets individually for each round with $N$ = {50,100, 150, 200, 250, 300,
    350, 400, 450 and 500}
17: END
```

It is obvious that SLPFA incorporates the benefits of gossip protocol in a self localized manner to control redundant packet forwarding The algorithm also guarantees the advantage that sensor node has to be active only during packet forwarding and no node has to localize itself with respect to a global coordinate system. This ensures that sensor nodes with smallest distance from their neighboring sensor nodes will also require minimum forwarding effort to forward the packet.

## 4. Simulation Setup

We presumed a very simple architecture for randomly deploying the sensor nodes for implementing a Wireless Sensor Network (WSN). An area of 500m x 500m was selected and the sensor nodes having a normal distribution with a transmission range of 200m were deployed for one scheduled event for different values of node densities. This section explains the definitions used in the algorithm followed by the discussion of test results and visualization of different sensor node densities.

### 4.1. Definitions

- $A$ denotes the area of the WSN.
- $D$ is the average number of sensor nodes per region.
- $r$ is the coverage radius of each sensor node.
- $N$ are the total number of deployed sensor nodes.
- $m$ are the number of forwarded packets.
- $h$ are the number of sensor nodes that have rebroadcasted the packet after its reception.
- $R_B$ denotes the ratio of number of sensor nodes that have rebroadcasted the packet to the number of sensor nodes in the intact network.
- P defines the probability by which a sensor node can receive a packet.
- $R$ denotes the transmission range of sensor node.

- $n$ denotes the number of sensor nodes selected as gossip targets.
- $E_N$ depicts the number of events scheduled for forwarding the packet.

On the basis of above definitions and mathematical calculations, equations (4.1) and (4.2) are modeled.

$$N = A\left(\frac{D}{\mathrm{r}^2}\right) \tag{4.1}$$

$$N = A\left(\frac{D}{r^2}\right) \tag{4.2}$$

The rebroadcast ratio $R_B$ manifests the efficiency of the gossip protocol since $R_B$ is inversely proportional to the broadcast efficiency. High value of $R_B$ results in high redundant rebroadcast with low broadcast efficiency. Therefore by applying equations (4.1) and (4.2), the efficiency of SLPFA is determined taking into account the minimum value of $R_B$, by applying equation (4.3).

$$R_{B=hr^2/AD} \tag{4.3}$$

The values of $A$, $D$ and $r$ are determinate, hence in order to obtain the minimum value of $R_B$, the value of $h$ should be minimized because if the node density $D$ increases then the value of $R_B$ decreases. SLPFA is evaluated for different values of $N$. The sensor node densities are shown respectively in Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10.

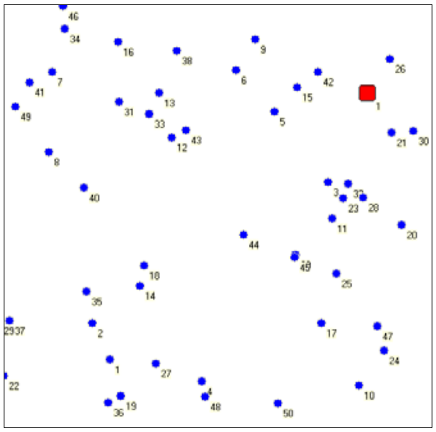

**Figure 1. Sensor Node Density ($N$ = 50)**

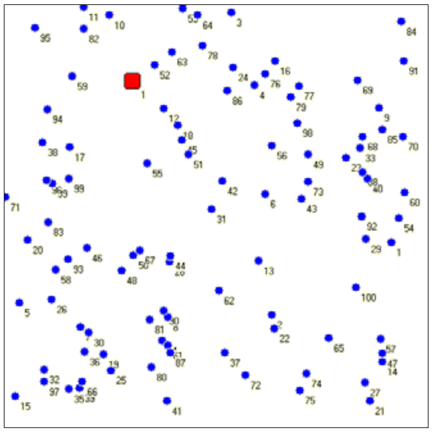

**Figure 2. Sensor Node Density ($N$ = 100)**

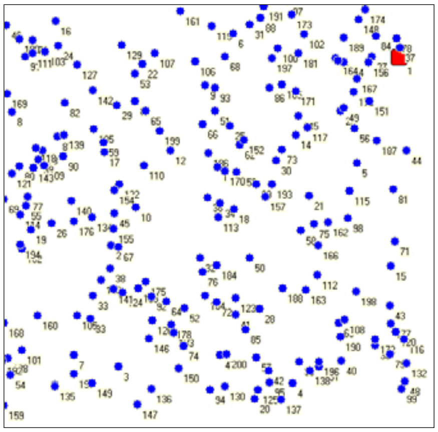

Figure 3. Sensor Node Density (*N* = 150)

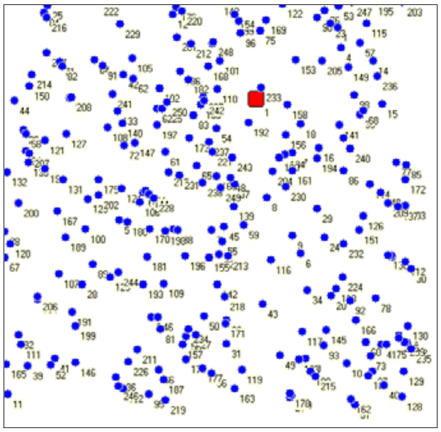

Figure 4. Sensor Node Density (*N* = 200)

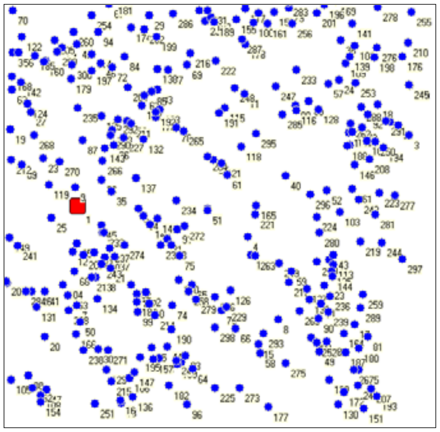

Figure 5. Sensor Node Density (*N* = 250)

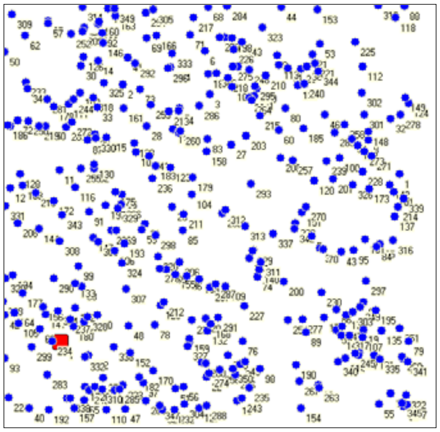

Figure 6. Sensor Node Density (*N* = 300)

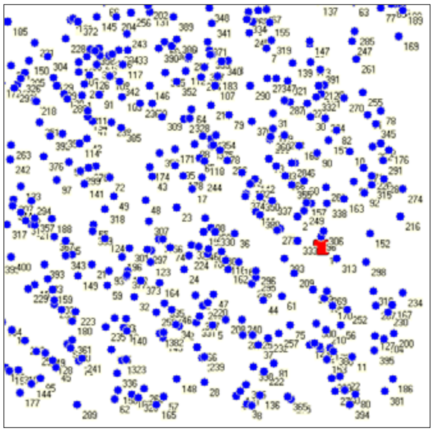

Figure 7. Sensor Node Density (*N* = 350)

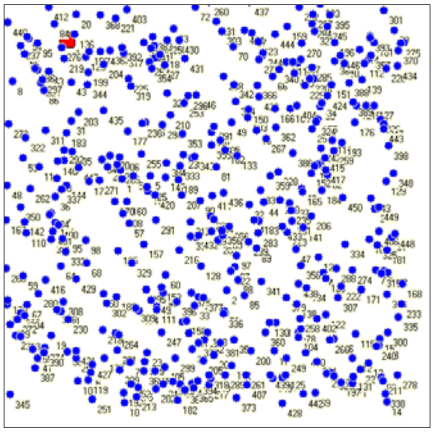

Figure 8. Sensor Node Density (*N* = 400)

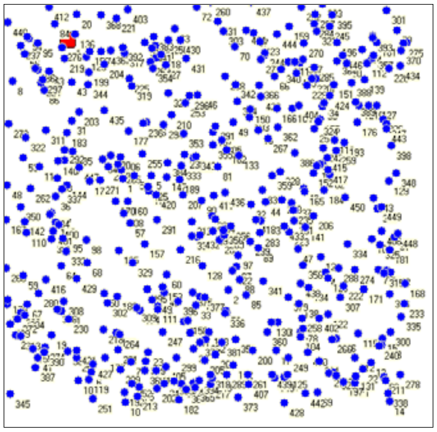

**Figure 9. Sensor Node Density (*N* = 450)**

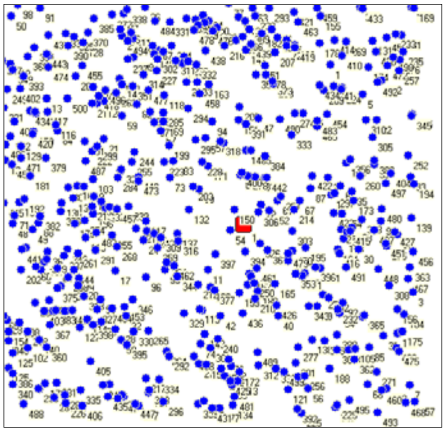

**Figure 10. Sensor Node Density (*N* = 500)**

## 5. Results

For analyzing the effect of SLPFA, we simulated a WSN constituting of different number of sensor nodes. The simulations were performed on SNet-Sim [15]. The randomly placed sensor nodes were simulated in an area of 500m × 500m, and each sensor node can communicate with neighboring sensor node. It was observed that SLPFA promoted efficient packet forwarding within the entire network besides maintaining a controlled level of redundancy despite the increase in node density. Therefore the stability of the proposed algorithm in high density sensor networks is guaranteed since the simulation for different values of *N* ranging from 50 to 500 was performed. The received packet counts and received redundant packet counts against different values of *N* are presented in Table 2. The simulation results verify the controlled redundancy within the network with the increase in number of sensor nodes over the same deployment area. Figure 11 shows the graphical data between number of sensor nodes and percentage of observed redundancy. The evaluation of controlled redundancy is promising for networks with large number of sensor nodes as in cases of sensor node failure the network can effectively retain its packet forwarding in a fault tolerant manner. The controlled redundancy will also serve in improving sensor node localization in WSNs where density of sensor nodes is a governing factor.

**Table2. Packet Counts during Packet Forwarding**

| Sensor nodes | Forwarded packets | Received packets | Redundant packets |
|---|---|---|---|
| 50 | 100 | 30 | 70 |
| 100 | 200 | 79 | 121 |
| 150 | 300 | 121 | 179 |
| 200 | 400 | 166 | 234 |
| 250 | 500 | 208 | 292 |
| 300 | 600 | 248 | 352 |
| 350 | 700 | 292 | 408 |
| 400 | 800 | 335 | 465 |
| 450 | 900 | 376 | 524 |
| 500 | 1000 | 424 | 576 |

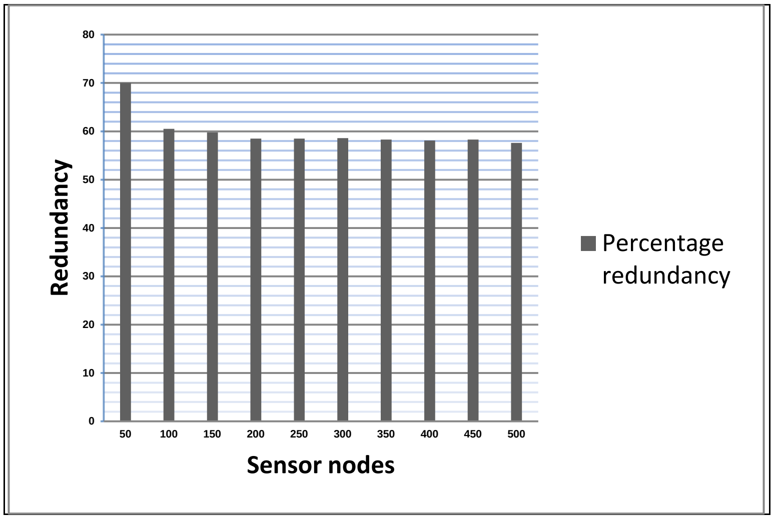

Figure 11. Redundancy Vs Number of Sensor Nodes

## 6. Conclusion

SLPFA utilizes the aspects of the gossip protocol towards controlling the redundancy and accurately estimates the received redundant packets without the location knowledge of the neighboring sensor nodes. Although the assessment of least redundancy during packet forwarding has been done in many studies [16-17] but to the best of our familiarity, we are the first to present a speculative study for redundancy assessment during packet forwarding in WSNs. SLPFA is scalable to sensor node density and works well for a small network topology with 50 sensor nodes ranging to a large network topology with 500 sensor nodes over the same deployment area. In most of the existing algorithms for WSNs, redundancy and number of sensor nodes are considered independently, however, we prove that localization can be significantly improved by combining these two aspects together during packet forwarding. The analysis of results show that the redundancy maintains a controlled level for increased values of sensor node densities, this approach can be used to improve self localization of unevenly arranged sensor nodes in dense networks as neighborhood location knowledge of sensor nodes does not cast much effect on the proposed algorithm.

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