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Level Controlled Gossip Based Tsunami Warning Wireless Sensor Networks

Santosh BHIMA, Anil GOGADA and Ramamurthy GARIMELLA
RSA Security India Pvt Ltd, IBC Knowledge Park Bannerghatta Road, Bangalore-560029, India
38-39-86-3/10, S. K Residency, 104 Area, Vishakapatnam-530037, India
International Institute Information Technology Hyderabad, Gachibouli, Hyderabad-500034, India
E-mail: bhima.santosh@rsa.com, anil_gogada@infosys.com, rammurthy@iiit.ac.in

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Abstract: This paper deals with a warning system based on distributed sensor networks employing level controlled gossip. Level controlled gossip is a technique that is being proposed which employs leveling and gossiping together. This technique reduces the number of messages by transmitting messages in the direction of base station and thereby increasing the life time of sensor network. By using various power levels at base station the sensor field is hierarchically partitioned into levels of increasing radius (containing various sensor nodes). The algorithm divides the entire sensor network into logical concentric zones based on proximity from the base station, whereby the packet is transmitted from a node of higher depth to nodes in the next zone with lesser depth. The transmission probability increases with the proximity of the Tsunami wave to the base station. The primary advantage of the protocol is transmitting a critical event with higher probability and at the same time conserving life time of the network for future monitoring. *Copyright © 2009 IFSA.*

Keywords: Leveling, Gossiping, Network lifetime

1. Introduction

One of the major advances in the field of surveillance technology is the deployment of distributed sensor networks. This has provided a means to monitor areas which are either unreachable or hostile to human existence. For this reason, sensor networks have to be left unattended for long periods of time which makes replacement and recharging of batteries a difficult task. It is therefore crucial to take measures for utilizing available resources in an efficient manner. Hence to prolong the life time of sensor networks we need to minimize the wastage of energy [1].

Tsunami is one such critical event which has to be monitored and the system (Tsunami Warning System) that monitors it should have a longer life time. The speed of the Tsunami wave is given by

$$\text{Speed} = \sqrt{\text{depth of the sea}} * g \quad (1)$$

As the tsunami wave approaches shallow water, its speed decreases as the depth of the sea decreases. As the constant energy flux is dependent on both wave speed and wave height, the height of the wave increases as it approaches shallow water.

Tsunami wave length is of order 100km and time period is of order hours. So the monitoring application should cover vast area for extended period of time without malfunction.

Flooding is the basic way of transmitting a message in a network that does not depend on location information from external sources like GPS. [5] proposes 'Flooding' as a way to route data. It also uses some techniques to avoid unrestricted flooding and reduce wastage of resources. There have been many improvements to the basic flooding technique. Despite those improvements, flooding produces many messages unnecessarily.

Leveling is a technique that drives the information packets in direction of the base station. This directional property restricts the packets to be transmitted only from an outer layer to inner layer, thereby reducing the number of messages broadcast [6]. We also use hierarchical partitioning to ensure this. In this paper, a progressive analysis of the available options for the system is made and the best ones among them are incorporated in the final model of Tsunami warning system.

The rest of this paper is organized as follows: Section 2 contains related work. Section 3 discusses about level controlled gossip, pure gossip methodologies and other implementation issues. Section 4 discusses about simulation results and Section 5 concludes our paper.

2. Related Work

Gossiping, as of now has been used with or without using location information. The protocols such as Regional gossiping [4] exists which location information to know the position of the sensor nodes. But with the assumption of knowing location information, there exists a better protocol called GPSR [3]. Gossip based ad-hoc routing [2] is by far the efficient form of gossip that doesn't need location information. We propose to use both gossiping [2] and leveling together as level controlled gossip routing algorithm. To the extent of our knowledge level controlled gossip is a novel improvement over gossip. We have analyzed both pure gossip and level controlled gossip in the context of Tsunami warning system.

3. Description

3.1 Leveling

We have assumed that the base station has the capability of transmitting at various power levels. During the initial deployment the base station sends a level-1 signal with minimum power level, all the nodes that receive the signal will set their level as 1. Next the base station increases its signal power to reach the next level and sends a level-2 signal. All nodes that receive the signal, but do not have a level assigned previously, set their level to 2.

This process continues until the base station sends signals corresponding to all the levels. The number of levels is equal to the number of different transmission levels at which the base station can transmit. Apart from this level information, there is no need of any local information. Leveling is done internally without the help of any external facilities such as GPS and in this manner it differs from other protocols that assume local information [3] [4]. At the end of the leveling phase, all the nodes will be assigned to certain levels. Each node belongs to a single level and the probability of that particular level will be assigned to all the nodes of that level.

The probabilities associated with each level can be set during leveling phase. The probabilities decrease as we move from inner levels to outer levels as shown by the relation.

$$P1 > P2 > P3 > ... > Pn - 1 > Pn.$$

Here P1, P2, P3...Pn denote the transmission probabilities with which a node should forward a received message to the nodes in other levels. These probabilities denote these probabilities can be varied any time by the base station to suite the monitoring requirements.

For proper communication between the levels, a node should have a coverage radius R, which is at least 2L, where L is the distance between any two adjacent levels. The coverage radius

$$R = 2L + \varepsilon, \tag{2}$$

where ε should be minimal so as to decrease the energy wastage due to signal propagation beyond the intended levels.

3.2. Pure Gossiping

After the initial leveling, in pure gossip the transmission probability of a message is set according to the level in which Tsunami event is first detected. Assuming that base station is in the direction of the coastal area, the criticality of the Tsunami increases with the proximity of the level in which it is initially encountered.

So, in the outer layers the gossip probability will be less and in the inner layers that are closer to the base station the gossip probability will be more. Once a message is received by a node, it checks to see if it is from a higher level. If it is from a lower or same level the message is discarded. If the packet is from a higher level, depending upon the gossip probability, the node either sends or discards the message that has to be transmitted.

Gossip based approach saves 35 % messages compared to pure flooding. These results are extensively studied in [2]. From [2] the gossip probability ranges from 0.6 to 0.8 assuming the node degree as 8 in random networks. In pure gossip, nodes in all the levels transmit the messages with equal probability, which is same as the probability of the level in which the event was detected. This is not the case in level controlled gossip where gossip probability increases during the transmission along the levels.

3.3. Level Controlled Gossip Approach

In Level controlled gossip, when an event is detected the message is broadcast with the probability of that level. When a node in the lower level receives this message, it transmits the message with

probability of its corresponding level. So, the same event is being transmitted at lower probabilities in outer layers and higher probabilities in inner layers.

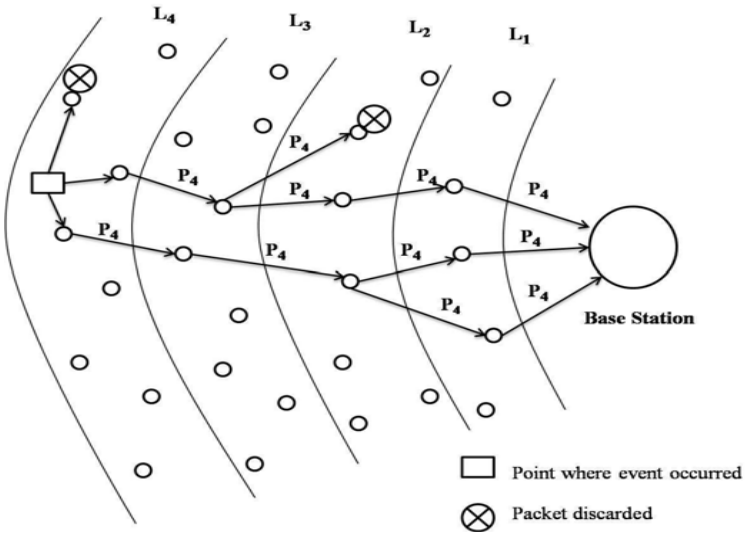

Fig. 1. Pure gossip approach: a node in level 4 starts broadcasting with its level probability. The nodes that chose to transmit the message will transmit it with same probability as that of the initial level probability (L4 probability).

The advantage of level controlled gossip is, it balances the gossip (probabilistic flooding) happening in the levels according to the proximity of the level to the base station. In the outer levels, the criticality of the event is less and hence it is broadcast with less probability. But as the Tsunami wave approaches the inner levels, the criticality of the event has increased. So the gossip probability of the event is also increased as we move inwards, level wise. This approach balances the network life time and monitoring reliability.

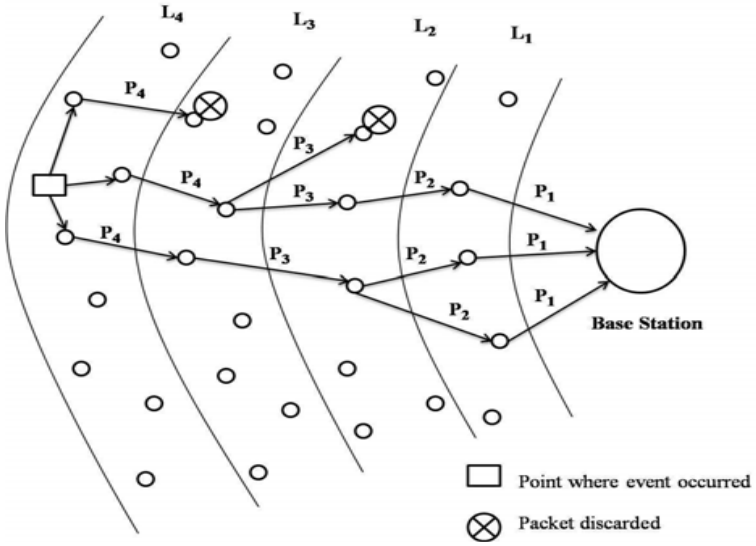

Fig. 2. Level controlled gossip approach: A node in level 4 starts broadcasting. The nodes that chose to transmit the message will transmit it with their own level probabilities. Some nodes discard the message.

3.4. Combination of Pure and Level Controlled Gossip Approach

Let the critical region be defined as the region within a threshold distance from the base station, where the occurrence of Tsunami is highly possible and devastating. For Tsunami monitoring system, we found that combination of pure and level controlled gossip is more efficient than any of the individual approaches. As the monitoring area is huge, so events in the areas which lie under critical region need to be reported with more prominence than the events in the areas which lie beyond the critical region. This should be done in a way that prolongs the network life time. If level controlled gossip is used in the critical region and pure gossip in the regions beyond critical region, then there will be maximum improvement of the network life time without risking the warning system. This is due to following reasons:

1) Messages from the non critical region are transmitted with the same minimal probability as that of the initial source level in which they are initiated, which saves number of messages in the inner levels (as the outer levels have less probability).

2) Messages from the critical region are transmitted with probabilities increasing inwards to base station. This approach optimizes the number of messages and at the same time reports the event with safe probability.

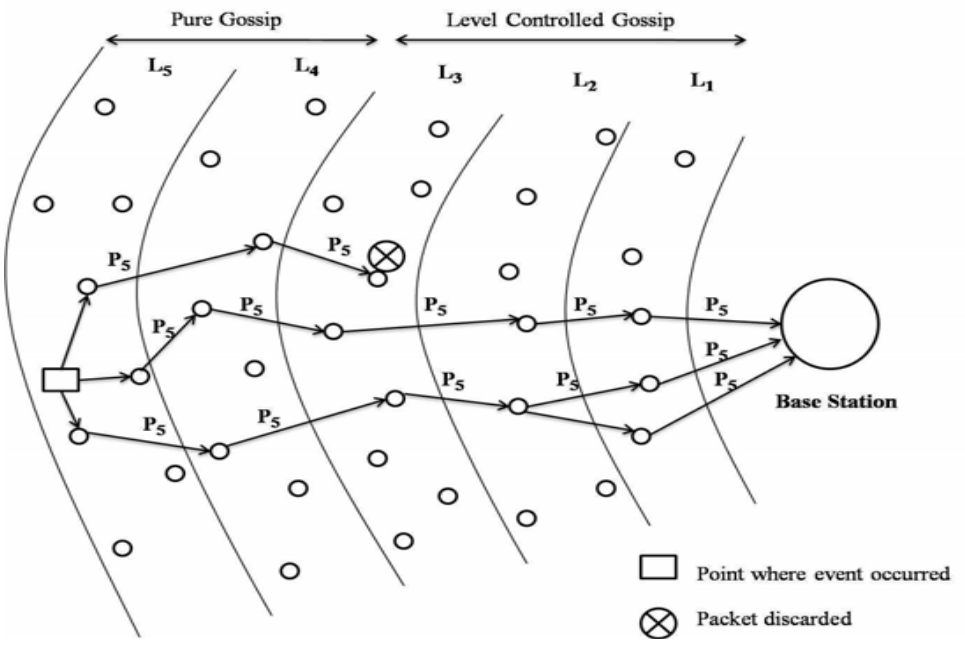

Fig. 3. Combined approach: First 3 levels are set to work in level controlled gossip mode and further levels in pure gossip mode. Here an event occurred in pure gossip region, so all the further gossiping happens as if the whole network is in pure gossip mode If the event had occurred in the level controlled gossip area, then the further communication would have happened as if the whole network is in level controlled gossip.

4. Simulation Results

Extensive simulation work has been done and the graphs plotted are based on the results obtained from a series of simulations. These algorithms were implemented using C language. From the plotted graphs it is proven that, the algorithms we proposed will increase the life time when compared to Gossiping.

Network Model. For the purpose of evaluating the algorithms, we simulated them by varying the number of nodes in the network. For each algorithm we started with a 100 node network and thereby generating the number of events that the network could handle. Similarly, the number of nodes has been varied up to 700 and the corresponding number of events that these networks could handle was plotted in the plot.

The two metrics of interest provided by our simulator are:
Definition 1. *Number of Events*: It defines the life time of the network.
Definition 2. *Number of Nodes*: The number of nodes that are present in the network.

Fig. 5 depicts that with a 700 node network model a Pure gossip approach has a larger network life time and is efficient than Fig. 4 (Gossiping). With 700 node network the Gossiping protocol network dies down at around 60 events where as the Pure gossip protocol network can withstand up to 80 events.

Fig. 6 depicts the network life time of Level controlled gossip and now compares it with the Fig.4 (Gossiping approach). Initially with a 100 node network both the protocols last until 80-100 events but, as the size of the network increases there is a change in the performances of both the protocols. With a 700 node network model, a Level controlled gossip model lasts longer and is quite efficient than Gossiping.

Fig. 7 depicts the network life time of a network model that employs a Combination of Level controlled gossip and pure gossip approach. Compare this with Fig. 4 (Gossiping) and it is evident that the Combination of Level controlled gossip and pure gossip is quite efficient than Gossiping. The above results shows that all the algorithms Level controlled gossip, Combination of Level controlled gossip and Pure gossip yields better results than Gossiping.

5. Conclusion

We proposed a novel idea of level controlled gossip which applies the concept of leveling and level controlled probabilities to pure gossip. Initial studies have shown that level controlled gossip, with appropriate variation of probabilities with levels, depending on the factors like node density, proximity from the base station, is a worthwhile improvement over pure gossip and other improvements of flooding which do not use GPS.

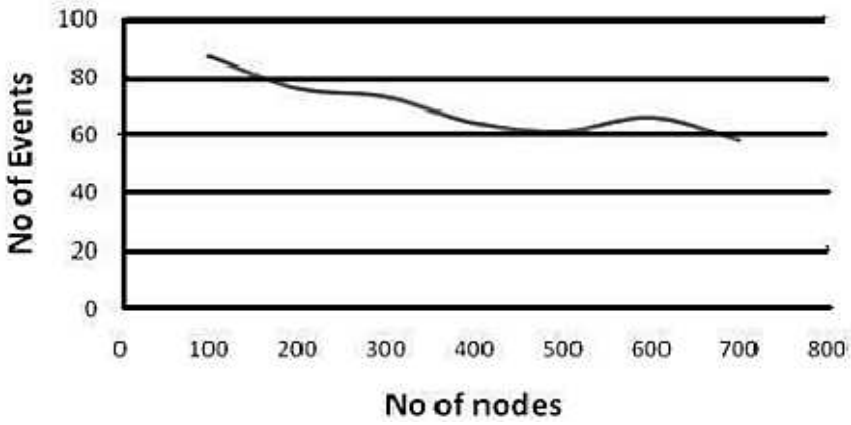

Fig. 4. Gossip based.

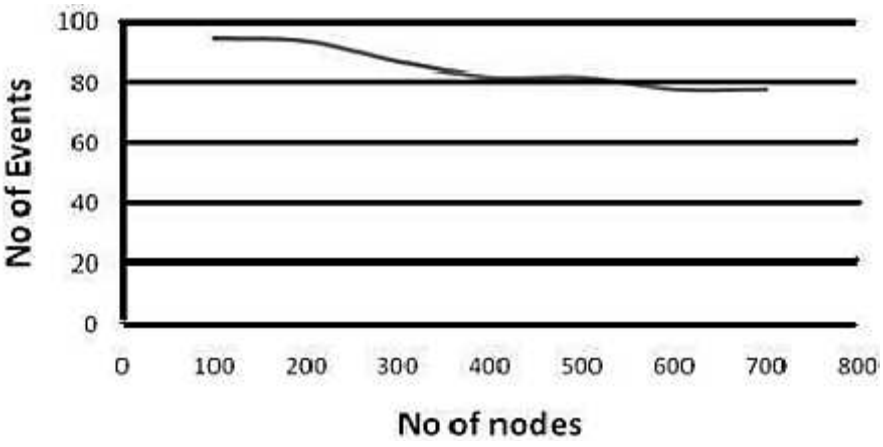

Fig. 5. Pure Gossip Based.

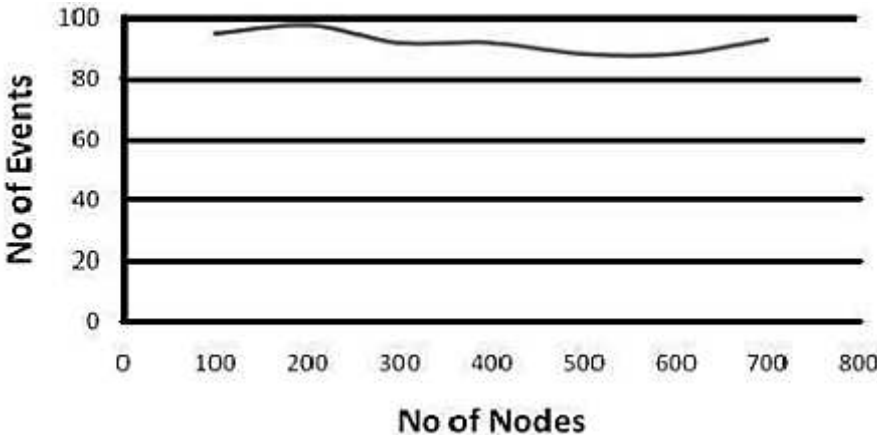

Fig. 6. Level Controlled Gossip.

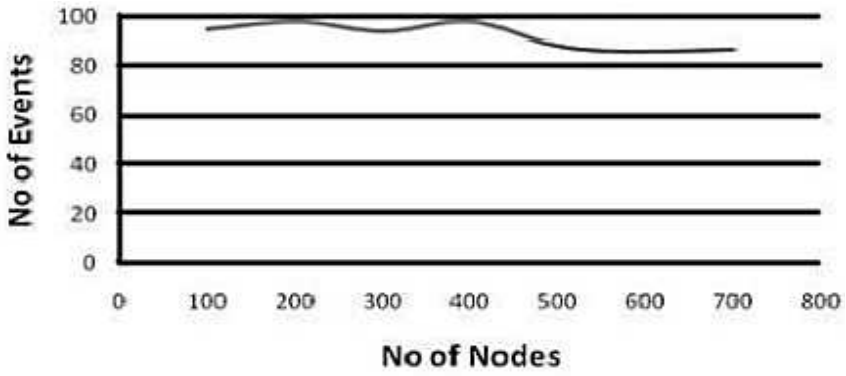

Fig. 7. Combination of Level Controlled Gossip and Pure Gossip.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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