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ORIGINAL ARTICLE

The effect of location errors on location based routing protocols in wireless sensor networks

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Abstract Location-based routing protocols use position information for making packet forwarding decisions, assuming perfect location information. Unlike topological routing algorithms, they do not need to exchange and maintain routing information. They work nearly stateless. However, in practice there could be significant errors in obtaining location estimates.

In this paper, the impact of location errors on power consumption of these protocols will be analyzed via developing a mathematical model represents the location errors that may occur in real deployment. Then a simulation of the power consumption of two location-based routing protocols, Geographic Random Forwarding (GeRaf) and Minimum Energy Consumption Forwarding (MECF), is carried out to evaluate the mathematical model.

Both the obtained simulation results and the developed mathematical model show that this type of routing protocols suffers from substantial performance degradation in terms of power consumption in presence of location errors.

1. Introduction

A wireless sensor network (WSN) is an infrastructure comprised of sensing (measuring), computing, and communication elements that give an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. WSN subjects to a unique set of resource constraints such as finite battery power and limited bandwidth. In a typical sensor network, each sensor node has a microprocessor, a small amount of memory, one or more sensing devices, and ability to communicate wirelessly with other nodes within its radio range. Usually a WSN consists of large number of sensors that are deployed randomly, and it has self-configuring ability that allows formation of connections and copes with the resultant nodal distribution. These inherent characteristics make routing in WSN very challenging, and push toward designing new routing protocols to optimize resource usage, especially power efficiency. This is because power is the key constraint, as sensors have to work unattended, sometimes for a long period of time once they are placed.

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Routing protocols in wireless sensor networks are classified in the following basic four categories.

1.1. Data-centric protocols

In data-centric protocols, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors [1].

1.2. Hierarchical protocols

WSN is divided to multiple clusters, and each cluster is managed by a special node, called cluster head, which is responsible for coordinating the data transmission activities of all sensors in its cluster [2].

1.3. Location-based protocols

In location-based protocols, sensor nodes are addressed by means of their locations. They use locations information for making packet forwarding decisions [3].

1.4. QoS-based protocols

It is also important to consider quality of service (QoS) requirements in terms of delay, reliability, and fault tolerance in routing in WSNs [6]. QoS based routing protocols try to find a balance between energy consumption and QoS requirements.

Location based routing protocols determine the path to send the traffic through by using the position information of the source, the direct neighbors of the source and the destination. As a result, very little routing information is needed and no energy is spent on route discovery, queries or replies. Node memory and computation requirements are decreased as well as the routing protocol's traffic overhead. In location-based routing, the process is localized and distributed so that all nodes are involved in the routing process [7].

In this paper, the power consumption of two routing protocols will be investigated. The first one is GeRaf, which is one of the location based routing protocols [4]. It is designed for wireless ad-hoc and sensor networks. In this protocol, at any hop, the sender node chooses the neighbor that is closest to the destination as next relay. While in the second protocol, MECF [5], at any hop, the sender node chooses the neighbor that is closest to it as next relay.

2. Related work

Location based routing protocols assume that the obtained location information is perfect. However, in reality there are errors in the location information. These errors are produced by the localization process. Many researches focused on this fact. [8] Introduces an analysis of the errors impact on location based routing in wireless ad hoc networks. This analysis is based on the assumption that the localization algorithm has an error characteristic that is circularly symmetric, i.e., the localization algorithm would localize a node anywhere within a disk around its actual position. The researchers analyzed and simulated only specific protocol description and observe the packet delivery ratio and the power consumption of that protocol. Another study [9] developed an analytical method for examining node's location error in multihop networks. The method depends on Cramer Rao bound (CRB) to compute the accuracy of localization. This study does not clarify the error's impact on location based routing protocols. On the other hand [10], evaluates localization algorithms used in WSN depending on traditional metrics, and introduces new metrics that can distinguish better among alternative localization algorithms without showing the effect of these localization errors on the routing protocols.

In this paper, a new mathematical model for localization errors in wireless sensor networks will be developed. This model is based on Gaussian distribution to comprise all the sources of location errors in WSN. Using this model, the impact of localization errors on the power consumption of location based routing protocols will be investigated. Finally, the model will be verified by simulating the power consumption of two location based routing protocols.

In summary, compared with the study in [8], Gaussian distributed location errors are introduced on node coordinates to study the effect of location errors on location based routing in general, not just for a specific protocol description. Compared with [9,10], this study investigates the effect of location errors on the power consumption of the location based routing protocols.

3. Mathematical model

There are many sources of location errors in the localization process. One of them is inaccurate measurement of distance or bearing due to sensing technology limitations or environment noise. Also, localization algorithms may cause errors due to the resource limitation of the sensors [11]. There are many other factors that contribute to the final error in the localization process such as network density, uncertainties in anchor locations and anchor density. Therefore, a Gaussian distribution is more appropriate to model location errors due to the many uncertainties involved in localization process. In this study, it will be assumed that we have large number of sensors deployed randomly in Euclidean plane. The location error at each node is modeled by a Gaussian distribution [12], with zero mean and finite standard deviation. The zero mean assumption follows the law of large numbers:

$$\lim_{n\to\infty} \frac{1}{n}\sum_{k-1}^{n} x_k = 0 \tag{1}$$

where n is the number of sensor in network, x_k is the location error at sensor k on one of the axes, k is an integer.

It will be assumed that the location errors for all nodes in a network are independent and the variance of Gaussian error on x-axis and y-axis for each individual node is equal.

Fig. 1 shows two sensors, P_i and P_j, with real location $P_i(X_i, Y_i)$, $P_j(X_j, Y_j)$, and measured location $P_i'(x_i, y_i)$, $P_j'(x_j, y_j)$, respectively (to simplify Fig. 1 we put P_i at the origin, with no errors i.e. $P_i = P_i'$, in the simulation every node has errors). According to our assumptions

$$X_i = x_i + w_i \tag{2}$$

$$Y_i = y_i + w_i \tag{3}$$