PROBABILISTIC INFORMATION DISSEMINATION ASPECTS IN WIRELESS SENSOR NETWORKS LOCATED IN HISTORICAL BUILDINGS

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Abstract. A recent application of wireless sensor networks for monitoring ambient vibrations in historical buildings, has necessitated the need for efficient information dissemination in such environments in order to minimize the effects of the energyvorous wireless transmissions on the system's lifetime. In this paper, flooding is considered as the most suitable information diseemination mechanism, aiming to reduce the number of redundant transmissions for the particular historical buildings deployment. A simple but representative analytical model is introduced and along with simulation results it is possible to estimate the smallest transmission radius for minimizing energy consumption in the particular environment.

Introduction

Wireless sensor networks (WSNs) [1], have been the focus of the wireless networks research communities for more than a decade with numerous applications in a wide area of human activities (e.g., health, science, environment). The nowadays small sizes but of increased computational power, transmission range and battery capacity [2] sensor devices allow for imagining numerous applications and in some sense it is expected that future human activities will always be under the surveillance of such sophisticated systems.

Following this trend, historical buildings are the focus of sensor applications regarding monitoring ambient vibrations in order to get estimations with respect to the buildings' conditions. For years the dominating sensor-monitoring technologies were based on wired sensors [3, 4] which can be either difficult (e.g., due to the condition of the building) or forbidden (e.g., due to prohibitive legislation) to install such a system. Technological advances allow for new wireless systems (e.g., [5, 6]) in order to avoid the hazardous installation problems in historical buildings.

Depending on the particular architecture and particularly when a wireless ad hoc sensor network is considered as the underlying system, there is an increased need for information dissemination. For example, apart from the ever need data collection process to the sink node, it may be required to synchronize clocks in case there is an absentia of a main control entity, as it is the case in most such system. Under this light, it is essential to avoid redundant transmissions and save as much battery as possible in order to prolong the system's lifetime.

In this paper flooding, e.g. [7] with forwarding probability equal to one, is considered as the main dissemination mechanism. The way to avoid redundant transmissons is through the determination of the smallest transmission radius under which the network is connected. Extensive experiments took place by considering sensor deployment as it would be the case in a historical building, the aim being the minimum transmission radius for energy conservation. Following a preliminary analysis and assuming a basic sensor deployment, a minimum value with respect to the previously mentioned radius is obtained which depends on both the volume of the building and the number of deployed sensors.

In the following section, useful definitions are given which will be used in the subsequent section of analysis to introduce the basic analytical model. Simulation results are presented in the sequel and the conclusions are drawn at the end of this paper.

Definitions

Historical buildings in this work are modeled as 3d-objects consisting of building's exterior walls. Wireless sensors are placed at random positions within the 3d-object. The following variables define Wireless Sensors Network's WSN characteristics. V_B is building's volume and N is the number of installed wireless sensors. L is total network's number of bidirectional links, or equivalently, the number of connections between wireless sensors. D is the "density" of sensors in the building, or the number of installed sensors per volume unit.

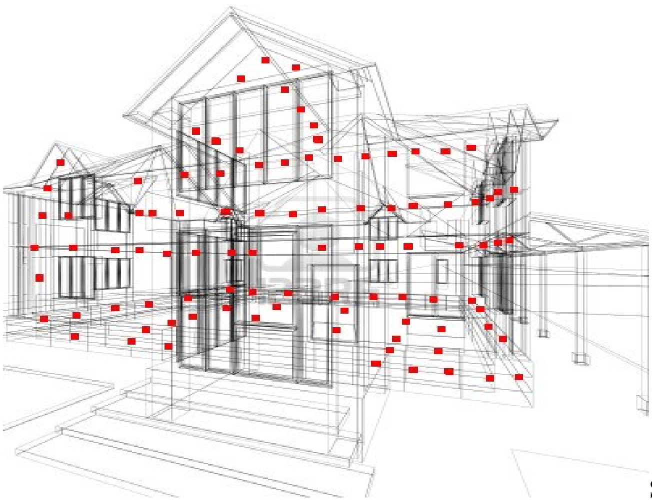
$$e \geqslant \geq \frac{1}{2} \text{ n} \log(n)$$

r is sensor's range. Sensors within that range are suposed to be connected with bidirectional links. v is sensor's volume range. v is considered as a sphere with radius r.

$$v = \frac{4}{3} \pi r^3$$

l is average links per sensor , that mean the average number of sensors that are inside v.

$$L \geqslant \geq \frac{1}{2} N \log(N)$$
(1)



Scetch 1: WSN installed in a building. Red dots represent the sensors. (original scetch from www.123rf.com, copyright Roman Sakhno)

Wireless sensors in this work have the following capabilities:

- Receive messages from other sensors.
- Form a message with sensor's measurements.
- Forward messages in range r.

Sensors energy load duration is reverse analogue to r.

Analysis

WSN in a historical building form a random network located on building's volume V_B. Efficient information dissemination with minimum r means that WSN is well operating (connected) and the duration of sensors energy load is maximized. As stated in [8] and and even more analytically on [9] a graph with n nodes and e edges is connected if :

$$e=\frac{1}{2}nlog(n)+\omega(n)$$

Based on the previous definition it is clear that any network that is the result of a probabilistic procedure (e.g. random graphs), is connected when :

$$e\geqslant\geq\frac{1}{2}nlog(n)$$

A connected WSN must have :

$$L\geq\frac{1}{2}N\log(N)$$

The above equation, Eq. (1) and easy calculations show that:

$$r^3\geqslant\geq\frac{3}{4}\frac{[V_B\log(N)]}{[\pi N]}$$
(2)

Eq. (2) points to the minimum r required in order to be *WSN* connected. With this value of r the duration of sensors energy load is maximized.

Simulation

A custom simulator in the programming language python has been created to test the proposed result.

Simulations were performed on two types of buildings, a belfry and a typical orthogonal building. On each simulation a WSN with 500 wireless sensors was created. Information dissemination was tested with sensor's r varying from 1m to 15m.

The results are presented as diagrams of coverage and number of messages per sensor's r. Value of r as analytical predicted is noted on each diagram .

First are the results of a WSN simulation installed on a belfry with dimensions 10m x 10m x 50m. 500 wireless sensors were randomly spread in the building. Using Eq. (2) the optimal estimation of r was: $r\geq 2.46m$

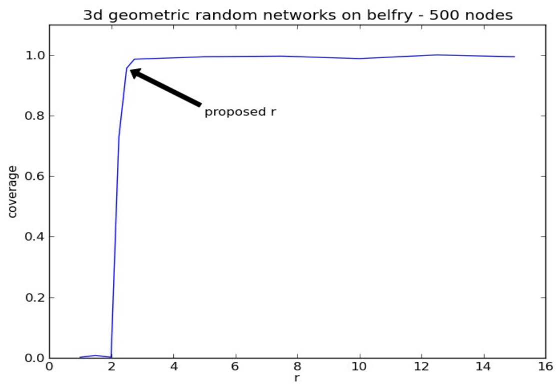


Figure 1: Coverage - radius of transmission diagram on 500 sensors WSN on a belfry.

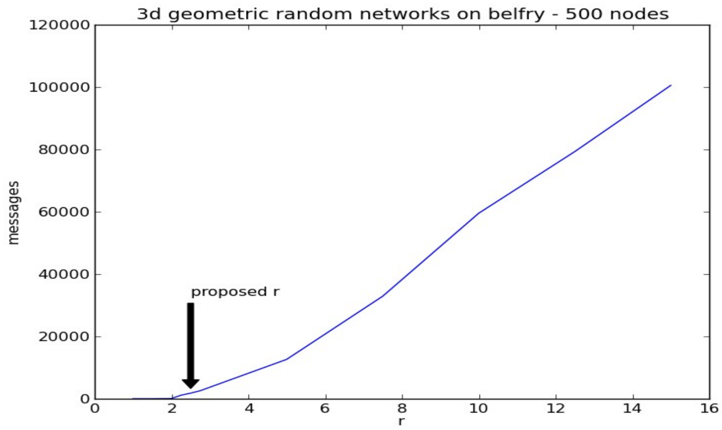


Figure 2: Message - radius of transmission diagram 500 sensors WSN on

On simulations WSN with 500 sensors installed on a belfry, coverage – radius of transmission diagram on Figure 1, shows that for analytically estimated *r* coverage is closely to 1, while message - radius of transmission diagram on Figure 2, shows that using analitacally estimated *r* a great reduction of messages is achieved.

The following results are from a WSN simulation installed on an orthogonal building with dimensions 10m x 30m x 15m. 500 wireless sensors were randomly spread in the building. Using Eq. (2) the optimal estimation of *r* was:

$$r \geq 2.37\,m$$

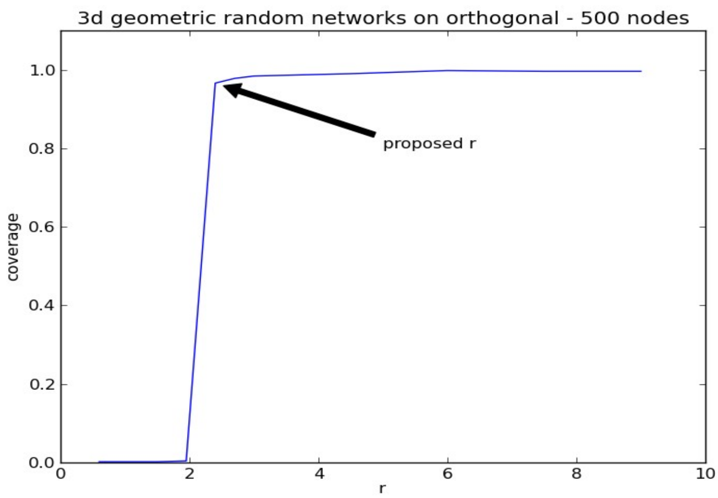


Figure 3: Coverage - radius of transmission diagram of 500 sensors WSN installed in an orthogonal building.

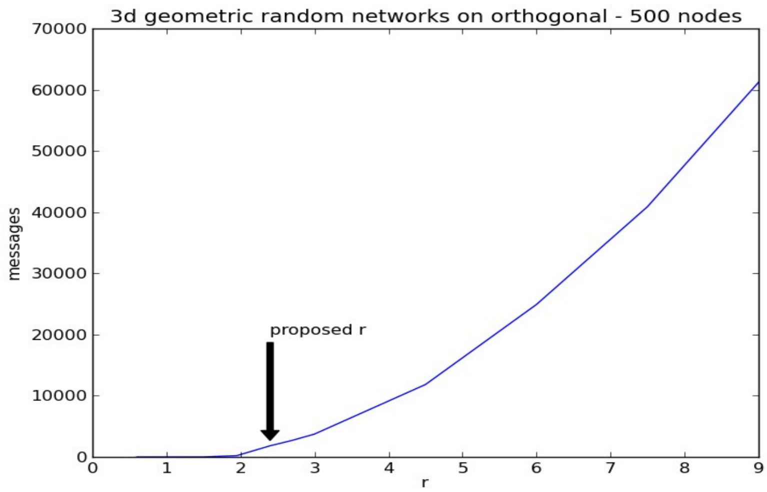


Figure 4: Message - radius of transmission diagram of 500 sensors WSN installed in an orthogonal building.

As coverage - radius of transmission diagrams on Figures 1, 3 show, analytical predicted *r* is the minimum value with WSN almost connected. In case of sensors on historical buildings coverage value for this *r* is sufficient. On message - radius of transmission diagrams on Figures 2, 4 reduction of needed messages for information dissemination is illustrated. Message reduction is analogue to the duration of sensors energy load that keeps WSN functional.

WSNs in historical buildings have wireless sensors installed in small distances. Minimizing the transmission radious by the proposed method, could conserve sensors energy by a big factor. Our simulation results show that predicted *r* is 1/6 to 1/10 of buildings dimensions. Since energy needed for wireless transmission is analogue to r^2 , reduction of energy from 1/36 to 1/100 is achieved.

Summary

In this paper the problem of efficient (i.e., of reduced energy consumption) information dissemination is revisited considering sensors deployed in historical buildings and taking into account the idiosyncrasies of such a deployment. Flooding is deployed and a simple but representative deployment scenario was analytically studied along with simulations in order to derive the smallest transmission radius under which the network is connected but also minimizes the need for energyvorous wireless transmissions.

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