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Procedia Computer Science 19 (2013) 1094 – 1100

Procedia
Computer Science

The 8th International Symposium on Intelligent Systems Techniques for Ad-hoc and Wireless Sensor Network (IST-AWSN)

Performance Study of an improved Routing Algorithm in Wireless Sensor Networks

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Abstract

The Relative Coordinate Rumor Routing (RCRR) is a hybrid routing protocol based on a straight line routing scheme proposed to overcome the drawbacks of the Rumor Routing (RR) protocol which is based on a random walk approach. This paper presents a performance study of the RCRR protocol for Wireless Sensor Networks. The main objective is to evaluate the performances of the new RCRR protocol under different situations and considering different factors such as network size or the impact of the positions of the Beacon nodes originally placed along the horizontal and the vertical line of the 4 cardinal points. Through the presented scenarios and simulations, it is shown that the energy consumption is much more in some cases and much less in other cases. Based on this study, guidelines can be deduced to improve the behavior of the RCCR routing protocol.

Selection and peer-review under responsibility of Elhadi M. Shakshuki

Keywords: Wireless Sensor Network, Routing Protocol, Energy Efficiency, Shortest Path , Topological Localisation

1. Introduction

The past few decades have been significant for the development of *Wireless Sensors Networks* (WSN). Wireless Sensor Networks consist of spatially distributed autonomous sensors that monitor Physical or environmental conditions. These include sensing temperature, sound, vibration, pressure, etc… They cooperatively pass their data through the network to a main location. In a wireless sensor networks, the lifetime of sensors is limited due to the fact that they are only self-alimented with a battery, and therefore have to use as little power as possible in order to minimize the energy consumption. The routing scheme

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Selection and peer-review under responsibility of Elhadi M. Shakshuki
doi:10.1016/j.procs.2013.06.154

usually used affects this power consumption. Many routing protocols have been developed, that aim to find the most efficient routing scheme that consumes the least amount of power, and therefore, extend the lifetime of the network. Rumor Routing (RR) [2] is a hybrid protocol which combines both proactive and reactive routing methods, balances event flooding and query flooding quite well. This protocol is much more adapted to the scenario where there are fewer data transmissions and a lot of queries. The random walk scheme creates wastage of energy and failure of queries to meet events through the generation of unnecessary routes. Rumor Routing has served as the basis for numerous routing algorithms that have been designed. These newly designed algorithms intended to improve the energy consumption, the end to end delay, or the throughput. A new routing algorithm called Relative Coordinate Rumor Routing (RCRR) [1], which is a straight-line routing method of both event and query, has been proposed. It improves the RR by using some topological and abstract localisation methods that shortens the source-to-sink route for the data transmission and saves the energy used for broadcasting. The approach deals much better with larger amounts of data. To this extent, the Sensor-MAC protocol has been adapted resulting in lower power consumption when compared to Rumor Routing. However, problem still exist when conducting simulations in large network areas and when dealing with the random deployment of mobile nodes. The performance of the RCRR is discussed in this paper with the evaluation of the energy cost, the efficiency of the query delivery, the impact of topological localisation.

The remainder of this paper is organized as follows: Section 2 presents a review of related work; Section 3 presents the theory behind energy consumption of the RCRR protocol; Section 4 deals with the different simulations conducted under different scenarios with a comparative analysis of the original RCRR with a modified scheme and the effects on the algorithm. Finally, Section 5 concludes the paper and provides recommendations and future works.

2. Related Work

A WSN is a network with thousands of randomly scattered simple sensor nodes with a limited data communication capability. Since long-range transmissions consume a lot of energy, routing must be based on short hops between communicating nodes. In [8], a survey of the existing routing techniques in WSNs which emphasizes the design challenges for routing protocols in WSNs is depicted. This study shows the design tradeoffs between energy and communications for each of the routing schemes considered. In [9], a data-centric and application-aware paradigm named Directed Diffusion in which sensors measure events and create gradients of information in their respective neighborhoods is proposed. It starts with a 'broadcast of interest' containing the tasks required of neighbors which is flooded through the whole network. A node that receives the interest message sets up a gradient toward the nodes that sent the interest. This process continues until the best path to the sink along the interest gradient is found. In [2], the author describes and evaluates through simulation the Rumor Routing approach which allows for queries to be delivered to events in the network. Furthermore, the author explains that the routing method employed is tunable. It allows for tradeoffs between setup overhead and delivery reliability. The event flooding and query flooding concepts are described, together with an overview of the algorithm.

A modified Rumor Routing approach is presented [4] in which it is demonstrated that a highly efficient data centric model of routing is more likely to improve the longevity of the network. It describes an improved Rumor Routing algorithm through simulation of existing features of Rumor Routing. The improved algorithm handles node failures and allows for tradeoffs between setup overhead and delivery reliability. The idea of intersecting query path and event path is elaborated in [7] as a routing scheme without any geographic information. In [11], and [12] the author proposes a virtual coordinates based routing (VCR) scheme which adopts a new criterion based on virtual coordinates converted from the absolute coordinates. Through extensive simulation experiments, the author shows that VCR achieves an efficient trade-off between energy consumption and end-to-end delivery latency. A performance analysis of source, shortest path, hierarchical and geographical routing strategies is presented in [13].

The performance of these three routing strategies is evaluated through simulations based on latency, End to End Delay, packet delivery ratio, routing overhead, and routing load. In [15], the author proposed 2 energy efficient algorithms based on the Gradient Based Routing protocol. The idea is to choose the best relay node to forward the packets and to insert new nodes in the network in order to extend the lifetime of the network. The author shows significant improvement on transmission probability and on the prolongation of the lifetime of the network which is up to 63%.

3. Energy Cost Theory

3.1. Energy Consumption Theory RCRR [1]

Energy consumption is modeled at the initialization phase with 4 beacons used to generate the localisation scheme and spread the coordinates to the other nodes as well as during the notification and query process. The following expression is obtained from the energy modeling of RR in [2]

$$E_t(q) = E_{path} * [n * TTL_n + (q - Q_f) * TTL_q * \theta_q + Q_f * N] \quad (1)$$

where

θ_q : The average hops ratio of TTL_{query} of the intersecting with notified nodes. The average hops number is the product of TTL_{query} and θ_q.

TTL_n : The time-to-live parameter for event notification agent.

TTL_q : The time-to-live parameter for query agent.

E_{path} : The average energy needed of an agent-generated route,

N : Number of nodes.

Q_f : The number of queries that need flooding.

- *Energy at Initialisation Phase*

The initialization part involves a flooding process which is a new process in RCRR and is not inherent in the RR scheme. Assuming that the network size is *N*, the number of nodes on one side, delimited by the axis, is of the order of $\sqrt{N}$, as well for the number of nodes on the axis. The following expression determines the energy:

$$E_{initial} = E_{path} * (N+2 * \alpha\sqrt{N}) \quad (2)$$

where

α is the ratio of re-flooding the nodes which is assumed to be less than 0.5%,

Adding to expression (1) which gives

$$E_t(q) = E_{path} * [n * TTL_n + (q - Q_f) * TTL_q * \theta_q + Q_f * N + (N+2 * \alpha\sqrt{N})] \quad (3)$$

- *Energy cost at the event notification spreading*

Two notification agents are sent, to the south and the north direction respectively, towards the beacon nodes. The energy consumption is related to the number of hops needed by the event notification agents to get to the beacon nodes. It is assumed that the events in the network are equal-probable. Therefore an average hop number can be computed based on the sum of all possible hop numbers divided by the total number of nodes. The final expression can be written as

$$E_{notice} = E_{path} * [\frac{(4N+1)(N-1)}{3N} + \sigma(N)] \quad (4)$$

- *Energy consumption of Query spreading*

As the query delivery is also based on the random-walk rule, the query will route through various paths to the destination. The assumption here is that if the query routes to both the horizontal beacon nodes, the total hop number of one single query sending ($Path_{Thqs}$) is the same as the one of notification spreading which is $Path_{Thns} = [\frac{(4N+1)(N-1)}{3N} + \sigma(N)]$. The Average route length can be estimated by the relation between the path length ($Path_n$) of one possible route and the probability of the route (P_n). But since this probabilistic equation in a random scenario is not easily computed, a simple model is designed, and thus, the equation of the Energy cost of a simple query becomes

$$E_{query} = E_{path} * [\frac{2*(4N+1)(N-1)}{9N} + \sigma(N)] \quad (5)$$

Finally, the energy cost of RCRR protocol is given by:

$$E_t(q) = E_{path} * [q * \frac{2*(4N+1)(N-1)}{9N} + \sum_{i=1}^{i=q} \sigma(N) + n * \frac{(4N+1)(N-1)}{3N} + \sum_{i=0}^{n} \sigma'(N + N^2 + 2\alpha N)] \quad (6)$$

where q and n are the numbers of queries and notifications spread in the network,
N^2 is the network size, and
$\sigma(N)$ is a Gaussian random variable, with zero standard deviation function of the network size.

4. Performance Study

4.1. Parameters setting for simulation

The performance of the Relative Rumour routing Coordinates RCRR protocol is evaluated with the network simulator NS-2 version 2.34 [10]. The evaluation configurations and results are given in this section. The Channel Control module requires some parameters to be specified for it to set up connections between the hosts inside the network. In NS-2, the wireless channel is assigned to the channel type, the two ray ground is assigned to propagation model, and the type of the physical layer is a wireless physical model. The antenna used is an Omni-directional antenna. The number of nodes varies from 30 to 120 nodes, the largest network area is equal to *A=2500*1900*, the simulation time goes from 285ms to 785ms and the initial energy is 100J on each node. The sending and receiving powers are 600mW and 100mW respectively. The other settings parameters are shown in the table below. It is assumed that the energy of one single process of the transmission and reception of one packet is *1J*, n is the number of notifications, and q is the number of queries. The network size varies from 9 (3^2) to 225 (15^2).
The other parameters are shown in the table below for clarity.

Table1: Simulation 1 Parameter Settings

Description	Parameters
Number of nodes	From 30 to 120
Number of events	From 1 to 10
Traffic type	CBR
Transport Type	UDP
Simulation Time	285 to 785ms
Number of queries/notification	2 to 50
Number of sources	1 to 8
Events details	Synchronous /Asynchronous

Figure 1 gives an overview of the simulation under NS-2. The topological position of the 4 beacon is changed from horizontal/vertical to diagonal. They are slightly deviated from their original position until the diagonal ends are reached. The nodes turns red when there is no energy left in the network and yellow or orange according to the energy consumed during data flow transmission.

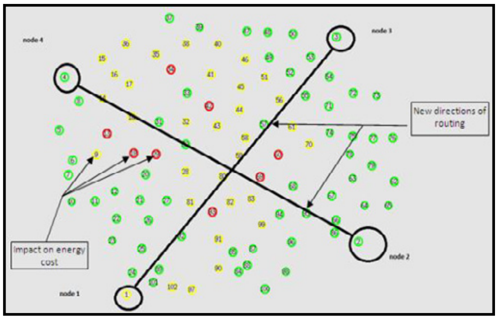

Figure 1: simulation of 100 nodes with change of routing direction

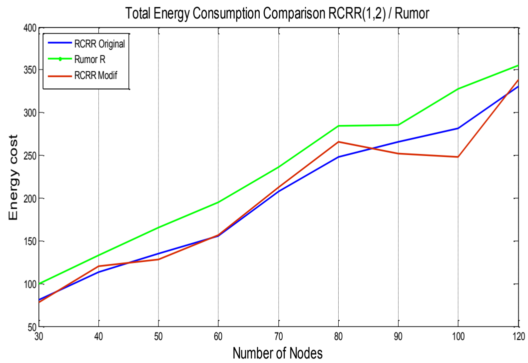

Figure 2: Total Energy cost Comparison

Figure 2 compares the total energy cost of the RR (green line), the RCRR (blue line) with original positioning at the 4 cardinal points, and the RCRR (red line) with the diagonal positioning. It is seen that though the change of positions of the beacons affects the energy cost, the RCRR algorithm still performs better than the Rumor Routing approach. It consumes less power than the RR and under some specific scenario the modified RCRR is performing much better than both RR and RCRR

4.2. Random scenario evaluation

In the random scenario, the case where the 4 beacon are not fixed in the cardinal ends is considered. In fact they are deployed in the network randomly with the other nodes. The flooding is still done at the initialization phase and the coordinates are spread from the 4 initializing nodes. We could observe a failure to cross the direction from the 4 initial beacons. This failure leads to a waste of energy and a failure of events to meet queries during the routing process of the RCRR.

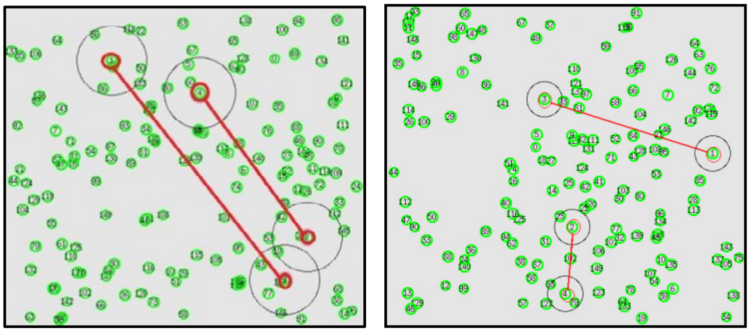

Figure 3: Cross link failure example on random deployment

Figure 3 shows the case where the beacons nodes fail to cross their lines in a random deployment environment. Such deployment leads to a failure to meet the event as the RCRR algorithm is based on the crossing scheme. The following graph shows the impact on energy. When the number of node increases the modified model of RCRR performs much better and consumes less power. On the other hand, it performs only slightly more in a network size inferior to 60 nodes.

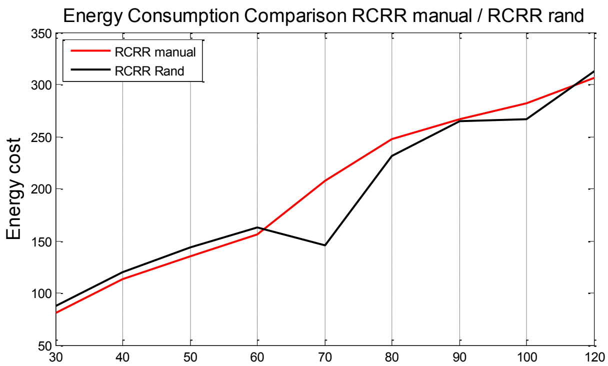

Figure 4: Energy cost Comparison in random deployment

5. Conclusion

In this paper, performance evaluation of the Relative Coordinates Rumor routing (RCRR) that was conducted in terms of Energy consumption was presented. The simulations were conducted using the network simulator NS-2. The evaluation took into account different scenarios.

The evaluation results showed that was an is improvement using the approach based on which the following conclusion can be made: (i) the performance of RCRR is not affected much by the change of the topological positioning of the beacons; (ii) the Energy cost is improved when using some specific scenarios; (iii) there is a possibility of improving the total cost energy of the RCRR while using random scenarios. Future works can include the consideration of more than 4 beacons during the initialisation phase and for the straight line routing scheme, or the consideration of a distance based localisation scheme implemented on the RCRR for enhancement.

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