Performance Evaluation of a Wireless Sensor Network Considering Mobile Event

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Abstract

Presently, there are many research work for sensor networks. In our previous work, we implemented a simulation system for sensor networks. But, we considered that the event node is stationary in the observation field. However, in many applications the event node may move. For example, in an ecology environment the animals can move randomly. In this work, we want to investigate how the sensor network performs in the case when the event node moves. We carried out the simulations for lattice topology and TwoRayGround radio model considering AODV and DSR protocols. We compare the simulation results for two cases: when the event node is mobile and stationary. The simulation results have shown that the routing efficiency for the case of mobile event node is better than the stationary event node using AODV protocol. Also, the goodput for the mobile event node case does not change too much compared with the stationary event case using AODV, but the goodput is not good when the number of nodes is increased.

1. Introduction

A Wireless Sensor Network (WSN) is a wireless network where the nodes are sensors, that is micro-devices with limited computation capacity and with on-board specific transducers. In Fig.1 is shown the physical architecture of WSN. Recently, we witnessed a lot of research effort towards the optimization of standard communication paradigms for such networks. In fact, the traditional Wireless Network (WN) design has never paid attention to constraints such as the limited or scarce energy of nodes and their computational power. Another aspect which is different from traditional WN is the communication reliability and congestion control. In traditional wired nets, one reasonably supposes that communication paths are stable along the transmission instances. This fact permits to use the end-to-end approach to the design of reliable transport and application protocols. The TCP works well because of the stability of links. On the other hand, in WSN paths can change over time, because of time-varying characteristics

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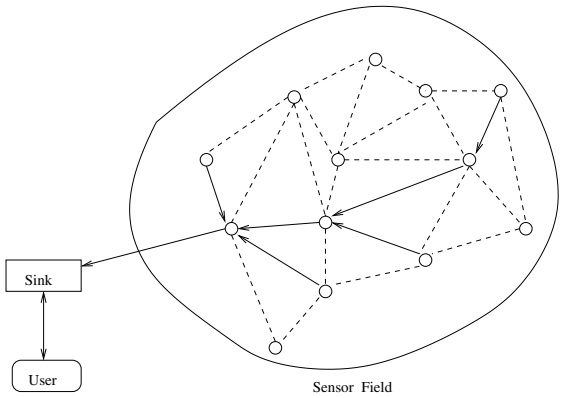

Figure 1. Physical architecture of WSN.

of links and nodes reliability. These problems are important especially in a multi-hop scenario, where nodes accomplish also at the routing of other nodes' packets.

Recently, there are many research work for sensor networks [1, 2, 3, 4]. In our previous work [5], we implemented a simulation system for sensor networks. But, we considered that the event node is stationary in the observation field. However, in many applications the event node may move. For example, in an ecology environment the animals can move randomly. In this work, we want to investigate how the sensor network performs in the case when the event node moves. We carry out simulations for lattice topology and TwoRayGround radio model considering two protocols: Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR). We compare the simulation results for two cases: when the event node is mobile and stationary. The simulation results have shown that the routing efficiency for the case of mobile event node is better than the stationary event node using AODV protocol. Also, the goodput for the mobile event node case does not change too much compared with the stationary event case using AODV, but the goodput is not good when the number of nodes is increased.

The remainder of the paper is organized as follows. In Section 2, we explain the proposed network simulation model. In Section 3, we discuss the routing efficiency and goodput concept. In Section 4, we show the simulation results. Conclusions of the paper are given in Section 5.

2. Proposed Network Simulation Model

In our WSNs, every node detects the physical phenomenon and sends back to the sink node data packets. We suppose that the sink node is more powerful that sensor nodes and it is always located a the borders of the service area. We analyze the performance of the network in a fixed time interval. This is the available time for the detection

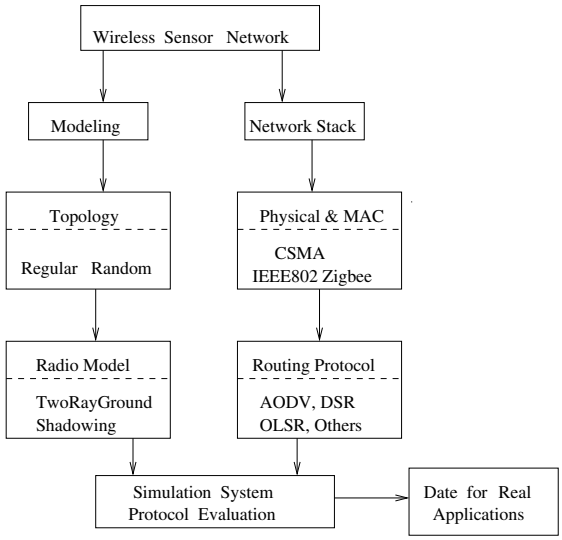

Figure 2. Network simulation model.

of the phenomenon and its value is application dependent. Proposed network simulation model is shown in Fig.2.

In this paper, we consider that a mobile event is moving randomly in the WSNs field. In Fig.3 is shown one pattern of movement event's path. We implemented a simulation system for WSNs considering moving event using ns-2. We evaluated the goodput and routing efficiency of AODV and DSR protocols using TwoRayGround propagation model and the lattice topology.

2.1. Topology

For the physical layout of the WSN, two types of deployment has been studied so far: the random and the lattice deployment. In the former, nodes are supposed to be uniformly distributed, while in the latter one nodes are vertexes of particular geometric shape, e.g. a square grid. as depicted in Fig. 4. In this work, we present results for the square grid topology only. In this case, in order to guarantee the connectedness of the network we should set the transmission range of every node to the step size, d, which is the minimum distance between two rows (or columns) of the grid. In fact, by this way the number of links that every node can establish (the node degree D) is 4. Nodes at the borders have $D = 2$.

2.2. Radio Model

There are three basic models for the propagation of the radio signals of sensor nodes: Free space model, TwoRayGround model and Shadowing model. In a simple deterministic model, the received power P_r at a certain distance

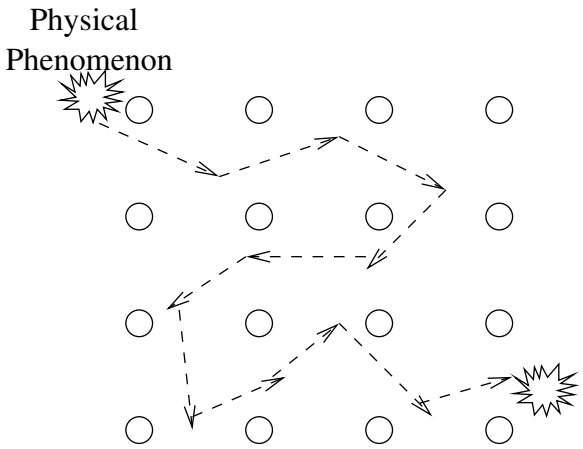

Figure 3. One pattern of movement event path.

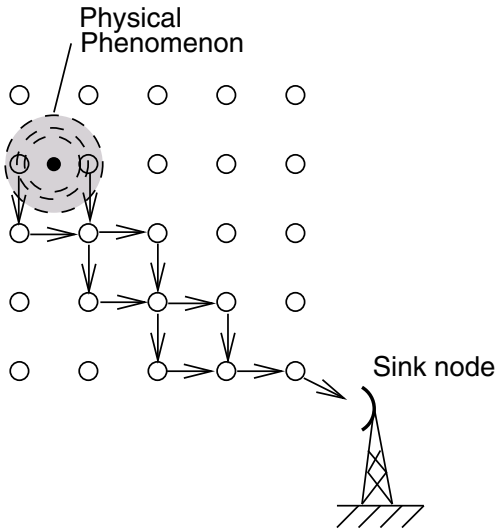

Figure 4. Lattice topology.

d is the same along all directions in the plane [1]. For example, in the case of Line Of Sight (LOS) propagation of the signal, the Friis formula predicts the received power as:

$$P_r(d) = P_t - \beta \ \ (\mathrm{dB}), \qquad (1)$$
$$\beta = 10 \log \left(\frac{(4\pi d)^2 L}{G_t G_r \lambda^2} \right)$$

where G_r and G_t are the antenna gains of the receiver and the transmitter, respectively, λ is the wavelength of the signal and L the insertion loss caused by feeding circuitry of the antenna, and β is the propagation pathloss. For omni-antennas, $G_R = G_t = 1$. The signal decay is then proportional to d^2.

In our simulation system, we use a more accurate model called TwoRayGround model, where in addition to the direct ray from the transmitter towards the receiver node, a ground reflected signal is supposed to be present. Accordingly, the received power now depends also on the antenna heights and the pathloss is:

$$\beta = 10 \log \left(\frac{(4\pi d)^4 L}{G_t G_r h_t h_r \lambda^2} \right) \qquad (2)$$

where h_r and h_t are the receiver and transmitter antenna heights, respectively. The power decreases faster than Eq. (1). The formula in Eq. (2) is valid for distances $d > d_c$, that is far from the transmitting node [6].

2.3. Routing Protocols

We are aware of many proposals of routing protocols for ad-hoc networks. Here, we consider reactive protocols such as AODV and DSR [7].

The AODV is an improvement of DSDV to on-demand scheme. It minimize the broadcast packet by creating route only when needed. Every node in network should maintain route information table and participate in routing table exchange. When source node wants to send data to the destination node, it first initiates route discovery process. In this process, source node broadcasts Route Request (RREQ) packet to its neighbors. Neighbor nodes which receive RREQ forward the packet to its neighbor nodes. Neighbor nodes which receive RREQ forward the packet to its neighbors, and so on. This process continues until RREQ reach to the destination or the node who know the path to destination. When the intermediate nodes receive RREQ, they record in their tables the address of neighbors, thereby establishing a reverse path. When the node which knows the path to destination or destination node itself receive RREQ, it send back Route Reply (RREP) packet to source node. This RREP packet is transmitted by using reverse path in formation in route table of each intermediate node. When the source node receives RREP packet, it can know the path to destination node and it stores the discovered path information in its route table. That is the end of route discovery process. Then, AODV performs route maintenance process. In route maintenance process, each node periodically transmits a Hello message to detect link breakage.

In DSR, the source node knows the entire path to the destination. And intermediate nodes don't need to maintain route information table for neighbor's address. This source routing information is stored in cache and updated when the node discover new route. DSR also consist of two mechanisms (Route Discovery and Route Maintenance process). In route discovery process, DSR also uses RREQ and RREP as AODV. However in DSR, intermediate nodes

[1] We are considering 2D networks, but similar results hold also in the more general case of 3D networks.

don't need to maintain route table because hop-by-hop path information (reverse path information) is stored in RREQ header when RREQ is forwarded from intermediate nodes. When destination node which knows the path to destination receives this RREQ packet, it sends back RREP to source node using header stored in RREQ packet. When the source node receives RREP packet, it knows the entire path to destination node and store the discovered path in cache. Route maintenance process is accomplished through the use of Route Error (RRER) packets. RRER packets are generated when the link is broken due to mobility of nodes.

3. Goodput and Routing Efficiency

In this section, we introduce the concept of "goodput" and Routing Efficiency (RE). We consider that after a sensor node detects the physical phenomenon, it sends the packets to the sink node via a routing protocol. The ability for transmitting packets for different protocols is different. Also, the RE of a protocol is affected by many network parameters such as wireless transmission radio model, network topology, and transmission frequency [4]. In order to compare the performance of different protocols, we consider the same simulation environment. For our system, we used TwoRayGround radio model and the network topology is regular [8, 9].

The goodput is defined at the sink, and it is the received packet rate divided by the sent packets rate. Thus:

$$G(\tau) = \frac{N_r(\tau)}{N_s(\tau)} \tag{3}$$

where $N_r(\tau)$ is the number of received packet at the sink, and the $N_s(\tau)$ is the number of packets sent by sensor nodes which detected the phenomenon. Note that the event-reliability is defined as $G_R = \frac{N_r(\tau)}{R(\tau)}$, where R is the required number of packets or data in a time interval of τ seconds.

We defined the RE parameter as the ratio of sent packets from sensing node with sent packet by routing protocol. Thus:

$$RE(\tau) = \frac{N_{sent}(\tau)}{N_{routing}(\tau)} \tag{4}$$

where $N_{routing}(\tau)$ is the number of sent packets by routing protocol, and $N_{sent}(\tau)$ is the number of sent packets by sensor nodes which detect the phenomenon.

4. Simulation Results

In this section, we present the simulation results. We implemented the simulation system using ns-2 simulator, with the support of NRL libraries [10]. For each routing protocol, the sample results of Eq.(3) and Eq.(4) are computed over $20s$ simulation runs.

In Fig.5 is shown the average value of RE using TwoRay-Ground model and AODV in case of stationary event. The RE is an increasing function of T_r, because as T_r increases, the number of sent packet by sensing node is higher than the number of packets used by routing protocol. In case of AODV, the RE decreases with the increase of number of sensor nodes. It should be noted that when the number of sensor nodes is increased, the number of routes is increased, thus the searching time to find a route also is increased. When the number of nodes is 256, the RE of AODV is the worst in our simulation.

The simulation results for the case of mobile event are shown in Fig.6. The RE is stable and better than in case of stationary event, especially when the number of nodes is increased. When $N = 12$, the performance is almost the same for both cases. But, in the cases of $N = 64, N = 100, N = 256$, the performance is better for mobile event case.

In case of DSR, the simulation results are shown in Fig.7 and Fig. 8. Comparing with AODV for the same time interval and the number of nodes, the RE of DSR is better than AODV. In the mobile environment, AODV sends the RREQ and when receives the reply from the sink it sends the packet to the sink. However, in the case of mobile event, when the transmission rate is lower the value of RE is not stable because of congestion situation. When the transmission rate is larger than 10pps, the RE becomes stable. However, the performance is still better than AODV. This is because the DSR invokes the local route repair using the alternative routes in route cache.

In following, we explain the results of goodput for the same environment. In Fig.9 is shown the goodput for stationary event, while in Fig.10 for mobile event in the case of AODV protocol. In both cases, when the number of nodes is increased, the goodput is increased. However, the goodput of stationary event is better than mobile event, but the

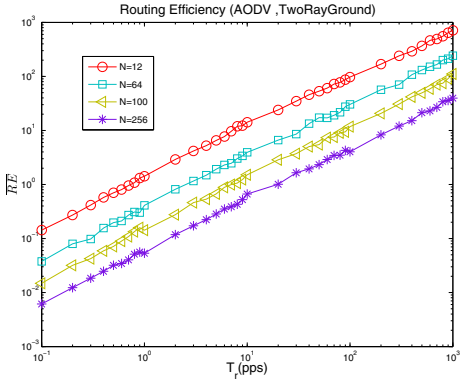

Figure 5. RE for stationary event (AODV).

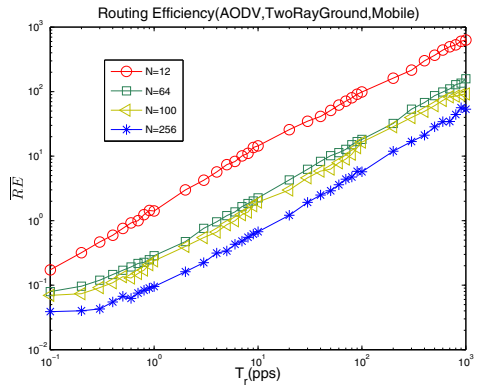

Figure 6. RE for mobile event (AODV).

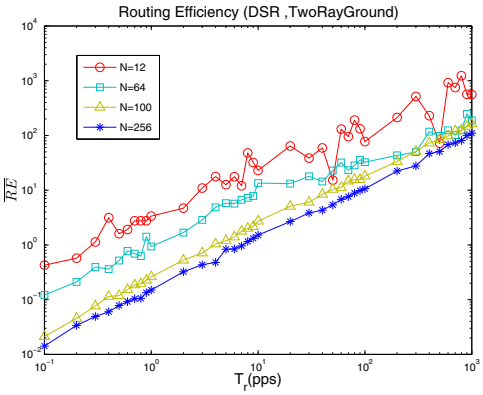

Figure 7. RE for stationary event (DSR).

goodput of mobile event is more stable.

In case of DSR, as shown in the Fig.11, the goodput of stationary event is almost the same with AODV (see Fig.9). However, in case of mobile event (see Fig.12), with the increase of number of nodes, the value of goodput is decreased much more compared with stationary event case. When the number of nodes is 256 the goodput is the worst and is not stable.

The goodput of AODV is better than DSR in case of mobile event. This is because when AODV performs route discovery, it uses the control messages RREQ and RREP. To control the broadcasts of RREQs, the source node uses an expanding ring search technique. In DSR, many RREQ packets are broadcasted to find the destination route. So, there are many packets loss [11, 12].

5. Conclusions

In this paper, we presented the implementation of a simulation system for WSNs using ns-2. We considered for simulations AODV and DSR protocols and evaluated the proposed system for two cases: stationary event and mobile event.

From the simulation results, we concluded as follows.

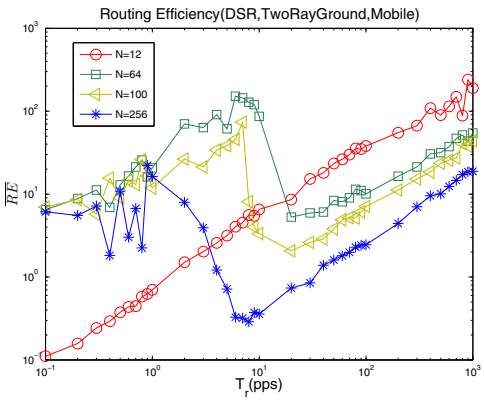

Figure 8. RE for mobile event (DSR).

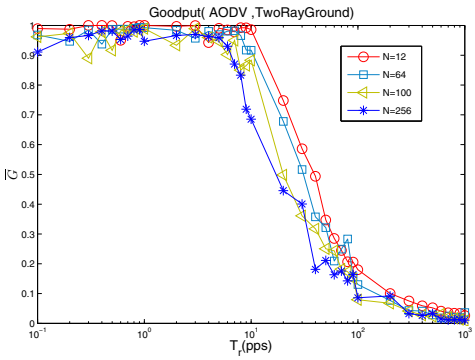

Figure 9. Goodput for stationary event (AODV).

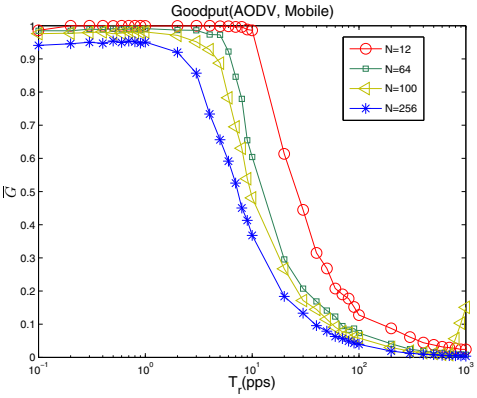

Figure 10. Goodput for mobile event (AODV).

- In case of AODV, the RE decreases with the increase of number of sensor nodes. When the number of nodes is 256, the RE of AODV is the worst.
- In the case of mobile event, for AODV protocol, the RE is stable and better than in case of stationary event, especially when the number of nodes is increased.
- Comparing with AODV for the same time interval and the number of nodes, the RE of DSR is better than

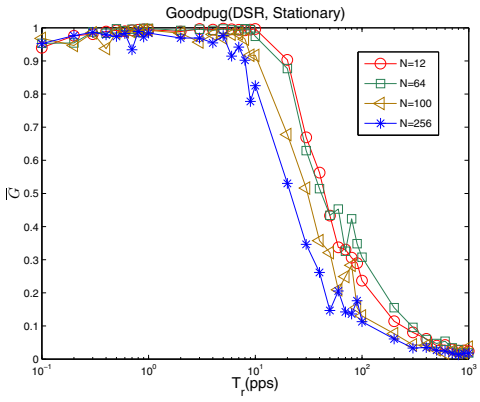

Figure 11. Goodput for stationary event (DSR).

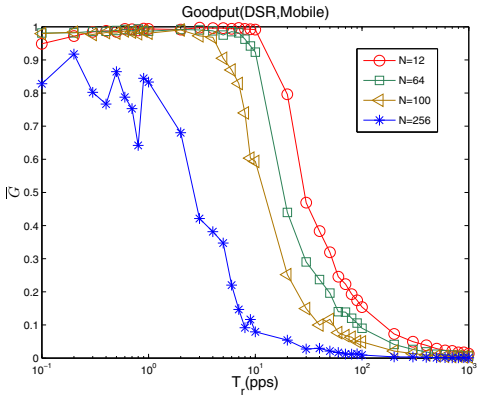

Figure 12. Goodput for mobile event (DSR).

AODV, but it is unstable.

- The goodput of AODV protocol for stationary event is better than mobile event, but the goodput of mobile event is more stable.

- In case of DSR, the goodput of stationary event is almost the same with AODV. However, in case of mobile event with the increase of number of nodes, the value of goodput is decreased much more compared with stationary event case. When the number of nodes is 256, the goodput is the worst and is not stable.

- The goodput of AODV is better than DSR in case of mobile event.

In the future, we would like to carry out more extensive simulations for many mobile events and other protocols. We also would like to consider the case of Shadowing radio model and the random topology.

Acknowledgment

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