IOP Conf. Series: Materials Science and Engineering **323** (2018) 012028 doi:10.1088/1757-899X/323/1/012028

Study on the effect of sink moving trajectory on wireless sensor networks

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Abstract. Wireless sensor networks are developing very fast in recent years, due to their wide potential applications. However there exists the so-called hot spot problem, namely the nodes close to static sink node tend to die earlier than other nodes since they have heavier burden to forward. The introduction of mobile sink node can effectively alleviate this problem since sink node can move along certain trajectories, causing hot spot nodes more evenly distributed. In this paper, we make extensive experimental simulations for circular sensor network, with one mobile sink moving along different radius circumference. The whole network is divided into several clusters and there is one cluster head (CH) inside each cluster. The ordinary sensors communicate with CH and CHs construct a chain until the sink node. Simulation results show that the best network performance appears when sink moves along 0.25 R in terms of network lifetime.

1. Introduction

Recent advancement in micro-electronics, computing and wireless communication has enabled the fast development of low-power and multifunctional sensor nodes, which can integrate sensing, processing and communication functions in their tiny volumes. These tiny sensor nodes can be randomly deployed over an area of interest to work collaboratively. Besides, they can self-organize themselves based on their local collaboration to form wireless sensor networks (WSNs) [1].

Energy efficiency and energy balancing is one of the primary research challenges to the successful application of WSNs. Sensor nodes are usually powered with limited batteries and they cannot be easily recharged after deployment. Besides, hotspot problem can be caused by unbalanced energy consumption among sensors, especially when sink node is static. Under such circumstance, sensor nodes close to sink node will have more traffic to forward and they tend to deplete their energy much quickly than other sensors which are far away from sink [2].

By adopting sink mobility technology [3-4], the following advantages can be achieved. First, the hotspot problem can get alleviated as sink node moves around and energy consumption can get balanced among sensor nodes. Second, the whole network energy consumption can get reduced with relatively shorter transmission distance between sensor and sink. Third, the transmission latency can be shortened and network throughput can be increased with proper mobile sink design. Finally, sink mobility technology can ensure good network connectivity even under sparse networks.

In this paper, we mainly study the effect of sink moving trajectory on wireless sensor networks, with special focus on network lifetime (or remaining nodes alive). We divide the whole network into several clusters with same size. In each cluster there is a cluster head (CH) and ordinary sensor nodes will communicate with cluster head while CHs construct a chain until the mobile sink. Extensive simulations are performed to study the effect of sink moving trajectory on WSNs.

2. Related Work

LEACH(Low-Energy Adaptive Clustering Algorithm) [5] is a typical hierarchical routing protocol, where the sensor nodes are divided into two types, cluster heads (CHs) and ordinary sensor nodes. A sensor node delivers the sensor data to its related CH and CHs take charge of forwarding and fusing the sensor data to the base station. CHs are randomly selected and each node could only be chosen once in a certain amount of rounds. PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [6] is an enhanced chain-based hierarchical protocol. In PEGASIS, each node transmits data package to the nearest neighbor which is closer to the base station than the source node. Several chains could be generated by this greedy algorithm, and the leader of the chain which is close to the base station takes the responsibility to forward the package to the base station.

A scheme called Velocity Energy-efficient and Link-aware Cluster-Tree(VELCT) is proposed [7]. The scheme contains two parts: set-up phase and steady-state phase. In set-up phase, the CHs are elected via threshold value and clusters form with better performance in an intra cluster communication. Then a few nodes are selected as Data Collection Node(DCN) to construct Data Collection Tree(DCT). In steady-state phase, CHs collect information from its members and forward the aggregated data to DCN and then the sink. Simulation results shows that it has a better performance in throughput, energy consumption and network latency than popular algorithms.

The authors proposed a scheduling mechanism based on spanning graphs by introducing mobile sink [8]. A heuristic path planning algorithm is presented to find a shortest path to avoid the obstacles. Mobile sink walks along the path and collect data from CHs via single-hop transmission. The results demonstrate that the algorithm extends the lifetime of the network effectively.

3. Our Proposed Routing Algorithm

3.1. Migration strategy of the mobile sink

In the algorithm, the direction and speed of the mobile sink are predetermined. The mobile sink moves around the center of the circle with a constant speed and a constant radius. Hence, the sink node only needs to broadcast its position in the initial parse. After certain time, the mobile sink moves to new position.

3.2. Clustering and CHs selection

Differ from other algorithms, we divided the whole network into n parts and every part is a cluster. Each sensor node calculates which cluster it belongs to via its position. At the beginning of each round, CHs selection will be conducted. The parameters of the selection are the residual energy of each nodev and the distance between one node and the mobile sink. The node close to the mobile sink broadcasts its weight in the cluster and claims a tentative CH. Only the nodes with higher weight broadcast its weight and become a new tentative CH. Finally, the node with the maximal weight is selected as the CH in each cluster.

3.3. Intracluster communication

There are two methods for a cluster member to communicate with its CH: direct transmission and multi-hop transmission. Any cluster member can communicate with its cluster head directly and the energy consumption is calculated using the following Formula 3:

$$E_1(S_i,CH_{S_i}) = \begin{cases} lE_{elec} + l\varepsilon_{fs} d(S_i\ ,CH_{\ S_i})^2, d(S_i\ ,CH_{\ S_i}) < d_0 \\ lE_{elec} + l\varepsilon_{\mathrm{mp}} d(S_i\ ,CH_{\ S_i})^4\ ,\ d\ (S_i\ ,CH_{\ S_i}) \geq d_0 \end{cases} \quad (1)$$

When cluster member has a long distance away from its cluster head, a relay node is chosen to forwarding the data package.

3.4. Formation of CH chain

In order to avoid long-distance communication between CHs and mobile sink, a chain of CHs is used. The process of the chain generation is divided into the following steps:

1) Mobile sink broadcast a message to require all the CHs to report their ID and position.
2) The CH which is closest to the mobile sink is chosen as the chain head.
3) Each CH transmits the fused date package to its neighbor CH using greedy algorithm.
4) Data transmission begins at the end of the chain and finally the chain head forwards the data to the mobile sink.

The result of chain generation is shown in figure 1.

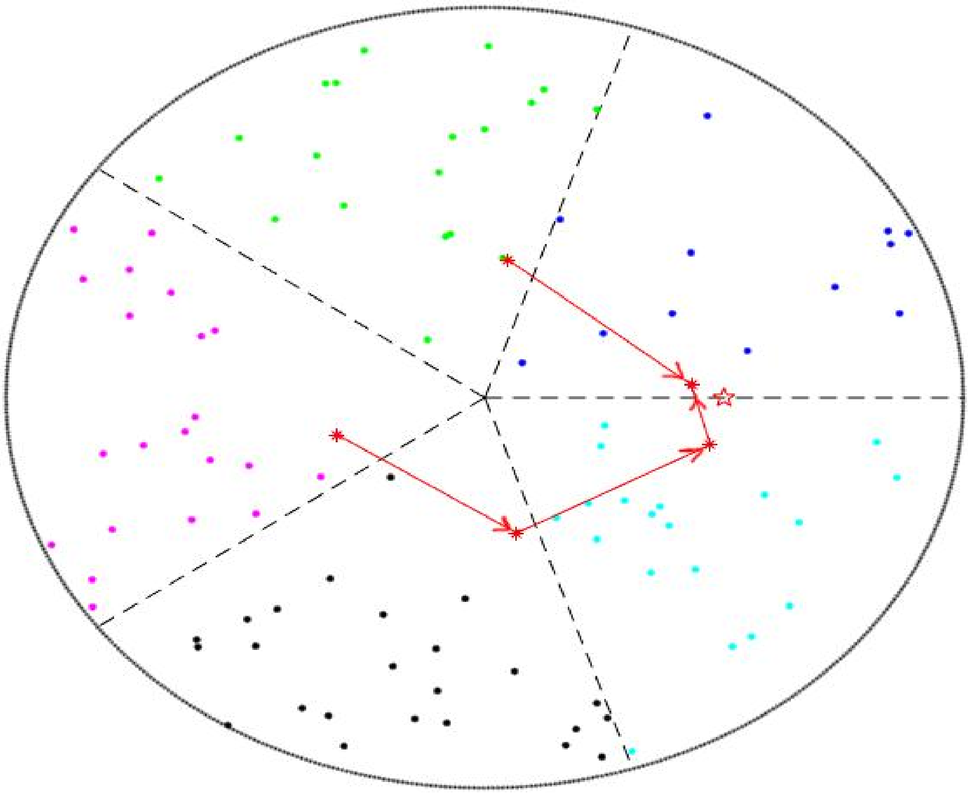

Figure 1. Chain generation.

4. Performance Evaluation

4.1. Simulation environment

In order to test our proposed algorithm, we use a MATLAB simulator to perform the simulation. The radius of the mobile sink is changed to explore the optimal performance. We also test our algorithm for WSNs with different network topologies from about 20 times.

4.2. Study on mobile sink radius

The trajectory of the mobile sink has a great influence on the performance of the network. We assume the mobile sink keep static(r=0) at the centre of the circle or moves around the center of the circle with the radius of 0.25R, 0.5R and R respectively. Simulation results are shown in figure 2.

From figure 2, we can clearly see that when the radius of the mobile sink equals about one fourth (0.25R) the network size, the network has the longest lifetime under different network topologies.

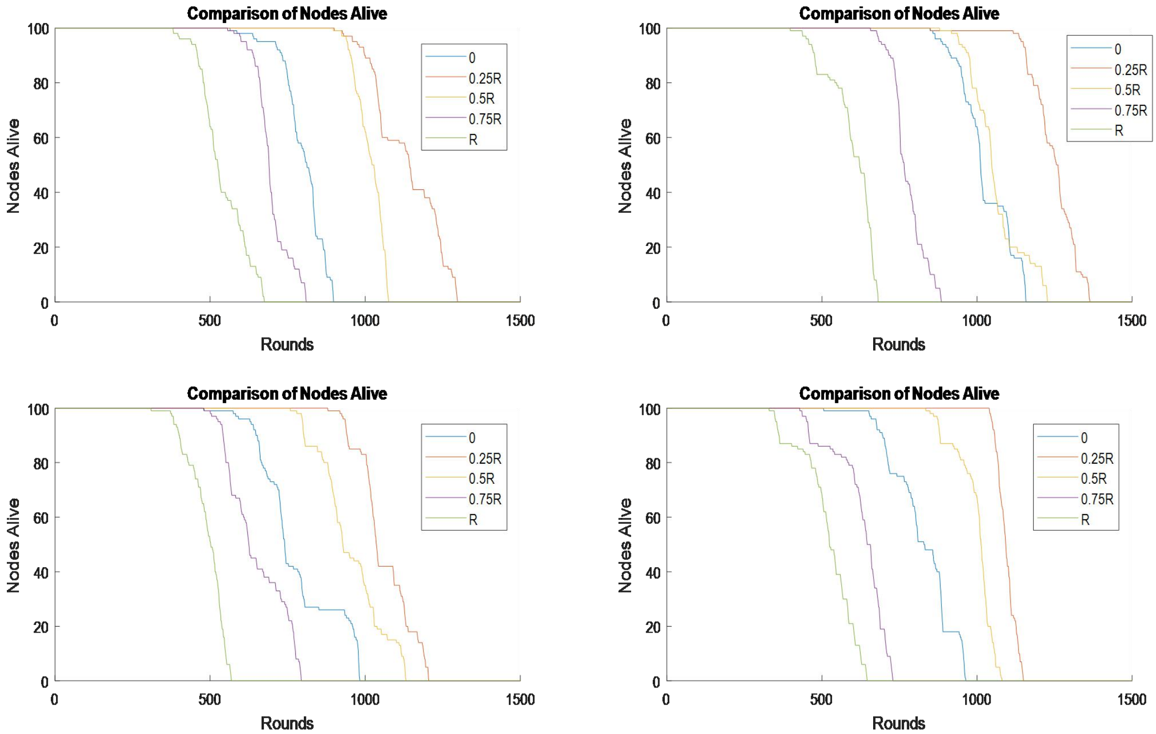

Figure 2. Different radius of mobile sink.

4.3. Study on different network size

We assume the network size is 150, 200, 300, 400 meters respectively. With the increase of the network size, the communication distance increases simultaneously. The lifetime of the network becomes short as the network size increases, while the mobile sink still has a better performance in terms of lifetime when its radius is one fourth R, as is shown in figure 3.

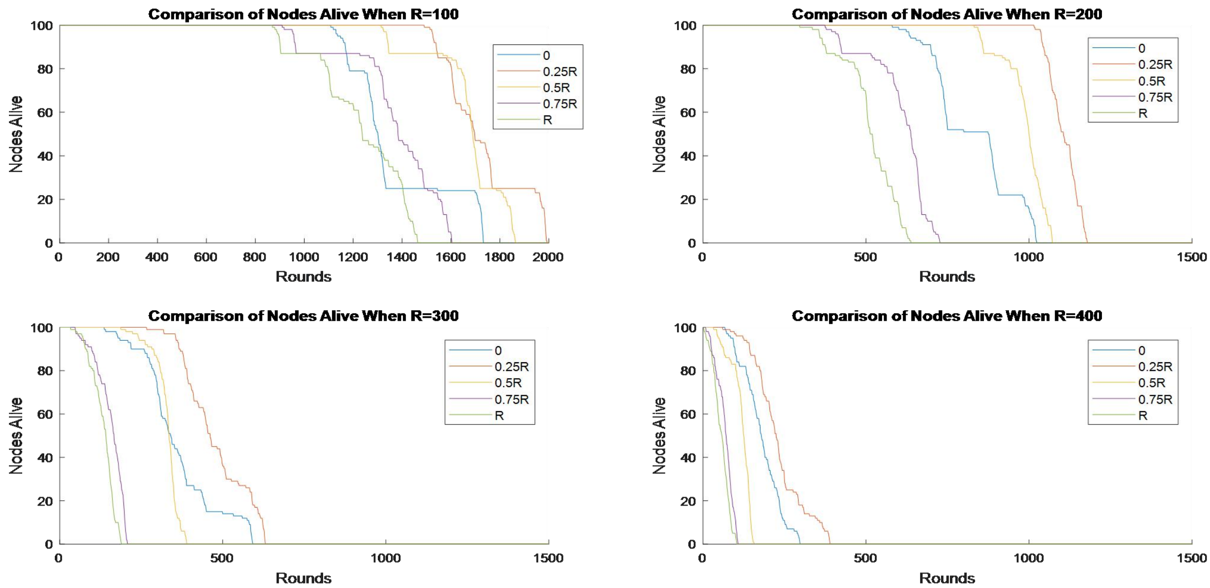

Figure 3. Different network size.

5. Conclusions

Mobile sink technology provides WSNs an alternative to alleviate the hot spot problem. In this paper, we combine the clustering method together with mobile sink strategy to improve network

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performance. Based on our extensive simulations, we observe that when sink node moves along 1/4 radius of circular network, it has best performance in term of network lifetime. In the near future, we will extend our simulation by considering multiple mobile sinks as well as other network metrics such as energy consumption, latency etc.

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