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Extending the Lifetime and Balancing Energy Consumption in Wireless Sensor Networks

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ABSTRACT

Network lifetime is a crucial performance metric to evaluate data-gathering wireless sensor networks (WSNs) where battery-powered sensor nodes periodically sense the environment and forward collected samples to a sink node. In this project, we propose an analytic model to estimate the entire network lifetime from network initialization until it is completely disabled, and determine the boundary of energy hole in a data-gathering WSN. Specifically, we theoretically estimate the traffic load, energy consumption, and lifetime of sensor nodes during the entire network lifetime. Furthermore, we investigate the temporal and spatial evolution of energy hole, and apply our analytical results to WSN routing in order to balance the energy consumption and improve the network lifetime. Extensive simulation results are provided to demonstrate the validity of the proposed analytic model in estimating the network lifetime and energy hole evolution process.

Keywords : Wireless Sensor Networks, FNDT, Died Time, ANDT

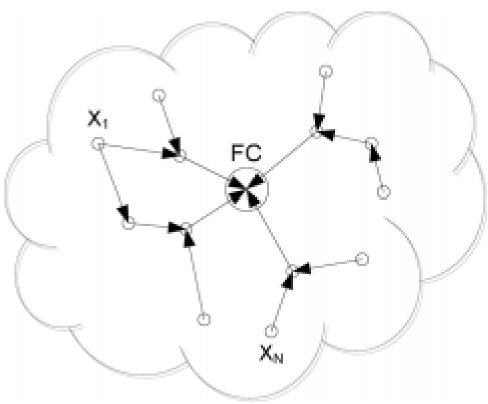
I. INTRODUCTION

Data gathering in large-scale wireless sensor networks (WSNs) relies on small and inexpensive devices with severe energy constraints. Network lifetime in this context is a critical concern as nodes may run out energy as a consequence of the high number of communications required to forward packets produced by nodes toward a data-gathering sink. A data-gathering WSN consists of a large number of battery powered sensor nodes that sense the monitored area and periodically send the sensing results to the sink. Since the battery powered sensor nodes are constrained in energy resource and generally deployed in unattended hostile environment, it is crucial to prolong the network lifetime of WSN. Meanwhile, as energy consumption is exponentially increased with the communication distance according to the energy consumption model, multi-hop communication is beneficial to data gathering for energy conservation. However, since the nodes close to the sink should forward the data packets from other nodes, they exhaust their energy quickly, leading to an energy hole around the sink. As a result, the entire network is subject to premature death because it is separated by the energy hole. There have been several existing works studying the energy consumption and network lifetime analysis for WSNs focus on the duration from network initialization to the time when the first node dies (i.e., First Node Died Time, FNDT), aiming to improve the network performances and optimize the FNDT. Chen et al. propose an analytic model for estimating the traffic load of sensor nodes and FNDT in a multi-hop WSN. General network lifetime and cost models are also discussed to evaluate node deployment strategies. Since network lifetime is limited by unbalanced energy consumption, Ok et al. propose a distributed energy balanced routing (DEBR) algorithm to balance the data traffic of sensor networks and consequently prolong the FNDT. As hierarchical routing has been proved to be beneficial for network performance, especially for the scalability and energy consumption, research works also study the FNDT of cluster-based WSNs. Lee et al. derive the upper bound of FNDT in cluster-based networks and investigate the effects of the number of clusters and spatial correlation on this bound. Liu et al. also discuss the FNDT of cluster-based networks, and propose a routing protocol to improve FNDT based on unequal cluster radii.

1. WIRELESS SENSOR NETWORKS

Wireless Sensor Network (WSN) is a collection of spatially deployed wireless sensors by which to monitor various changes of environmental conditions (e.g., forest fire, air pollutant concentration, and object moving) in a collaborative manner without relying on any underlying infrastructure support. Recently, a number of research efforts have been made to develop sensor hardware and network architectures in order to effectively deploy WSNs for a variety of applications. Due to a wide diversity of WSN application requirements, however, a general-purpose WSN design cannot fulfill the needs of all applications. Many network parameters such as sensing range, transmission range, and node density have to be carefully considered at the network design stage, according to specific applications. To achieve this, it is critical to capture the impacts of network parameters on network performance with respect to application specifications.

A wireless sensor network (WSN) consists of a large number of distributed nodes with sensing, data processing, and communication capabilities. Those nodes are self-organized into a multi-hop wireless network and collaborate to accomplish a common task. As sensor nodes are usually battery-powered, and they should be able to operate without attendance for a relatively long period of time, energy efficiency is of critical importance in the design of wireless sensor networks.



A WSN is a collection of embedded sensor nodes with wireless networking capabilities. Collectively the sensor nodes establish a wireless network for transferring, processing and monitoring the sensed data. In order to ensure a small form factor, the sensor nodes are highly integrated and provide minor processing capabilities and limited memory. More stringent, the battery-powered nodes have to carefully orchestrate the power-hungry radio device if a yearlong independent operation is targeted. To make matters even worse, wireless communication is inherently unreliable and limited in range. Altogether this makes it a very demanding task to ensure a reliable, timely and energy efficient transport of the sensed data over possibly multiple hops.

Reliability is of utmost importance in a safety-critical environment. Additionally, there are often regulations imposing strong demands in terms of message latency and the availability of the sensor nodes.

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, enabling also to control the activity of the sensors. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

A Wireless Sensor Network consists of small battery powered wireless devices, that are capable of monitoring environmental conditions such as humidity, temperature, noise, etc. Sensor networks do not have a fixed infrastructure but form an ad hoc topology. Wireless sensor networks are emerging as a promising platform that enable a wide range of applications in both military and civilian domains such as battlefield surveillance, medical monitoring, biological detection, home security, smart spaces, inventory tracking, etc. Such networks consist of small, low-cost, resource limited (battery, bandwidth, CPU, memory) nodes that communicate wirelessly and cooperate to forward data in a multi-hop fashion.

II. LITERATURE SURVEY

1. Network Lifetime Maximization for Estimation in Multi-hop Wireless Sensor Networks

We consider the distributed estimation by a network consisting of a fusion center and a set of sensor nodes, where the goal is to maximize the network lifetime, defined as the estimation task cycles accomplished before the network becomes nonfunctional. In energy-limited wireless sensor networks, both local quantization and multi-hop transmission are essential to save transmission energy and thus prolong the network lifetime. The network lifetime optimization problem includes three components: *i*) optimizing source coding at each sensor node, *ii*) optimizing source throughput of each sensor node, and *iii*) optimizing multi-hop routing path. Fortunately, source coding optimization can be decoupled from source throughput and multi-hop routing path optimization, and is solved by introducing a concept of *equivalent 1-bit MSE function*. Based on the optimal source coding, the source throughput and multi-hop routing path optimization is formulated as a linear programming (LP) problem, which suggests a new notion of *character-based routing*. The proposed algorithm is optimal and the simulation results show that a significant gain is achieved by the proposed algorithm compared with heuristic methods.

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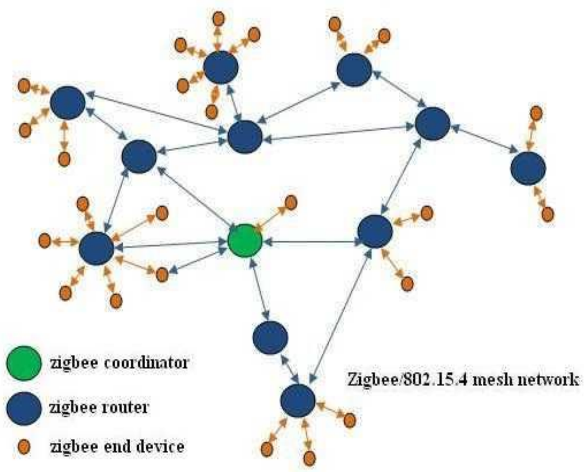
To maximize the network lifetime for the estimation application, three factors are needed to be optimized together: *i) source coding, i.e., quantization level of each observation, ii) source throughput, i.e., total number of observations or total information bits generated by each sensor, and iii) multi-hop routing path to transmit the observations from all sensors to the fusion center*. This problem can be formulated as a nonlinear programming (NLP) problem. Further, as we will show in this paper, source coding optimization can be decoupled from source throughput and multi-hop routing optimization and solved by introducing a Concept of equivalent 1-bit MSE function. It is noted that the proposed algorithm determines the optimal quantized locally at each sensor without knowing other sensors' information, thus it can be implemented in a distributed manner. On the other hand, the source throughput and multi-hop routing needs to be optimized jointly and it can be formulated as a linear programming (LP) problem based on the optimal source coding. It is interesting to see that the solution implies a *character-based routing*, where a sensor node only relays other sensors' observations that are more accurate than its own observations, which is different from the traditional distance-based routing, where sensor nodes closer to the fusion center relay information for sensor nodes farther away from the fusion center.

Drawbacks

Further generalization of the new notions of function-based network lifetime and character-based routing is an interesting direction for the future work. A distributed implementation of the character-based multihop routing to achieve the maximum network lifetime bound and some simple heuristic algorithms to achieve the close-to-optimal performance are also interesting directions we plan to undertake in the future. To facilitate the problem, we have assumed in this paper that the observation noises among different sensors are uncorrelated and the channels from the local sensors to the fusion center are error free. As the future work, we also plan to relax the above assumptions and study the more general distributed parameter estimation problems.

2. Distributed Compressive Sampling for Lifetime Optimization in Dense Wireless Sensor Networks



The problem of data sampling and collection in wireless sensor networks (WSNs) is becoming critical as larger networks are being deployed. Increasing network size poses significant data collection challenges, for what concerns sampling and transmission coordination as well as network lifetime. To tackle these problems, in-network compression techniques without centralized coordination are becoming important solutions to extend lifetime. In this paper, we consider a scenario in which a large WSN, based on ZigBee protocol, is used for monitoring (e.g., building, industry, etc.). We propose a new algorithm for in-network compression aiming at longer network lifetime. Our approach is fully distributed: each node autonomously takes a decision about the compression and forwarding scheme to minimize the number of packets to transmit. Performance is investigated with respect to network size using datasets gathered by a real-life deployment. An enhanced version of the algorithm is also introduced to take into account the energy spent in compression.

Experiments demonstrate that the approach helps finding an optimal tradeoff between the energy spent in transmission and data compression.

We address the data compression problem in a large-scale WSN first analyzing the performance of both a classical gathering scheme and CS, and then proposing a mixed algorithm able to reduce the overall number of packets transmission ensuring data compression. Our solution is a mixed fully distributed algorithm in which each node autonomously takes a proper decision about compression, aiming to reduce the number of outgoing packets. The goal of this paper is to extend the network lifetime and reconstruct the original signal at the collector with good quality limiting the number of packets circulating within the network. This study is based on a previous work by the same authors. The first part of this paper describes the original algorithm, whereas the second part introduces several improvements with respect to the original version. In particular, the innovative contribution is clearly exposed in Section VIII when power consumption optimization is performed considering the energy used for compression. The analysis is not performed on a fixed dimension network, but the scalability of the proposed solution is investigated in networks of increasing size.

Drawbacks:

This analysis is not performed on a fixed dimension network so we change the protocol and improve the network life time.

III. EXISTING SYSTEM

The energy consumption balancing problem originated as an optimal transmitting data distribution problem by combining the ideas of corona-based network division and mixed-routing strategy together with data aggregation. We first propose a localized zone-based routing scheme that guarantees balanced energy consumption among nodes within each corona. Although most of existing works are effective to estimate FNDT, the period from FNDT to the time when all the sensor nodes are dead or the network is completely disabled (i.e., All Node Died Time, ANDT) is relatively long. For most applications, a small portion of dead nodes may not cause a network failure, although they can impact the network performances. Thus, this period is nonnegligible for the entire network lifetime. On the other hand, performance analysis on this period is difficult and intractable because the network is unstable after a few nodes die. Once the nodes with heavy load die, some other nodes should relay the data originally forwarded by these dead nodes. It leads to dynamical changes of the routing paths, as well as the traffic load of sensor nodes. Therefore, it is necessary to analyze the performance and network lifetime after FNDT.

DISADVANTAGES:

- It point out that energy hole does not always emerge close to the sink and highly depends on some network parameters.
- Energy consumption is high
- Reduce Lifetime

IV. PROPOSED SYSTEM

Estimating the traffic load and energy consumption of sensor nodes, as well as the duration of each network stage. We first divide the network into a number of small regions where the nodes have similar distances to the sink. Since the energy consumption of the sensor nodes in the same region should be the same from a statistical point of view, we use the average energy consumption of this region as the nodal energy consumption of this region. In this paper, we propose an analytic model to estimate the entire network lifetime from network initialization until it is completely disabled, and determine the boundary of energy hole in data-gathering WSNs. To accurately estimate the energy consumption of sensor nodes, we consider the energy consumption not only for data transmitting and receiving, but also for idle listening. Specifically, our contributions are threefold. (i)We propose an analytic model to estimate the traffic load, energy consumption and lifetime of sensor nodes during the entire network lifetime. Furthermore, we estimate the network lifetime under a given percentage of dead nodes, and the remaining energy of the network based on our analytical results. Extensive simulations demonstrate that the proposed analytic model can estimate the network lifetime within an error rate smaller than 5%. (ii)Based on the lifetime analysis of sensor nodes, we investigate the temporal and spatial evolution of energy hole from emerging to partitioning the network, which provides a theoretical basis to mitigate or even avoid energy hole in WSNs. (iii)To validate the effectiveness of our analytical results in guiding the WSN design, we apply them to WSN routing. The improved routing scheme based on our analytical results efficiently balances the energy consumption and significantly improves the network lifetime, including FNDT and ANDT.

ADVANTAGES:

- It increases the network lifetime.
- Low data collection latency.
- It estimates the network lifetime and energy whole evolution process within an error rate smaller than 5%.

APPLICATIONS

- Military surveillance
- Environmental monitoring
- Infrastructure and facility diagnosis
- Other industry applications

V. CONCLUSION

In this project, we have developed an analytic model to estimate the traffic load, energy consumption and lifetime of sensor nodes in a data-gathering WSN. With the analytic model, we have calculated the network lifetime under a given percentage of dead nodes, and analyzed the emerging time and location of energy hole, as well as its evolution process. Moreover, two network characteristics have been found based on our analytic results, which can be leveraged to guide the WSN design and optimization. Our simulation results demonstrate that the proposed analytic model can estimate the network lifetime and energy hole evolution process within an error rate smaller than 5%. Finally, we have applied our analytic results to WSN routing. The improved routing scheme based on our analytical results can efficiently balance the energy consumption and prolong the network lifetime.

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