

Energy Efficient Scheduling in Wireless Sensor Networks

Diwakaran S

Assistant Professor, Department of Electronics and Communication Engineering,
Kalasalingam University, India

Abstract: *In this paper, we are interested in minimizing the delay and maximizing the lifetime of event-driven wireless sensor networks for which events occur infrequently. In such systems, most of the energy is consumed when the radios are on, waiting for a packet to arrive. Sleep-wake scheduling is an effective mechanism to prolong the lifetime of these energy-constrained wireless sensor networks. However, sleep-wake scheduling could result in substantial delays because a transmitting node needs to wait for its next-hop relay node to wake up. An interesting line of work attempts to reduce these delays by developing "anycast"-based packet forwarding schemes, where each node opportunistically forwards a packet to the first neighboring node that wakes up among multiple candidate nodes. In this paper, we first study how to optimize the anycast forwarding schemes for minimizing the expected packet-delivery delays from the sensor nodes to the sink. Based on this result, we then provide a solution to the joint control problem of how to optimally control the system parameters of the sleep-wake scheduling protocol and the anycast packet-forwarding protocol to maximize the network lifetime, subject to a constraint on the expected end-to-end packet-delivery delay. Our numerical results indicate that the proposed solution can outperform prior heuristic solutions in the literature, especially under practical scenarios where there are obstructions, e.g., a lake or a mountain, in the coverage area of the wireless sensor network.*

Keywords: delay, energy-efficiency, sensor network, sleep-wake scheduling.

1. Introduction

Recent advances in wireless sensor networks have resulted in a unique capability to remotely sense the environment. These systems are often deployed in remote or hard-to reach areas. Hence, it is critical that such networks operate unattended for long durations. Therefore, extending network lifetime through the efficient use of energy has been a key issue in the development of wireless sensor networks. In this paper, we focus on event-driven asynchronous sensor networks with low data rates, where events occur rarely. This is an important class of sensor networks that has many applications such as environmental monitoring, intrusion detection, etc. In such systems,

There are four main sources of energy consumption: energy required keeping the communication radios on; energy required for the transmission and reception of control packets; energy required to keep sensors on; and energy required for data transmission and reception. The fraction of total energy consumption for data transmission and reception is relatively small in these systems because events occur so rarely. The energy required to sense events is usually a constant and cannot be controlled. Hence, the energy expended to keep the communication system on (for listening to the medium and for control packets) is the dominant component of energy consumption, which can be controlled to extend the network lifetime. Thus, sleep-wake scheduling becomes an effective mechanism to prolong the lifetime of energy-constrained event-driven sensor networks. By putting nodes to sleep when there are no events, the Energy consumption of the sensor nodes can be significantly reduced.

Various kinds of sleep-wake scheduling protocols have been proposed in the literature. Synchronized sleep-wake scheduling protocols have been proposed in [2]–[6]. In these protocols, sensor nodes periodically or a periodical exchange synchronization information with neighboring nodes. However, such synchronization procedures could incur additional communication overhead and consume a considerable amount of energy. On-demand sleep-wake scheduling protocols have been proposed in [7] and [8], where nodes turn off most of their circuitry and always turn on a secondary low-powered receiver to listen to "wake-up" calls from neighboring nodes when there is a need for relaying packets. However, this on-demand sleep-wake scheduling can significantly increase the cost of sensor nodes due to the additional receiver. In this paper, we are interested in asynchronous sleep-wake scheduling protocols such as those proposed in [9]–[11]. In these protocols, each node wakes up independently of neighboring nodes in order to save energy. However, due to the independence of the wake-up processes, additional delays are incurred at each node along the path to the sink because each node needs to wait for its next-hop node to wake up before it can transmit the packet. This delay could be unacceptable for delay-sensitive applications, such as fire detection or a tsunami alarm, which require the event reporting delay to be small.

2. Optimal Anycast Forwarding Policy

We considered three parameters for our scheme, Wake-up rate - The time period taken to wake the sensor node from sleep state, Forwarding set - It consists of nodes that can deliver the packet very quickly to the sink Priority- When multiple nodes send an acknowledgement after an ID signal, based on priority, source node will send the packet. The

algorithm of optimal anycast follows: let us consider 12 nodes and want to transmit packet from source node 2 to destination node 10,

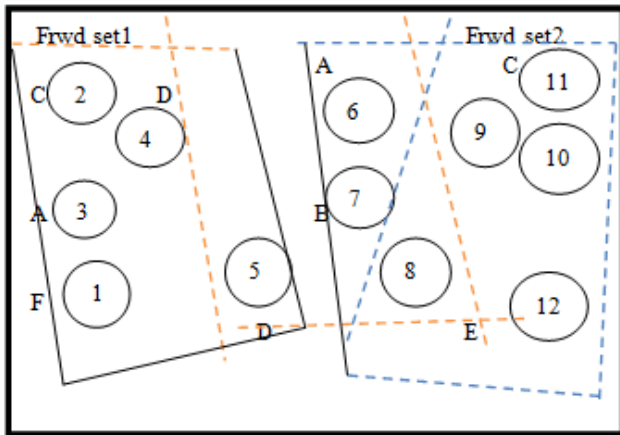


Figure 1: sensor nodes

We considered the wake-up rate follows the Poisson random process. The letters denoting A, B, C, D, E, and F in the sensor nodes denote their priorities in respective forwarding sets. The node 2 will contain set of nodes (forwarding set); similarly, node 10 also contains the same set

The Beacon and ID signal will be transmitted at the period of T_a and T_b , any node among the forwarding set will hear the signal and responds through sending acknowledgment to node2. After receiving acknowledgment, packet gets transmitted to that particular node and node 2 went to sleep. The process get repeated up to the packet reaching destination. If more than two nodes send acknowledgment, based on priority, the packet gets transmitted.

The flowchart following will explain the optimal anycast scheme used sleep-wake scheduling. Consider six nodes in the forwarding set1, among them, node 2 alone in wake situation. It sends the beacon and ID signal to neighbor nodes frequently. If anyone neighbor node hears the signal, it send acknowledgment to the wake node. The packet get transmitted, the node 2 turns in to sleep mode. The process gets repeated until the packet reaches the node 10, that is, its destination. If none of the neighbor hears the signal, the node 2 has to wait up to next turn. The rotation based on priority, it also help in balancing load as well as energy efficiency management. It will maximize the network life time. It will lead to energy efficient scheduling for wireless sensor network. The simulation was done using the Network simulator-2 (NS2) tool; the results were discussed on the next section. It includes the various cases, such as, same wake up rate-Uniform and same wake up rate- Non-uniform and differentiate wake up rate-Non-uniform.

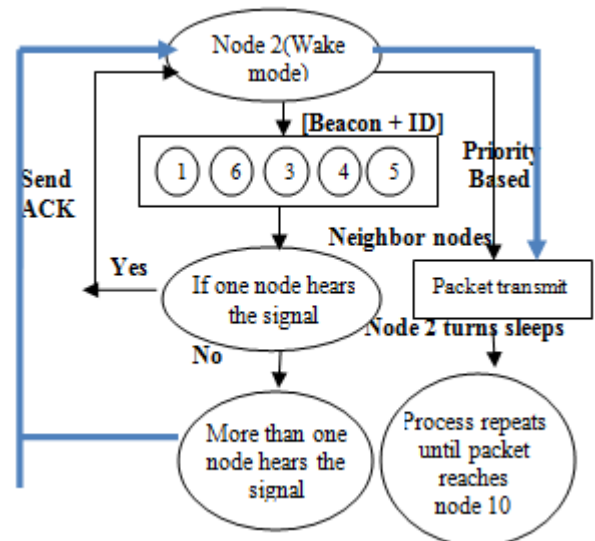
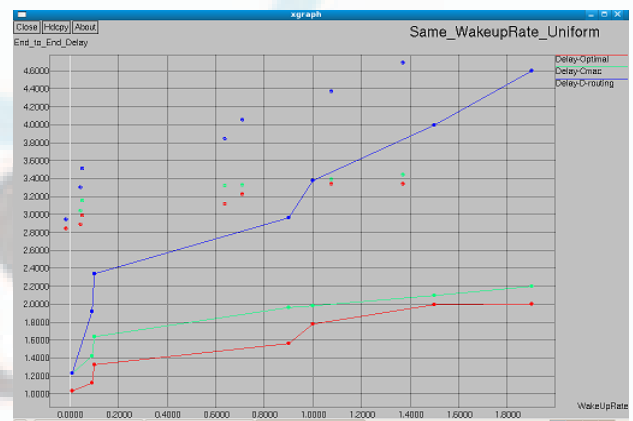


Figure 2: Flowchart for optimal anycast scheme

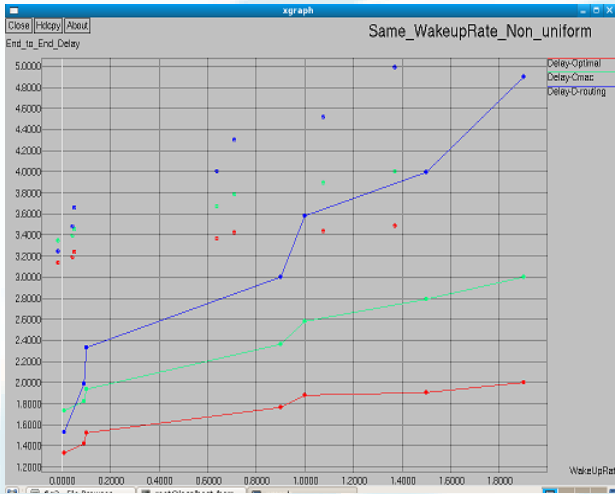
3. Simulation Results and Performance Analysis

The simulation results will provide the performance of optimal anycast forwarding by comparing with C-Mac and D-routing algorithm. C-Mac will deliver the packet based on first acknowledgement signal from next hop or neighbor node. D-routing will deliver the packet based on node weight age. There are three cases, **first case: Uniformly Deployed Homogeneous Nodes** we first simulate a wireless sensor network with 400 uniformly deployed nodes over a 1×1 km area with the sink located at the lower left corner. We assume that the transmission range from each node is a disc with radius 100 m. We also assume that all nodes are homogeneous, i.e., all nodes have the same wake-up rate

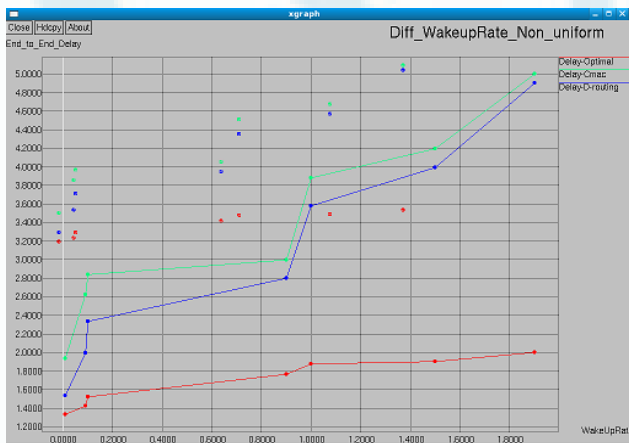


Second case: Homogeneous Nodes With a Connectivity Hole, We next simulate a topology where there is a connectivity hole in the sensor field. This is motivated by practical scenarios, where there are obstructions in the sensor field, e.g., a lake or a mountain where sensor nodes cannot be deployed. From this figure, we observe that the optimal anycast algorithm substantially outperforms the C-MAC. In our optimal algorithm, in order to reduce the delay, a packet is first forwarded to neighbors with negative progress but

smaller end-to-end delay. However, under the C-MAC, all packets are forwarded only to nodes with positive progress. Thus, the anycast-based heuristic algorithms depending only on geographical information could perform poorly. Unlike the C-MAC algorithm, we observe that the connectivity hole does not significantly affect the performance of the hop-counting algorithm, as the hop-count is a global metric that depends on connectivity of nodes, rather than their geographical locations.



Third case: Heterogeneous Nodes with a Connectivity Hole So far, we have assumed that all nodes have the same wake-up rate. We now simulate the case of heterogeneous wake-up rates. This kind of diversity can occur when nodes are deployed with different amount of initial energy or are deployed at different times. From this figure, we observe that the optimal anycast algorithm can significantly reduce the delay compared with the D-routing algorithm.



4. Conclusion and Future work

In this paper, we develop an anycast packet-forwarding scheme to reduce the event-reporting delay and to prolong the lifetime of wireless sensor networks employing asynchronous sleep-wake scheduling. Specifically, we study two optimization problems. First, when the wake-up rates of the sensor nodes are given, we develop an efficient and

distributed algorithm to minimize the expected event-reporting delay from all sensor nodes to the sink. Second, using a specific definition of the network lifetime, we study the lifetime-maximization problem to optimally control the sleep-wake scheduling policy and the anycast policy in order to maximize the network lifetime subject to an upper limit on the expected end-to-end delay. We plan to generalize our solution to take into account non-Poisson wake-up processes and other lifetime definitions.

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Author Profile



Diwakaran S received the B.E degree in Electronics and Communication Engineering from PSNA college of Engineering in 2008 and M. Tech Degree in Communication Systems from B.S. Abdur Rahman University in 2011 respectively. He completed MBA (General Management) from Anna University in 2013. He currently pursue Research work on Resource Management in Wireless sensor Networks. His interested areas are Wireless sensor networks and Digital communication.

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