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Study on 2-hop Scheme for Data Collection in Wireless Sensor Networks

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Sensors in wireless sensor networks (WSNs) usually form a tree topology and the sensed data are transmitted to a sink using multihop communication. However, multihop communication causes the phenomenon of unbalanced energy consumption, in which sensors close to the sink are overused due to transmitting not only their own sensed data but also data from other sensors, and they will die out early, resulting in network collapse although there may be still significant amount of energy in other sensors. Therefore, network lifetime could be prolonged if the energy consumption of all sensors in the network is balanced. In our research, the network lifetime of a WSN is defined as the time elapsed since the network started operating until one sensor run out of battery.

For any data gathering applications, especially in large-scale networks, a small delay in data collection is desired. In this research, data collection delay is defined as the time for all packets from all sensors in network to be received by the sink. However, also with multihop communication, a packet is relayed by many nodes before arriving at the sink, which causes a high delay in data collection.

There are two main objectives of our research, first, to increase the network lifetime of WSN by balancing energy consumption of each sensor throughout the network, and second, to reduce the delay in data collection. To obtain this, we propose a scheme called "2-hop scheme". Our proposed scheme exploits energy tradeoff between hop-by-hop transmission and 2-hop transmission. Hop-by-hop transmission is a basic communication pattern in WSN, where a packet is forwarded to the next hop until it reaches the sink. This basic communication consumes less energy at each hop; however, it causes high load of packets relay at nodes near the sink, resulting unbalanced energy consumption, as mentioned above. 2-hop transmission is another pattern of communication in WSN (in our research, we assume that each sensor can increase the transmitting power so that the transmission range is increased), where a packet is forwarded not to the next hop, but instead to the 2-hop-away node. For illustration, let us consider three sensors S_3, S_2, and S_1. The next hop of S_3 is S_2 and the next hop of S_2 is S_1. In hop-by-hop transmission, packets from S_3 are forwarded to S_2. In 2-hop transmission, packets from S_3 are forwarded not to S_2, but to S_1. 2-hop transmission consumes more energy than hop-by-hop transmission; however, it can help reduce the load (the total number of packets to be transmitted) at each node. By elegantly combining these two patterns of transmission, energy consumption of sensors in the network could be balanced and the network lifetime could then be prolonged.

More specifically, a packet is transmitted in hop-by-hop transmission with a probability p, and is transmitted in 2-hop transmission with probability $1 - p$. By choosing optimal transmission probability p for each node, the expected energy consumption of all nodes could be balanced and then, the network lifetime is proved to be maximized.

We analyze our proposed scheme for chain topology networks, binary tree topology networks and then for general tree topology networks. For chain and binary tree topology networks, we give a method to find optimal transmission probability for each node, so that energy consumption is balanced and network lifetime is maximized. For general tree topology network, it is difficult to find optimal transmission probability for each node; we then assign the same transmission probability for all nodes in the network, and use a simulator to estimate how much our proposed scheme could help increase the network lifetime compared to hop-by-hop scheme (hop-by-hop scheme is the conventional scheme where data is sent only in hop-by-hop transmission). Simulation results show that our proposed scheme outperforms the hop-by-hop scheme not only in term of network lifetime but also in term of data collection delay. With chain and binary tree networks, we also analyze the cases when initial battery levels in sensors are different to each other and give a method to find optimal transmission probabilities for the sensors.