Revisiting the Effectiveness of Energy-Conserving Techniques in Energy Harvesting Wireless Sensor Networks

Sayan Sen Gupta

Internet of Things (IoT) envisages a global network in which a multitude of everyday objects are equipped with sensors and network connectivity, allowing them to send and receive data over the internet. Due to the interactions among a wide variety of devices, IoT promises to lead to host of new applications that utilize the potentially enormous amounts of generated data to provide new services to citizens, companies and public administrations.

Wireless Sensor Networks (WSNs) are an integral part of IoT. A WSN consists of sensor nodes that collect information and transmit it to a data fusion center over a single or multi-hop wireless channel. Conventional WSNs are severely constrained by the availability of sufficient energy in the batteries of the sensor nodes. Several energy-efficient techniques have been extensively researched to enhance their lifetime. Exploiting energy harvesting (EH), by which nodes can recharge their on-board battery by harvesting energy from renewable sources, is an exciting new approach that circumvents the vexing lifetime challenge. While the EH nodes can replenish their batteries in case they run out of energy, depending on the sensing and communication technique used and the randomness of the energy harvesting process, they can be occasionally unavailable. This degrades the sensor networks performance.

We study the effect of energy-conserving techniques on the mean squared error (MSE) performance of a multi-node EH WSN, in which the EH sensor nodes amplify and forward their measurements to a fusion node. We show that the design of these techniques is no longer driven by the monotonic trade-off between maximizing lifetime and compromising system performance. Instead, the focus shifts to optimizing the parameters of these techniques so as to minimize the MSE. We first derive closed-form expressions and a lower bound for the MSE of the censoring technique, in which nodes with channel power gains below a threshold do not transmit to conserve energy. We also characterize the optimal censoring threshold of the technique.

Next, we present a novel adaptation of the ordered transmission technique for EH WSNs. In it, the sensors transmit in the decreasing order of their channel power gains and only a subset consisting of nodes with the largest channel power gains transmit. As above, we derive the lower bound of the MSE in closed form and characterize the optimal subset size. We also present a new hybrid technique, in which the nodes are first censored based on their measurements and a subset of them with the largest channel power gains transmit. Our results show that when the energy available is less, the hybrid scheme outperforms the ordering scheme which, in turn, outperforms the censoring scheme. Furthermore, all three schemes outperform the conventional approach in which all the sensors attempt to transmit.

Future work involves analyzing these techniques for the practically relevant and theoretically challenging scenario in which the sensor observations are spatially correlated. We also intend to generalize the approach to account for imperfect channel information at the sensor nodes and the fusion node.