Abstract

Wireless sensor network (WSN) is a resilient and effective distributed data technology that cooperatively monitors and records the physical environment and then wirelessly communicates the data. The development of wireless sensor network was motivated by military applications such as battlefield surveillance, but with the emergence of smart devices, such networks have gained recognition in many industrial and consumer applications. Wireless sensor network requires a sensor node wherein uninterrupted collection, computation, dissemination, storage, and communication of data go on all the time. Such sensor nodes' realization requires sufficient or continuous energy supply to improve the sensor node lifetime to prevent information degradation, and loss. But, the conventional sensor nodes are powered by finite capacity batteries that pose stringent energy constraints. As a result, to overcome this problem, energy management schemes like energy conservation methods and energy harvesting (EH) (a technique to scavenge energy from the environment) is used to maintain an energy flow in the sensor node. The harvested energy is stored in the battery to avoid the sensor node's performance hindrance due to the intermittent and random nature of the harvested energy.

The use of energy management schemes fulfills the need for continuous power supply to improve sensor node lifetime, but the finite lifetime of the battery becomes a bottleneck in sensor node lifetime. Once the battery dies, the sensor node runs out of energy and becomes non-functional, implying a finite lifetime along with additional cost and complexity to regularly change the batteries. Thus, for an enhanced lifetime, an energy storage device (ESD) with a longer lifetime (a large number of charge/discharge cycles) than a battery becomes the need. Also, the energy-efficient transmission policies are an essential energy conservative method, as most of the energy is consumed during communication by the sensor node. The optimal transmission policies are computationally complex and burden the low power sensor nodes. Thus, a transmission policy that provides a complexity-performance trade-off is needed to improve sensor network lifetime. Most of the research till date has considered an ideal battery for the analysis, but practically, energy storage devices possess some imperfections that lead to energy loss affecting the sensor node lifetime and performance. Thus, identifying those imperfections and considering them for energy optimization makes the system closer to practical application.

The research work aims to bring the concept of energy harvesting wireless sensor network a bit closer to the practical application by bringing out the solutions for the issues that affect the sensor node lifetime. Firstly, the issue of the performance-complexity trade-off of the transmission policy is addressed. In this sequence, a new energy-efficient transmission policy is proposed. The proposed policy has low complexity as compared to the optimal policy and provides near-optimal performance. The transmit power is decided based on the current channel state, where the transmitter only knows the channel and energy statistics. The transmission policy is proposed considering sensor node wit battery. After transmission protocol, the issue of energy storage device lifetime is resolved by identifying an alternative storage device with a large number of charge/discharge cycles. In this reference, supercapacitor (SC) has gained importance as energy storage device because of high power density, low energy density, and high shell life (charge/discharge cycles more than battery), which are suited for sensor node applications. But, the high self-discharge rate creates an issue for low power sensor nodes. The imperfections of SC are modeled for sensor node applications, to be used in the simulation analysis. The performance of the imperfect supercapacitor and battery are analyzed in different scenarios using the optimal dynamic programming policy. In the same sequence, the next part of the thesis is oriented towards analyzing supercapacitor's suitability and performance in a sensor node, using

the proposed transmission policy. The suitability is analyzed by comparing it with the battery. The research done in this thesis on energy storage device and their imperfection and transmission policy complexity-performance trade-off will enable a better system design for energy harvesting wireless sensor network. Resource allocation schemes, network lifetime, and performance will be benefited from this research work.