Abstract

The use of Wireless Sensor Networks in automated environment monitoring has grown significantly in the past decade because they are small, cheap and easily scalable compared to their traditional wired counterparts, which have dominated this area for a long time.

Africa and the developing world present unique challenges for these systems. The poor penetration of electric power grids requires battery-powered deployments, which must consume as little power as possible to maximize battery life in the short and long term. The high temperature environments in some areas and the hardware platforms chosen to implement these sensor networks require the battery chemistry to be evaluated against these same constraints. Finally, the effects of seasonal patterns and microclimate variations require the solar energy harvesting units (solar cells) to be sized using new data-driven techniques, because the traditional techniques may underestimate the required size by a large factor. As such, the techniques necessary to implement robust very low power WSNs in the region are still very much open questions.

This study investigated the techniques of reducing energy-related failures in environment monitoring WSNs. It concentrated on the three main parts of the WSN power system: the energy-harvesting unit, the energy storage unit and the load. To maximize battery life and prevent short-term failure, this study proposed several low power design guidelines and further implemented an ultra-low power WSN gateway. The study proceeded to compare various electrochemical energy storage technologies for three WSN use cases: the implemented gateway, traditional high-power gateways and the transmitter nodes. Using Li-ion batteries as the preferred energy storage technology, the study then collected performance data for the low power gateway for over 50 days and used this data to propose two new techniques to size the solar panel optimally.

The gateway implementation achieved an ultra-low power consumption of 55mW compared with values of 200-4000mW in the work of peers between 2008—2017, while maintaining core environment monitoring functionality. Of 11 commercially available battery chemistries investigated, Lithium-based technologies were found to have the most favorable intersection of six parameters of importance. Li-ion capacitors, recommended for some transmitter nodes, had their self-discharge evaluated at 45^0C and 60^0C. The self-discharge was found to be 8-19% after 10,000 minutes for 40F and 270F capacitors. For optimal solar panel sizing, the transfer function estimation technique and the discrete-calculus technique gave strong correlations of 0.93 and 0.84 and low RMSE values of 1.6% and 9%, respectively, between actual observed and predicted values of battery state of charge. Finally, a prototype-level economic analysis revealed that the suggested interventions achieved an overall low cost and low power compared to peers during this period.

By considering the techniques proposed in this study, design engineers can develop robust WSN-based automatic weather stations that can operate longer under limited solar insolation, have longer battery lifespan and be adaptable to various solar insolation profiles.