Power Management of Habitat Monitoring Wireless Sensor Network Systems

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Abstract

Wireless Sensor Networks are more adaptive for habitat monitoring applications than other techniques. This is because of the high distribution density and self-organization of tiny sensor nodes. This paper reviews the deployment of Wireless Sensor Networks for habitat monitoring. It begins with a brief introduction of Habitat Monitoring Wireless Sensor Networks. The following sections will mainly discuss the methodologies that have been used for long-term Habitat Monitoring Wireless Sensor Network Systems. This paper aims to compare and contrast different kind of power management when deploying a Habitat monitoring Wireless Sensor Network Systems. The reliability of a long-term Habitat Monitoring Wireless Sensor Network Systems mainly depends on them. Thereafter, this paper will point out the key points and significant views of the studies about deployment of Habitat Monitoring Wireless Sensor Network Systems and finally present conclusion with recommendations for further studies.

Keywords: Habitat Monitoring, Wireless Sensor Networks, Network Architecture, Power Management

Introduction

The past decade has witnessed a burgeoning interest in Wireless Sensor Network (WSN), which spans from habitat monitoring to health applications. Lots of research has been done via deploying a WSN system. WSN systems can not only be used as a tool for researchers, but also a significant tool for human beings. The Structure Health Monitoring (SHM) System is a good example. According to the statistics, the estimation value of both US and Canada Civil infrastructure assets is US$25 trillion. As a precaution method, SHM applications have magnificent social and economic impact on the society. Because of the low deployment and maintenance cost, large physical coverage and high spatial resolution, WSN is the state of the art approach for SHM system [1].

With the development of technology, researchers are seeking for new methods to monitor the habitat of our planet. Traditional methods use data loggers (e.g., intrusive probes and weather stations). These instruments are usually very large and expensive. Due to these drawbacks, those data loggers can only be deployed sparsely.

Data loggers cannot be long-term used for experiments either. This feature is a hurdle for biologist to conduct a long-term monitoring experiment. The biggest drawback of them is the fact that when researchers want to apply such instrument, they have to work very close to them. Human activities can largely disturb the environment and influence the data they are collecting. However, the appearance of WSN, to some extent, has solved this problem. Sensors can be integrated on a very small circuit board that is also known as a node. Through the nodes network, node can communicate with each other within the network. Meanwhile, it is very economical to conduct a long-term study with WSN, because the cost of building a node and its maintenance are much cheaper than buying an off-the-shelf data logger. The paramount advantage of building a WSN for habitat monitoring is the fact that WSNs permit real-time data access without paying visits to sensitive habitats for several times [2].

Due to these advantages, biologists prefer WSNs to monitor habitat for certain area. In order to meet the requirement of biologists, plenty of Habitat Monitoring Wireless Sensor Network Systems have been deployed. This paper will critically review a number of these systems to find the gaps between them.

Scope and method

All of the 10 relative articles are selected from the database of Springer, ACM and IEEE. The criterion of the selections is whether or not the article has strong relationship with my topic and the Impact Factor. All of these related articles were published later than 2000. Due to the fact that there are many components deployed for a Habitat Monitoring Wireless Sensor Network System, this paper will mainly reviews the comparisons between different methodologies of power management since that is the main challenge to deploy a Habitat Monitoring Wireless Sensor Network System. Details of comparisons will be explained. At the same time, this paper only focuses on long-term habitat monitoring. The methodology that is applied for short-term habitat monitoring or indoor WSN deployment will not be discussed in this paper.

Review

Power management has become a main challenge to researchers for deployment of long-term WSN systems. Many WSNs systems for habitat monitoring have been deployed. Power management has always been the prior problem to these systems. Power management is not simply to choose a better battery, but to thoroughly develop the whole system including algorithms, architectures and circuit design. All of these aspects contribute to the power supply.

In the summer of 2002, scientists have deployed a WSNs system for Leach's Storm Petrel Monitoring on the Great Duck Island, Maine, USA [2]. In order to conduct a long-term monitoring for these petrels, low duty cycle operation has to be designed. First, each sensor has been designed as a rechargeable battery-powered device. Second, a simple periodic application has been installed in each node, which allows the node to enter its lowest-power state for 70 seconds. Third, all of the in-the-field equipment operated at a full duty cycle by a solar cell and rechargeable battery. Fourth, a passive infrared detector has been implemented to meet low power requirements. Fifth, when each sensor received data, it would not be directly propagated to the Internet. Because sending data needs much power, the system is designed to transfer all of the received data to a base station where adequate power is provided. According to the experiments, the protection of nodes is insufficient. In the field, when wet, the sensor would suffer to generate a low-resistance path between the batteries. Nevertheless, the result of examinations to test voltage of batteries reveals that the batteries were unable to supply adequate current for the node. In addition, when the voltage dropped below 2.5V (the lowest operating voltage for nodes without the voltage regulator), the boost converter on the node would be able to extract only 15% more energy from batteries. This means that the batteries lifetime is much shorter than expected. The results of this article show that the voltage of batteries is a key criterion for power management in this kind of systems. Meanwhile, the package strategy is also an issue needed to be taken into consideration. Due to the changeable environment where the WSNs system of habitat monitoring deployed, an adequate protection for sensors is indispensable for the design of the whole system. In order to have a stable voltage for the nodes, a boost converter which introduces noise and increase power consumption should not be carried out any more [3]. A compatible replacement for the boost converter is to use lithium-based batteries.

Szewczyk et al. have continued the experiments with lithium-based batteries for nodes [3][4]. In this later experiment, the whole system used S-MAC medium access control for low-power operation instead of the older one to solve MAC-layer synchronization of nodes. In order to reduce the power consumption, the network was improved to be time-synchronized. At the same time, a schema called low-power listening (LPL) has been introduced in this article. Via this schema, the average rate of active node on Great Duck Island is 2.2%, which indicates the power consumption of the entire system has been reduced. And the lithium-based batteries have been put into use. According to the energy counters at the MAC layer and in the sensing application, the lifetime of the batteries has significantly increased. Other experiments that have been conducted by other researchers demonstrated consistency to this choice. ZebraNet [5] is a wildlife monitoring and tracking wireless sensor network system. In this article, researchers have replaced the heavy lead-acid battery with lithium-ion polymer cells. Although this experiment aimed at tracking wild animals and the network structure is not the same as the Great Duck Island experiment, the same choice of batteries reflects that the lithium chemistries is compatible for a long-term outdoor habitat monitoring wireless sensor network system. Similar example could also be seen in the wireless sensor network for habitat monitoring on Skomer Island [6]. In addition, in this system, researchers have equipped a secondary 12V (7Ah) lead acid battery to accompany with the lithium-ion batteries. Although the node will be heavy and large, it insures a high long-term outdoor performance of the entire system. This method seems to be the combination of the ZebraNet [5] and the Great Duck Island petrel monitoring system [2]. The packaging strategy of this system has used a waterproof case to contain the equipment of the node, which largely avoided the wet affection to the batteries. This would prevent the damage of the batteries. In the meantime, there are still some researchers deploy their WSNs systems with converter and normal batteries. Gao and Jin [7] have introduced a novel wireless sensor networks platform for habitat surveillance, which was still using a converter and 2 AA batteries. Although its indoor experiment results showed a good performance of the entire system, according to the previous experiments, it is still doubtful that whether this platform could be long term used in habitat monitoring.

Although choosing lithium-ion batteries is a good method for deploying a Habitat Monitoring Wireless Sensor Networks, there are still some undefined conditions would cause failure of batteries. Due to various conditions of monitored environment, there will not be any method could adapt to all of the conditions. According to the previous researches, there are still many other kind of methods can be done to reduce the power consumption. Researchers could use a duty-cycle mechanism to reduce the awake period of nodes to save energy or apply a low-power listening (LPL) schema. Meanwhile, the network architecture could also be taken into consideration. For example, the time-synchronized network architecture could reduce the power consumption of the entire network. In addition, in system design, the MAC layer protocols are another essential part of power management as well. Compare to the experiments that have been conducted on the Great Duck Island, the application of S-MAC showed a better performance in low power operation. In the Habitat Monitoring Wireless Sensor Network System on Skomer Island, a MAC protocol similar to X-MAC has been carried on. It also showed a good performance for reducing power consumption. The S-MAC [8] protocol is short for the Sensor Medium Access Control protocol which is specifically designed for WSNs. Three techniques have been used in this protocol to achieve low power duty cycling, which are periodic sleep, virtual clustering and adaptive listening. Compared to IEEE 802.11, this protocol has a leap on power conserving properties. However, the X-MAC [9] showed that the S-MAC is out of date. The X-MAC is based on asynchronous duty cycling techniques. Buettner et al. argued that the awake period of asynchronous technique can be much shorter than the use of synchronous technique which is just what the S-MAC uses. According to the experiments that Buettner et al. [9] have implemented, X-MAC performed better than other synchronous techniques based on MAC protocol. Although the X-MAC showed a better performance in the lab, the experiment that has been conducted on Skomer Island did not show adequate in-the-field data to support the theory. Therefore, further in-the-field experiments are needed to be done.

Conclusion

This literature Review has discussed in some details of several methods of power management of long-term Habitat Monitoring Wireless Sensor Network Systems. According to the comparisons, the lithium-ion battery is the most proper choice for future deployment of WSNs systems for habitat monitoring. The in-the-field experiments which have been conducted on the Great Duck Island and the Skomer Island have identified that. However, it is difficult to choose a proper MAC protocol for the system, because there are no adequate in-the-field data for the comparison. In the meantime, except of S-MAC and X-MAC, other energy-efficient MAC protocols which are used for WSNs have been developed. The UWAN-MAC [10] has been specifically developed for underwater acoustic wireless sensor networks. It is also an energy-efficient MAC protocol. Therefore, different kinds of MAC protocol can be used for different kinds of habitat monitoring systems. Future deployment of habitat monitoring systems needs to consider the experiment environment and to choose the proper MAC protocol. In order to have a better power management, any part of the system is needed to be taken into consideration. Researchers are trying different methods to achieve a low power consumption WSNs system. Hempstead et al. [11] have developed an ultra-low power system architecture for WSNs applications. This architecture could be used to extremely reduce the power consumption of the hardware and the software on the circuit board of nodes. However, without any in-the-field experiments, this system can hardly be used in disciplinary science research even it shows a terrific performance in the lab. The power management is the mainly challenge for a WSNs especially for a long-term habitat monitoring system. Whether or not a Habitat Monitoring Wireless Sensor Network System can be long-term used is largely depended on power management. The design of power management of the entire system is still worth researching.

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