Computer Networks 79 (2015) 166–187

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Survey Paper

Reliability in wireless sensor networks: A survey and challenges ahead

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ARTICLE INFO

Article history:
Received 17 September 2013
Received in revised form 28 November 2014
Accepted 17 December 2014
Available online 6 January 2015

Keywords:
Wireless sensor networks
Reliability
Redundancy
Retransmission

ABSTRACT

Ensuring energy efficient and reliable transport of data in resource constrained Wireless Sensor Networks (WSNs) is one of the primary concerns to achieve a high degree of efficiency in monitoring and control systems. The two techniques typically used in WSNs to achieve reliability are either retransmission or redundancy.

Most of the existing research focuses on traditional retransmission-based reliability, where reliable transmission of data packets is ensured in terms of recovering the lost packets by retransmitting them. This might result in additional transmission overhead that not only wastes sensors' limited energy resources but also makes the network congested and in turn affects the reliable transmission of data. On the other hand, employing redundancy to achieve reliability in WSNs has received comparatively lesser emphasis by the research community [35] and this area warrants further investigation. In redundancy-based reliability mechanisms, a bit loss within a packet can be recovered by utilizing some form of coding schemes. This ability to correct the lost or corrupted bits within a packet would significantly reduce the transmission overhead caused by the retransmission of the entire packet.

Both retransmission and redundancy can either be performed on a hop-by-hop or an end-to-end basis. Hop-by-hop method allows the intermediate nodes to perform retransmission or redundancy. On the other hand, in the end-to-end approach, retransmission or redundancy is performed only at the source and the destination nodes. However, a hybrid mechanism with an efficient combination of these retransmission and redundancy techniques in order to achieve reliability has so far been neglected by the existing research. Depending on the nature of the application, it is also important to define the amount of data required to ensure reliability. This introduces the concept of packet or event level reliability. Packet reliability requires all the packets from all the relevant sensor nodes to reach the sink, whereas event reliability ensures that the sink only gets enough information about a certain event happening. Thus retransmission or redundancy techniques using hop-by-hop or end-to-end mechanisms aim to achieve either packet or event level reliability.

This paper presents a survey on reliability protocols in WSNs. We review several reliability schemes based on retransmission and redundancy techniques using different combinations of packet or event reliability in terms of recovering the lost data using hop-by-hop or end-to-end mechanisms. We further analyze these schemes by investigating the most suitable combination of these techniques, methods and required reliability level in order to provide energy efficient reliability mechanism for resource constrained WSNs. This paper also proposes a 3D reference model for classifying research in WSN reliability, which will be used to perform in-depth analysis of the unexplored areas.

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http://dx.doi.org/10.1016/j.comnet.2014.12.016
1389-1286/

1. Introduction

Wireless Sensor Networks (WSNs) have been the preferred choice for the design and deployment of next generation monitoring and control systems [1,2]. It has now become feasible to deploy massive numbers of low-cost sensors to monitor large regions over the ground surface, underwater or in the atmosphere [3]. The most significant benefit of sensor networks is that they extend the computation capability to the physical environment where human beings cannot reach [4]. They can operate for prolonged periods in habitats that are hostile, challenging or ecologically too sensitive for human visitation [5]. Moreover, they have the potential to provide a wealth of data about the environment in which they are deployed and deliver the data across the network to the end-users [6,7].

At the heart of WSNs are the sensor nodes. A sensor node is a device that possesses sensing, computation and communication capabilities. Depending on their sensing components and the application requirements, sensor nodes can be used to monitor different phenomena like temperature, light, motion, pressure and humidity. The processing module of the sensor node is able to do computation on the sensed data and also on the data received from other sensors. The communication module in sensor nodes is used to send and receive the data packets to and from the neighbouring nodes [8]. Since a single sensor provides only limited information, a network of these sensors is used to provide coverage over large environments.

Fig. 1 shows a typical Wireless Sensor Network (WSN) comprising of several sensor nodes and a sink node. The sensor nodes continually sense data from the environment and send them to the sink node. In most scenarios, tens to as many as thousands of such sensor nodes are distributed throughout a region of interest, where they self-organize into a network through wireless communication and collaborate with one another to accomplish a common task [2]. The sink receives all the sensed data from these sensor nodes, processes them and sends them to the end user.

Due to the nature of traffic in WSNs, where all sensor nodes in the network forward their sensed data towards the sink, the area around the sink becomes more congested with all the traffic flowing towards and converging on the sink. In addition to losing packets through congestion, packets are also lost due to transmission errors, packet collision, interference, node failure (due to energy depletion) or other unforeseeable reasons. Furthermore, due to the short range of the sensor nodes, data might have to travel a large number of hops which, in turn, introduces a lot of entry points for errors that can also become the cause of packet loss. Thus, for successful monitoring of an environment, the critical data collected by the sensor nodes need to be reliably delivered to the sink, requiring the lost data to be recovered. Given the nature of error prone wireless links, ensuring reliable transfer of data from resource constrained sensor nodes to the sink continues to be one of the major challenges in the field of WSNs.

Various protocols have been proposed using different techniques to cope with the challenge of achieving reliability in wireless sensor networks. We investigate the methods involved in creating the overall reliability technique and find the best possible combination of the available options by introducing a three-dimensional (3D) reference model to categorize the work done on providing reliability in WSNs, as shown in Fig. 2. In later sections, the 3D reliability reference model will be unfolded to perform in-depth analysis, pointing out the unexplored and efficient combination of the techniques to encounter the challenge of achieving reliability in WSNs. Existing data transmission reliability protocols belong mainly to one of two techniques which are retransmission or redundancy. These techniques ensure reliability by recovering the lost data using a hop-by-hop or an end-to-end method, while adopting either packet or event level reliability based on the application requirements. The terminologies used for these

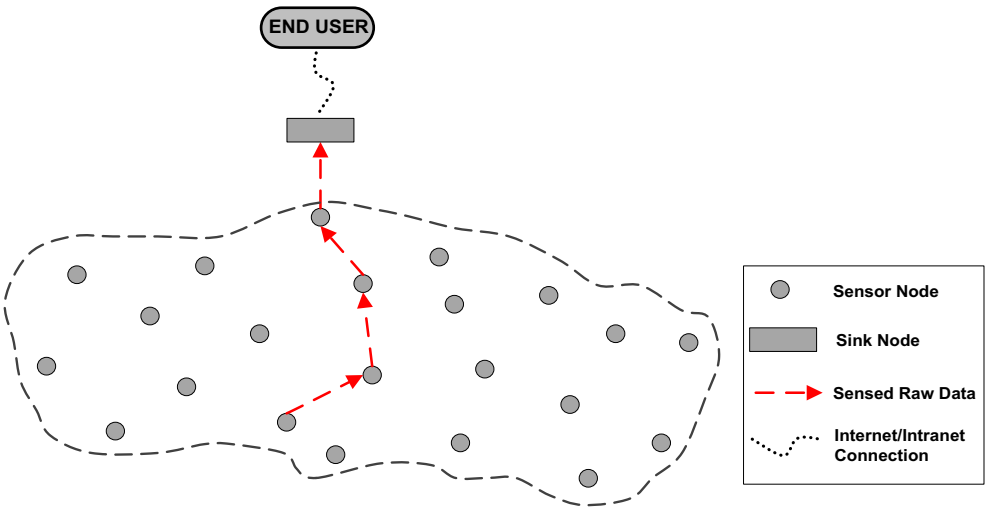

Fig. 1. Wireless sensor network.