ARTICLE IN PRESS

Computer Science Review ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Computer Science Review

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

Survey

A comparative study on popular MAC protocols for mixed Wireless Sensor Networks: From implementation viewpoint

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ARTICLE INFO

Article history:
Received 14 July 2015
Received in revised form
21 September 2016
Accepted 28 September 2016
Available online xxxx

Keywords:
Medium Access Control (MAC)
Mixed Wireless Sensor Networks (MWSN)
Network life-time
Throughput

ABSTRACT

Sensors cooperate and coordinate with each other to disseminate sensed data in the network. In establishing coordination among sensors such that they can access the shared wireless medium, Medium Access Control (MAC) protocol plays an important role. In this article, we presented an analytical study on some popular MAC protocols for Wireless Sensor Networks (WSNs). Based on the design techniques, MAC protocols for WSNs are classified into two main categories: single-layer and cross-layer. MAC protocols such as S-MAC, T-MAC, B-MAC and X-MAC are selected to study the design approaches of single-layer genre. BoX-MAC-1 and BoX-MAC-2 are selected to analyze cross-layer design approaches. This survey paper aims at reporting an implementation viewpoint of different design approaches of MAC protocols in WSN. We have considered mixed WSNs that exhibits node movement (e.g., static, mobile) and changes in communication medium (e.g., air, water). Representative protocols are implemented in Castalia simulator and evaluated on the basis of important performance metrics such as energy consumption, network lifetime, throughput and end-to-end delay. The merits and demerits of different protocols are also compared.

Contents

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http://dx.doi.org/10.1016/j.cosrev.2016.09.004
1574-0137/

Please cite this article in press as: T. Maitra, S. Roy, A comparative study on popular MAC protocols for mixed Wireless Sensor Networks: From implementation viewpoint, Computer Science Review (2016), http://dx.doi.org/10.1016/j.cosrev.2016.09.004

1. Introduction

In general, WSNs provide low cost solutions of real-world monitoring applications such as traffic monitoring, climate and habitat monitoring, tracking enemy movements and so on. In such applications, a large number of sensor nodes are deployed into the target area to monitor the environment by sensing different physical phenomena. However, large scale deployments, limited battery power, low computation capability, limited storage facility and other unique properties represent main challenges to the development of WSNs. Thus, in most of the WSN applications it is difficult to achieve high energy efficiency along with good network performance. Furthermore, the distributed nature of sensor networks makes energy-efficient protocol design particularly challenging. In this context, network lifetime is perhaps the most important metric for the evaluation of sensor networks. Therefore, computational operations and communication protocols must be made as energy efficient as possible. The wireless interface is the primary consumer of energy in sensing devices which combines computation and radio. MAC layer directly access the physical layer and controls the radio. Thus, energy-efficient protocols for WSNs envisioned to have long network lifetime are heavily dependent on MAC layer.

In the early days, a typical WSN was considered as static network where all sensors were purely static. However, due to the dynamic nature of events and hostile environment, a pure static WSN may not be suitable to achieve the goal. Thus to enhance its capability and flexibility to support the monitoring missions, mobility is introduced to some sensors. Moreover, combining multimedia sensors, acoustic sensors, physiological sensors, environmental sensors (e.g., light, temperature, humidity, pressure, sound etc.) to form a mixed WSN (MWSN) with different sensing capabilities provides several advantages compared with the traditional WSN. For example, in precision agriculture solution using WSN, only ground environmental sensors may not be sufficient for monitoring. In this specific application, MWSNs of underwater i.e., acoustic sensors and ground environmental sensors provide a new method for environment monitoring of the crop land. In ground WSN, sensor devices are located at specific locations to monitor soil quality (such us temperature, moisture, salinity etc.) as well as soil motion. In addition, another WSN may be placed in a pond or nearby water body to measure the salinity and the quality of the water supplied to the crop land. A schematic diagram of a MWSN with ground and underwater sensors is shown in Fig. 1.

In this paper, we defined mixed WSN as a special type of WSN which consists of different types of sensors (e.g., multimedia, acoustic, physiological, environmental, etc.) and can be placed on the ground or underwater. Therefore, different communication mediums, i.e., air for ground sensors and water for underwater sensors are used. Moreover, these sensor nodes can be stationary or mobile as per their requirement or role in the network. Mobile sensors are expensive but provide distinct advantages over static nodes. In particular, mobility of selected sensor nodes can improve coverage and provides tactical advantages for tracking and trapping in hostile environments. Thus, MWSNs are designed to increase the coverage of target area. However, network topology changes rapidly due to the mobile sensor nodes in the MWSNs. The term mixed in MWSN is used to highlight the presence of several features of a node in the network, e.g., sensor types, communication medium and node movement.

MWSNs belong to the general category of intermittently connected networks or delay tolerant networks [1,2]. At any time, a fully connected path between source and destination cannot be guaranteed in such networks or such a path is highly unstable. MWSNs are widely used in many ongoing projects to get low cost solution such as SIGMA (jointly collaborate with NASA) [3], SenIT (developed by DARPA) [4], smart-home (developed by NIBIB) [5], and many more.

1.1. Related work

Previous research works have been focused on various MAC protocols in WSNs, some notable literature reviews are presented in [6–13]. The survey in [6] reviews weaknesses and strengths of MAC protocols with respect to communication patterns. Challenges to design a MAC protocol for WSNs are described in [7]. In [8], Dong et al., described a comparative study of several mobility-aware MAC protocols, and analyzed the challenges caused by mobility at the link layer. The latency issue of some asynchronous MAC protocols in WSNs and their comparison with respect to latency in a static WSN were reviewed by Doudou et al. in [9]. Zhao et al. in [10] reviewed some MAC protocols for WSNs. The main focus was to observe advantages and disadvantages of MAC protocols in a wireless environment. The authors in [10] concluded that self adaptive MAC layer [14] may be suitable to handle such hostile environment like WSN. In [11], Chen et al., presented a comparative study of several types of MAC protocols for underwater acoustic environment and also highlighted the challenges. The recent MAC protocols are energy-efficient as well as support efficient delivery in dense networks as discussed in [12]. Ju et al. [13] demonstrated a comprehensive survey on the cooperative MAC protocols for wireless communication in order to find the performance of MAC protocols when MAC layer cooperates with other layers. However, existing protocols may not be self sufficient to handle complexities of MWSN environment. Thus, it is very essential to investigate the requirements and challenges of MWSN first and then design a suitable MAC protocol which can efficiently handle this environment.

1.2. Contribution

The main difference between this paper and existing articles is in the main attention given here on the implementation details. That allows us to provide more comprehensive understanding on this specialized area. Before going to design a new MAC protocol for MWSNs, it is necessary to understand the existing popular and basic MAC protocols and as well as their drawbacks and limitations by analyzing the simulation results. In this paper, we

Please cite this article in press as: T. Maitra, S. Roy, A comparative study on popular MAC protocols for mixed Wireless Sensor Networks: From implementation viewpoint, Computer Science Review (2016), http://dx.doi.org/10.1016/j.cosrev.2016.09.004