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Review article

A fuzzy logical controller for traffic load parameter with priority-based rate in wireless multimedia sensor networks

Young-Long Chen*, Hung-Pin Lai

Department of Computer Science and Information Engineering, National Taichung University of Science and Technology, No. 129, Sec. 3, Sanmin Road, Taichung 404, Taiwan

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ABSTRACT

In *wireless multimedia sensor networks* (WMSNs), sensor nodes use different types of sensors to gather different types of data. In multimedia applications, it is necessary to provide reliable and fair protocols in order to meet specific requirements of *quality of service* (QoS) demands in regard to these different types of data. To prolong the system lifetime of WMSNs, it is necessary to perform adjustments to the transmission rate and to mitigate network congestion. In previous works investigating WMSNs, *exponential weighted priority-based rate control* (EWPBRC) schemes with *traffic load parameter* (TLP) schemes in WMSNs were used to control congestion by adjusting transmission rates relative to various data types. However, when the TLP is fixed, a large change in data transmission causes a significant difference between input transmission rate and the estimated output transmission rate of each sensor node. This study proposes a novel *fuzzy logical controller* (FLC) pertaining to TLP schemes with an EWPBRC that estimates the output transmission rate of the parent node and then assigns a suitable transmission rate based on the traffic load of each child node, with attention paid to the different amounts of data being transmitted. Simulation results show that the performance of our proposed scheme has a better transmission rate as compared to PBRC: the delay and loss probability are reduced. In addition, our proposed scheme can effectively control different transmission data types insofar as achieving the QoS requirements of a system while decreasing network resource consumption.

Contents

1. Introduction

Rapid technological advances in wireless communication systems, low power digital electronics, small scale energy supplies, micro-microprocessors and low power radio technologies now enable low-power multi-functional sensor devices to detect and react to changes in their surrounding environments. These sensor devices are equipped with a small battery, a tiny micro-processor and a set of transducers that are used to acquire information which reflects these changes in the surrounding environment of the sensor node. The emergence of low power and minute wireless sensor devices has led to intensive research in the last decade which, in turn, has led to the development of *wireless sensor networks* (WSNs) [1].

A *wireless sensor network* (WSN) consists of one or more sink nodes and numerous sensor nodes scattered in a wireless field, which collaborate with each other to accomplish certain tasks. Specifically, a wireless sensor network is a physical device which

* Corresponding author. Tel.: +886 4 22196621; fax: +886 4 22196341.
E-mail address: ylchen66@nutc.edu.tw (Y.-L. Chen).

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integrates information from sensor computing and wireless communication processing. Mutual propagation of data is sent from neighboring nodes to the *base station* (BS). A *wireless multimedia sensor network* (WMSN) [2] is an extended application of WSNs such that the sensor can be equipped with a multimedia device, e.g., a miniaturized microphone, battery or video transceiver; therefore, WMSNs have the capability to transmit multimedia data such as still images, video and audio streams, along with the ability to monitor data. Resource constraints on WMSNs include: energy, memory, bandwidth, buffer size and processing capability. Since multimedia data transmission requires high transmission rates and the ability to process massive amounts of data, the high data transmission rate common to WMSNs often causes congestion. This, in turn, deteriorates the *quality of service* (QoS) of multimedia applications.

With regard to WSNs, limited power, bandwidth, high density network and large scale deployments underscore some challenges to the management and design of WSNs. As such, these challenges demand energy awareness and protocol designs at all layers of the networking protocol. Efficient use of sensor energy resources is the main design consideration in developing protocols and algorithms with regard to sensor networks and has dominated most of the research pertaining to WSNs. Furthermore, WMSNs, in real-time applications, require strict constraints on both delay and throughput in order to report the time-critical data to the processing sink within certain time limits and bandwidth requirements without loss. Hence, energy awareness for sensor networks with different layers requires an efficient utilization of network resources, as well as effective access to sensor readings [3].

In WMSNs, disseminating packets are used to carry information and transmit data via a hop-by-hop process. The transmission priorities of heterogeneous WMSNs differ between real-time transmission and non-real-time transmission. Real-time transmission has major constraints such as delay and bandwidth jitter, but is more tolerant to packet losses. Transmission rates do not need to be controlled in real-time transmission, which has the highest priority, but non-real-time transmission uses an active queue management scheme [4] to allocate transmission rate. Studies of factors affecting QoS in network transmission, including packet loss probability, delay and throughput, indicate that packet loss probability and delay can usually be mitigated.

In network transmissions, QoS enables stable and predictable data transmission service in order to satisfy network users' requirements. Internet data flows, such as those for e-commerce, multimedia data transmission and massive file downloads, usually require massive transmissions of burst data which then cause congestion [5]; notably, increased bandwidth cannot solve the resulting insufficiencies with regard to network resources. The *internet engineering task force* (IETF) defines a service differentiation model [6] to guarantee the QoS of end-to-end transmission.

Energy consumption is also an important issue in regard to wireless networks. Chamodrakas and Martakos [7] proposed a network selection method based on a modified fuzzy version of the *technique for order preference by similarity to the ideal solution* (TOPSIS) with regard to QoS and energy consumption. Additionally, Chen et al. [8] proposed scheme utilizes local information regarding feedback control commands for power adjustments in wireless cellular networks. In [9], the authors proposed a *fuzzy logical controller* (FLC) to manage rates and achieve selective power control for *code division multiple access* (CDMA) systems. In the literature [10], FLC combined with power control vis-a-vis window-based transmission rate management was proposed in a multimedia CDMA cellular system. The FLC is used to make adaptive rate adjustments and monitor power control in regard to transmission rate. Here, two input values, *signal-to-interference ratio* and *error-to-error change*, are used to adjust transmission rate control and power control. Furthermore, some studies [11,12] proposed using the FLC power control to select a suitable channel using non-linear time variant characteristics.

A model based on transmission priority has been proposed to mitigate network transmission congestion in a WMSN. In terms of transmission rate, the fixed *traffic load parameter* (TLP) scheme was used for adjustment purposes. In the TLP [13] scheme with *exponential weighted priority-based rate control* (EWPBRC), the transmission data exhibit massive variations and a large error between input transmission rate and estimated transmission rate for each sensor node, resulting in inconsistent network resource allocation. The traffic load parameter was a fixed value to yield such that the delay and loss probability for the WMSN is increased.

This paper proposes a new scheme in which we use FLC to regulate traffic load parameters based on EWPBRC for controlling the transmission rate of each sensor node, in order to avoid resource waste caused by excessive adjustments of the transmission rate. However, a transmission rate that is too low can cause excessive adjustments, leading to too much delay. The proposed scheme has two FLC input variables: transmission rate error and error change. Via the FLC, the traffic load parameter is adjusted in order to optimize the transmission rate of each sensor node.

The remainder of this paper is organized as follows: Section 2 consists of an investigation of related research regarding WMSNs in transmission congestion control; Section 3 provides details regarding the proposed scheme for improving transmission; Section 4 contains the simulation results; and Section 5 offers our conclusions.

2. Related works

This section describes the effects of transmission congestion on network resources and QoS. Currently, traditional *transmission control protocol* (TCP) is widely used in computer networks; TCP uses packet confirmation to provide reliable transmission. The congestion control architecture used to meet the QoS requirement of WMSNs in different data types is also discussed.

For data transmission in WSNs, the network transmission model layer must be coordinated. Different layers have different control topics. During data transmission, the *media access control* layer (MAC), RTS/CTS and ACK mechanisms enable transmission to the sensor node of each mobile. In WMSNs, the MAC layer gathers the transmitted information and measures queuing delay in order to compute the transmission rate [14].

Transmission rate congestion control in WSNs has been studied extensively. Congestion leads to massive packet loss; consequently, the re-transmission of lost packets causes further congestion and wastes network resources, while decreasing the reliability of data detection and collection. Congestion in WSNs [5] may be embodied by node-level congestion or link-level congestion. In node-level congestion, when the packet-arrival rate exceeds the packet service rate at each sensor node, buffer overflow increases packet loss when the node transmits data. Link-level congestion occurs in wireless transmissions when the nodes use the same channel, such as in *carrier sense multiple access with collision detection* (CSMA/CD). When multiple active nodes use the same channel, the resulting collision is detected [15] and the node in the collision must sends out a congestion message to the entire network. At this moment, all network nodes must cease transmission and enter a waiting state.

There are two approaches to control congestion: network resource management and traffic control [5]. Network resource management mitigates congestion via the increase of network resources. This is undertaken, for instance, through an enhancement of bandwidth where congestion is slowed. When this method is used, the precise adjustment of network resources is required in