

A Cross-Layer QoE-Based Approach for Event-Based Multi-Tier Wireless Multimedia Sensor Networks

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ABSTRACT

Wireless Multimedia Sensor Networks (WMSNs) are attracting attention from both academic and industrial environments due to the rapid development of low-cost multimedia sensors. With the enhancement of the multimedia content captured by multimedia devices, WMSNs play an important role in pervasive and ubiquitous systems. The multimedia content in these networks has the potential to enhance the level of collected information, by enlarging the range of coverage, and enabling multi-view support. In the case of WMSN applications, the multi-tier network architecture has proved to be more beneficial than single-tier architecture in terms of energy-efficiency, scalability, functionality and reliability. In this context, a multimedia event detection application is a promising application for multi-tier WMSNs, where the lower-tier nodes detect an event occurrence by means of scalar measurements, and the higher-tier nodes will be woken up to send real-time video flows from the event area. The transmission of multimedia content requires a certain quality level from the user's perspective, while energy consumption and network overhead should be minimized. Among the existing mechanisms for improving video transmissions, application-level Forward Error Correction (FEC) is regarded as a suitable solution to improve video quality level from the user's standpoint. In this work, the authors propose an adaptive cross-layer approach, which includes a Quality of Experience (QoE)-aware FEC mechanism for WMSNs by generating redundant packets, based on frame importance from user's experience. Additionally, the authors introduce a multi-tier routing protocol to select the best route to transmit multimedia data. According to the simulation results, the proposed cross-layer approach achieved high video quality level with reduced transmission of redundant packets, which will bring many benefits to a resource-constrained system.

Keywords: Event Detection, Forward Error Correction (FEC), Multi-Tier Routing Protocol, Quality of Experience (QoE), Wireless Multimedia Sensor Networks (WMSNs)

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INTRODUCTION

The proliferation of multimedia content and the demand for new audio/video services in the "Internet of Things" (IoT) applications (Atzori et al., 2010) have ushered in a new era based on multimedia information. These applications have led to the evolution of Wireless Multimedia Sensor Networks (WMSNs) (Tavli et al., 2012), which have attracted interest of researchers because of the availability of low-cost and mature technologies in camera and scalar sensors. WMSNs are composed of wirelessly interconnected nodes equipped with multimedia sensor devices, such as cameras and microphones, to enable the nodes to retrieve video and audio streams, and still images, as well as scalar sensor data.

WMSNs enable a large class of applications ranging across diverse areas in both civilian and military areas, such as multimedia surveillance, environmental monitoring, traffic control, smart cities and other IoT applications. The multimedia content in these applications gives support to end-users (or systems) to visually determine the real impact of an event, be aware of what is happening in the environment, enhance the level of information collected, and provide multi-view support (Alaei & Barcelo-Ordinas, 2012). Thus, the users can make use of the visual information to take action for object/intruder detection. In this study, we focus on intrusion detection scenario with real-time video support.

Different network architectures have been proposed to provide different application requirements. However, the multi-tier network architecture with heterogeneous nodes is the most suitable solution for routing protocols in WMSNs to improve scalability, resilience and energy-efficiency, as shown by (Almalkawi et al., 2010). Moreover, this must be carried out through efficient routing decision to improve the video quality, energy-efficiency, and scalability in event-based WMSNs (Ehsan & Hamdaoui, 2012). Multimedia dissemination should support Quality of Service (QoS) and Quality of Experience (QoE) requirements so that video content can be delivered with,

at least, a minimum video quality level from the user's perspective, together with energy-efficiency and scalability. These issues impose more constraints on the designing of a reliable multi-tier routing protocol for WMSNs (Wijnants et al., 2010).

Solutions involving multimedia transmission must take into account the video characteristics from the user's perspective to increase the user's satisfaction, while keeping the content with a good quality level. In this context, frames with different priorities compose a compressed video, and according to the user's perspective, the loss of high priority frames causes severe video distortion. Thus, a key principle for a QoE-aware multimedia dissemination in multi-tier WMSN applications is the protection of high priority frames in congestion/link error periods (Serral-Gracià et al., 2010). Furthermore, the constraints of sensor nodes increase the effects of wireless channel errors, and the application-level Forward Error Correction (FEC) can be employed as an error control scheme for handling losses in real-time WMSN communications (Yousof Naderi et al., 2012). FEC schemes achieve robust video transmission by sending redundant data, and when the original information is lost, the data can be recovered from the redundant information. Application-level FEC adds h redundant packets to a set of n original source packets. The redundant packets can be used to reconstruct a lost frame, and thus, enhance the video quality level to meet the requirements of human experience.

Multi-tier event detection applications with multimedia support require a cross-layer approach to provide video dissemination with a high quality level from the user's perspective, together with scalability, energy-efficiency and low network overhead. In this context, the multi-tier routing protocol must provide a route selection scheme that employs cross-layer information to find reliable routes. Moreover, priority frames must be protected in congestion/link error periods by taking into account an application-level FEC mechanism, which

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