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QoS-Optimized Adaptive Multi-layer (OQAM) architecture of wireless network for high quality digital video transmission ☆

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A B S T R A C T

Quality of Service (QoS) optimization is an important design goal in wireless video transmission. The application (APP) layer 802.11e medium access control (MAC) layer, and physical (PHY) layer of the wireless protocol stack can be jointly designed for the exchange of information. This will optimize the performance of wireless network for real-time digital video transmission. This paper proposes an innovative 'QoS-Optimized Adaptive Multi-layer (OQAM)' architecture. It ensures reliable and high-quality video transmission over communication channels. The channel exhibits wide variability in throughput, delay, and packet loss. The simulation is performed using EvalVid and Network Simulator-2. Enhanced Intra Prediction (E*n*IP) algorithm with H.264/MPEG4 Advanced Video Coding (AVC) is proposed at the APP layer. This H.264/MPEG4 AVC is a non-scalable video enCOder/DECoder (CODEC). Improved MAC Adaptive Retry Limit ($IMAL_r$) is proposed as smart-packet drop mechanism at the 802.11e MAC layer. It uses packet overflow drop (P_{ov}) and expired-time packet discard (P_{ex}) algorithm. Enhanced Adaptive Forward Error Correction (E*n*AFEC) is proposed at the PHY layer. The aforementioned algorithms are jointly considered in the proposed OQAM architecture, which increases the coding efficiency, reduces end-to-end delay and increases reliability of wireless network for real-time Video over Wireless (VoW) transmission.

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1. Introduction

Since the past few years, broadband wireless networks have been gaining popularity due to their features of high data rate and large coverage. Accompanied by the fast growth of wireless networks and the huge success of Internet video, wireless video services are expected to be broadly deployed in the near future. The past few years witnessed the worldwide deployment of IEEE 802.11 wireless networks. There is rapid proliferation of technologies such as Bluetooth, IEEE 802.11, 3rd generation (3G) and worldwide interoperability for microwave access (WiMax). These technologies are encouraging network service providers to offer high-quality VoW services to mobile users. Also, VoW is predicted to be the 'killer application' for the 4th generation (4G) wireless networks such as the Long Term Evolution (LTE). According to recent prediction, video transmitted to and from mobile devices will exceed 60% of the global mobile data traffic by 2014 [1]. Although the next-generation wireless technologies promise higher bandwidth, the problem of more reliability with low delay during VoW transmission is largely unresolved. As assorted types of wireless networks are converging into all IP networks i.e., the Internet, it is crucial to scrutinize video delivery over the wireless internet [2].

Various VoW schemes must also consider the video-centric QoS constraints to ensure the timely delivery of the video frames. Efficient coding, transmission control and error control techniques are required to meet the needs of QoS performance for real-time VoW transmission [2,3]. Subsequently, a new standard, 802.11e [4,5], was developed aiming to provide enhanced performance for real-time applications. An optimized QoS control method is necessary to transmit the video over IEEE 802.11a/e Wireless Local Area Networks (WLANs) to guarantee the quality [6].

The main objective of this work is to investigate the effects of main parameters of various layers of the protocol stack to support

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real-time video transmission, and to optimize the performance of wireless network to provide the best user-perceived video quality under application-centric QoS constraints.

This research is based on the constructive method of the related publications and technologies. Section 2 gives a brief overview of related and background work about video compression techniques at the APP layer, various issues related to the 802.11e MAC layer and error control techniques at PHY layer as exposed in the literature. It also defines various attributes of proposed work. Section 3 outlines the proposed OQAM system architecture. Further it describes various independent techniques/algorithms proposed by the authors in their previous work including E*n*IP algorithm for H.264/MPEG4-AVC at APP layer [7] and E*n*AFEC algorithm at PHY layer [8]. As proposed by Hossein Bobarshad et al. [9], the Adaptive Retry Limit (AL_r) algorithm is adopted with improvement in calculation of P_e and called as $IMAL_r$. This algorithm uses the smart-packet drop with P_{ov} and P_{ex} at the 802.11e MAC layer. Section 4 describes the superior performance of the proposed OQAM framework through simulations using EvalVid and NS-2 and discusses the results. Section 5 outlines conclusions and future work.

2. Overview of related and background work

One of the key limitations of existing common-layered design approach of wireless system is that it relies on the assumption that any scheme or protocol implemented at one of the layers, will improve the QoS parameters at the other layers too, and will always result in better performance for the upper-layer protocols. To overcome this assumption, a multi-layered design approach is needed, where information among layers is exchanged and parameters are jointly optimized for richer interfaces among the layers of the protocol stack. The characteristics such as channel characteristic and cross-layer architectures have to be carefully considered in the assessment of end-to-end performance of wireless link, particularly for VoW transmission.

There are certain features and requirements [3] of live VoW communication:

- The packetization scheme at the source has a significant impact on the user-perceived video quality. Not all the bits of a coded video bit stream are of equal importance in determining the user-perceived video quality.
- Enabling continuous and smooth playback is very important to achieve a good user experience.
- The quality of the video received under poor network conditions needs to be enhanced.

To provide end-to-end QoS, the video applications should be aware of and accommodative to the variation of the wireless network condition. This accommodation comprises of network adaptation and media adaptation [2]. Joint optimization strategies across various layers of the protocol stack have recently been proposed to improve the performance of real-time VoW transmission [10]. Various multi-layer architecture schemes involving APP–MAC–PHY layers [11–15] have been proposed in the literature as a solution to improve the end-to-end performance of video transmission over WLANs. However, when WLAN is used for VoW transmission, it has some problems such as defining the priority, lack of sharing information between PHY, MAC and APP layers, limitation of QoS parameter for video, and the QoS policy based on the video contents. To determine the optimal strategy, all the possible strategies can be exhaustively examined. The responsible parameters for each layer to evaluate the utility (e.g., quality under the given constraints) corresponding to each strategy can be identified and one of the parameter with the highest utility [12] can be selected.

The classification of cross-layer architecture for VoW transport is done [16] into five categories such as top-down, bottom-up, application-centric, MAC-centric and integrated approach. The top-down approach is used in this paper where the higher layer optimizes the parameters and strategies at the next lower layer.

In this paper, the authors have contributed by providing optimized joint consideration of APP–MAC–PHY layer architecture which can be used to improve the end-to-end performance-building framework in wireless network design for live VoW transmission. Based on the investigation of the research efforts on VoW transmission, the innovative OQAM system is proposed with the following attributes:

- Network: a packet-based network.
- Channel: wireless LAN (IEEE 802.11).
- Target layers: PHY, 802.11e MAC and APP.
- Target parameters: error control coding at the PHY layer, transmission control mechanism at the MAC layer and compression at the APP layer.
- Optimization parameters: bit rate at APP layer as it does not involve the change in MAC layer; channel loss probability (P_e) jointly for MAC and PHY layer.
- Assessment quantities: coding efficiency, EPSNR, delay, throughput and reliability.

The video transmission system without optimization is working as QoS – Adaptive Multilayer (QAM) architecture.

3. Proposed OQAM system architecture

With the expected end-to-end user-perceived quality as the objective function, this paper presents a model of real-time VoW transmission system that ensures the stringent QoS requirements. Various algorithms mentioned above in isolation are used in the multi-layer design approach with appropriate modifications in view of optimization. The detailed transmission control protocol/Internet protocol (TCP/IP) Open System Interconnection (OSI) model is as shown in Fig. 1.

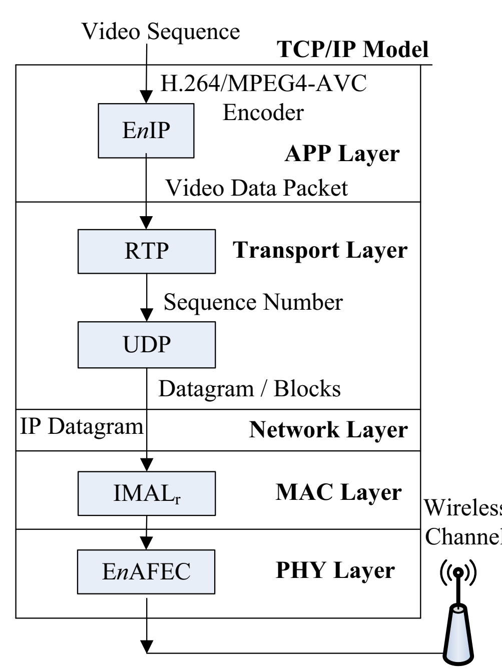

Fig. 1. TCP/IP model for multi-layer structure.

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