Evaluation of Video Transmission over Wireless Network with CLD Approach

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Abstract Wireless networks are widely used in the real world. Due to technology innovations in wireless networks, wireless devices are able to participate in multimedia content transmission. Every wireless device can act as transmitter and receiver of video content. However, there are many issues with video transmission over wireless networks. The reasons are due to mobility of devices and resource constrained nature. There are many layers in OSI reference model. By using enhanced layered approach it is possible to improve video transmission. However, joint optimization of different layers can help in increasing performance of video transmission further. This is the motivation behind the cross layer design (CLD) approaches. In this paper, we proposed a CLD that considers two layers namely the PHY layer and the MAC layer. In PHY layer Scalable Video Coding (SVC) is employed in PHY layer in order to adapt to required transmission rates and based on the dynamic capacity assignment is made to other layer, the MAC layer. We made simulations using NS2 to demonstrate proof of the concept. The results of experiments revealed the utility of the proposed CLD approach. Performance of the proposed CLD is compared with basic video transmission approach in terms of latency, throughput, delay and PSNR.

Keywords: Wireless networks; video transmission; cross layer design; PHY layer; MAC layer.

1. Introduction

Wireless networks became important as they provide convenient means of communication and data sharing. Moreover, there have been growing trend of using mobile devices in all walks of life. Mobility has become an important feature as it can help to have continued connection to digital world. Each node in wireless network can act as source node or destination node. Since wireless networks are handy and can be established with relative ease, they are used in rescue operations in the wake of disasters. Moreover, the low-latency video and voice transmission capability of the wireless devices make it more useful. They can also support multimedia streaming applications where data transfer rate is high with delay constraints.

Though wireless networks provide many advantages, they also throw many challenges. The challenges include interference among nodes, link failures caused due to mobility, and other problems like Quality of Service (QoS). In case of traditional networks, layers are designed independently. In case of wireless networks improving layers independently may not be able to optimize data transmission. However, wireless networks can support joint optimization of layers for producing high performance data transfers. It is essential in case of multimedia streaming applications where QoS is expected. With joint optimization resource utilization can be improved and the decisions made at different layers can influence QoS of video being transmitted over network. Compression and formatting is done in application layer. End to End delivery of packets is under control of transport layer. Figure.1 presents different layers exist in OSI reference model.

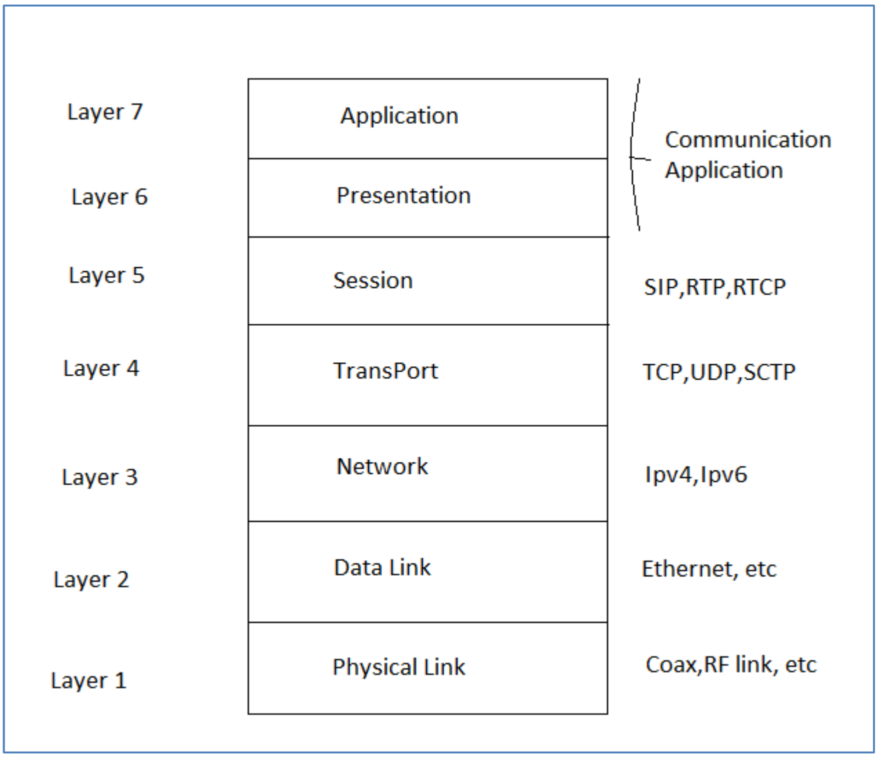

Figure 1: Different layers in OSI reference model

Among the function of data link layer, the Medium Access Control (MAC) layer supports wireless broadcasting and file sharing to different users. On the other hand, the PHY layer can take care of big error rate and data rate. By optimizing the PHY layer, it is possible to optimize data transfer and improve QoS of videos. The cross layer approach can help in improving video quality. Therefore cross layer design (CLD) is given importance in this paper. We preferred joint optimization of the PHY and the MAC layers. At the PHY layer, an approach known as Scalable Video Coding (SVC) is used for leveraging bit oriented streams where users can adjust rate of transmission over different wireless links. This can result in the dynamic capacity assignment exhibited in the MAC layer.

With video streaming it is important to have scalability. As wireless networks are resource constrained, it is important to have steps for improving scalability. In order to achieve this, it is essential to have real-time service for adapting dynamically to different transmission conditions. By providing given QoS, the wireless applications should adapt to the runtime conditions. It is true with multimedia sessions as they consume more resources where adaptability plays vital role. The bit rate adaptation capability can help in scalability and computational needs. This is the motivation behind the SVC based optimization of PHY layer. Device capabilities and runtime channel conditions are to be considered. Scalability is achieved with adaptable approach that can improve QoS.

The MAC layer plays an important role in controlling access to channel for helping many wireless devices to share the same link fairly and effectively. With the increase in the multimedia applications, MAC is expected to support various QoS needs of applications. MAC protocols are generally grouped into two types. They are known as schedule-based and contention-based. In this paper, contention based voluminous video traffic with energy efficiency and delay sensitive requirements. The video resources getting dynamic state information of the network is not easy as there are multiple hops, paths and heterogeneity of devices are involved. At intermediate nodes, information-centric data transmission is not easy. Intermediate nodes are not fully aware of packetized video contain expect to have some knowledge on video information.

Therefore, it is important to achieve a good trade off between transmission and in-network processing, CLD is required. Moreover CLD achieves QoS and Quality of Experience (QoE) needs by using rate control maintenance of path and link, energy and radio resource. Under given application-specific constraints, it is very challenging to have a dynamically adaptable CLD for improving QoS in wireless multimedia streaming applications. Our contributions in this paper include design and implementation of CLD with joint optimization of the PHY and MAC layers with aforementioned improvements. The remainder of the paper is structured as follows. Section 2 provides review of literature. Section 3 presents the proposed CLD and its underlying algorithm. Section 4 provides experimental results while section 5 gives conclusions and recommendations for future work.

2. Related Works

There are many CLD approaches that came into existence. The approaches are categorized into internal interlayer and external decentralized as explored in [1], [2], [3], and [4]. WiMAX is the technology used for broadband services. They can adapt old and new technologies. WiMAX has advantages such as flexibility, advanced architecture, attractive prices and superior performance. Error resiliency tool is explored in [5] with H.264/AVC. The tool is known as Flexible Macro block Ordering (FMO). Error-concealment approaches are studied in [6] known as second-generation error concealment. Improving efficiency of video transmission is explored in [7].

Region of Interest (ROI) based encoding of videos with high compression rate with improved QoS is studied in [8]. The concept of telemedicine is explored for the transmission of video with compression technique is realized [9]. Propagation models and measures are studied in wireless networks for improving video transmission [10]. Applications of video transmissions including healthcare, tele-consultation and emergency management are studied for propagation models and multimedia applications [11]. The process of lost motion recovery with error concealment and importance is studied in [12]. Outer Boundary Matching Algorithm (OBMA) is employed in [13] for better video quality while transmitting data.

Error concealment is focused on [14] with different features including optimization of temporal error. This was able to reduce number of errors in the video transmission over wireless networks. Error concealment for video transmission is investigated for improving video streaming quality with inter-frame and intra-frame concealment. CLD and its utility are investigated in [15] for better quality video transmission and Voice over IP (VoIP). Perceptual coding concept is used in [16] for transmission of digital images over wireless networks. The ROI is also studied in [17] where ultrasound video coding is used to demonstrate the advantage of focusing on ROI. High compression efficiency and effective video transmission over wireless networks is explored in [18] and [19]. In the literature, it is found that there is need for further research on joint optimisation of layers for improving multimedia streaming applications in terms of QoS. In this paper, we presented a CLD approach with joint optimization of the PHY and the MAC layers.

3. Proposed Method

Video applications over wireless networks need special attention and treatment. Since wireless applications do have constraints in terms of resources and mobility, there should be an approach that considers multiple layers to get optimized jointly to provide expected QoS in such applications. When multimedia applications are being rendered in wireless networks, it is important to support with expected QoS. That is the reason to have a CLD for optimization.

When it comes to joint optimization, the PHY and the MAC layers are considered for building a CLD. When multimedia contains including video and audio is being streamed in wireless links, it is essential to have a mechanism to handle it properly. For instance, video information is known as delay-sensitive data. It needs to be broadcasted or rendered to end users with causing delay. Since it is delay sensitive, there must be some mechanism to handle it. Other hand delay-insensitive information can be handled differently.

In order to achieve, joint optimization of the PHY and MAC layers we proposed a methodology. At the PHY layer, an approach known as Scalable Video Coding (SVC) is used for leveraging bit oriented streams where users can adjust rate of transmission over different wireless links. This can result in the dynamic capacity assignment exhibited in the MAC layer. Thus joint optimization can help in improving QoS and QoE. The MAC layer plays an important role in controlling access to channel for helping many wireless devices to share the same link fairly and effectively. With the increase in the multimedia applications, MAC is expected to support various QoS needs of applications. Contention-based MAC with voluminous video traffic is considered. The overview of the proposed methodology is shown in Figure 2.

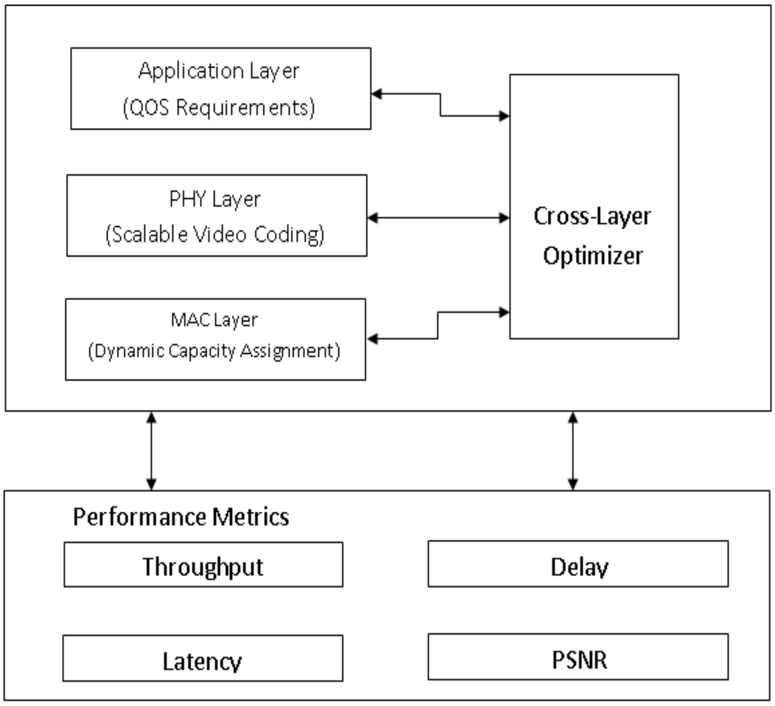

Figure 2: Proposed CLD and performance evaluation

As presented in Figure 2, there are three layers involved in the proposed optimization. The application layer is used to obtain requirements pertaining to QoS. This is essential to understand the needs of the multimedia streaming application in hand. This can help in proper optimization of the PHY and MAC layers. The PHY layer is the first layer found in the OSI model. It takes care of data transmission at bit level between devices associated with the network in question. It helps in synchronized communication in presence of multiple devices connected to the network. It is the most complex layer in the OSI model due to plenty of hardware technologies that came up. It converts logical communications into hardware-specific operations for achieving reception and transmission of signals. Other functionalities of the PHY layer are bit by bit delivery of data, standardized interface for sending data, modulation, line coding, channel coding, forward error correction, equalization, carrier sense and collision detection, circuit switching and start-stop signalling.

The MAC layer is one of the sub layers of data link layer. It provides mechanisms for channel access and addressing. This will help many devices to participate in communications by sharing the channels. MAC controller is the hardware that implements MAC protocol. It is the interface between PHY layer and logical link control sub layer. In a multi-point network, the MAC is something like full-duplex channel for logical communications. Such channel provides different services namely unicast, broadcast and multicast. MAC sub layer provides different functionalities such as access control, protection from errors, transparency in data transfer, conveyance source information, addressing of destination, frame delimiting and recognition. MAC has interfacing with PHY layer and its upper layers. This is the important reason why MAC and PHY layers can work in random with each other. The optimizations made in the PHY layer are accessible to MAC layer. In other words MAC layer gets influenced by the changes in the PHY layer.

Scalable video coding is the main focus for optimizing PHY layer. In fact, there is joint optimization of the PHY and the MAC layers. Based on the changes in PHY layer, dynamic capacity assignment takes place in the MAC layer. SVC is a standard pertaining to encoding. It leverages encoding of high-quality videos that may contain bit streams with subset of bit streams as well. It helps in video transmission between nodes without degradation of video quality. In devices that participate in wireless networks with less resources, SVC can help improve quality of video transmission.

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Algorithm: Adaptive Scalable Video Coding
Inputs   : Video V
Output   : Encoded Video V'
Start
Make multiple layers from V
Assign priority level to each layer
Apply coding to layers to get one base layer and two or more enhanced layers
The 3 or more layers have quality in increasing order
Consider memory, bit rate, computation, and resolution for scalability
Compare with all layers
Choose the layer that optimizes video quality
End
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Listing 1: Pseudo code for ASVC algorithm

The pseudo code for ASVC algorithm can help in creating different layers of video with different levels of quality. This can adapt to the runtime situations of a wireless network for transmitting data with QoS needed. The proposed optimization with the PHY and the MAC layers is implemented and evaluated the performance with metrics such as PSNR (to fine video quality), throughput, delay and latency.

Table 1: Performance metrics

Performance Metric	Description
Peak Signal Noise Ratio (PSNR)	Used to find quality of video before and after transmission. It is measured as follows.
$PSNR(n)dB = 20log_{10}\left[\frac{V_{peak}}{\sqrt{\frac{1}{N_{col}N_{row}\sum_{i=0}^{N_{col}}\sum_{j=0}^{N_{row}}[Y_S(n,i,j)-Y_D(n,i,j)]2}}}\right]$	
Latency	It is the time taken before video transmission starts.
Throughput	It is the amount of data transferred.
Delay	It is the delay which is exhibited in video transmission in wireless network.

Table 1 shows performance metrics used in the evaluation of the proposed CLD approach for video transmission. The results of these metrics are presented in the following section. These metrics provide a means of measuring performance of the proposed CLD.

4. Experimental Results

In this section we compare the performance gain obtained by applying cross-layer optimization for Scalable Video coding and modified 802.11e and admission control are used by the optimizer to predict video quality. We analyze the performance in terms of PSNR, throughput, delay and latency.

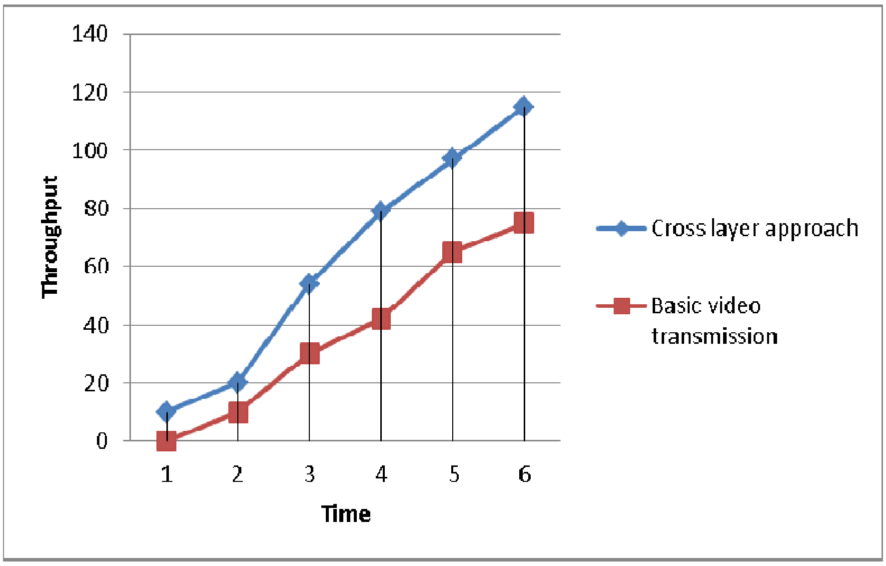

Figure 3: Throughput performance comparison

As presented in Figure 3, it is evident that horizontal axis represents simulation time while vertical axis shows throughput performance. The results showed two important observations. The first observation is that cross layered approach showed better performance when compared with basic video transmission approach. The second observation is that the throughput performance is increased for both approaches as the simulation time increases.

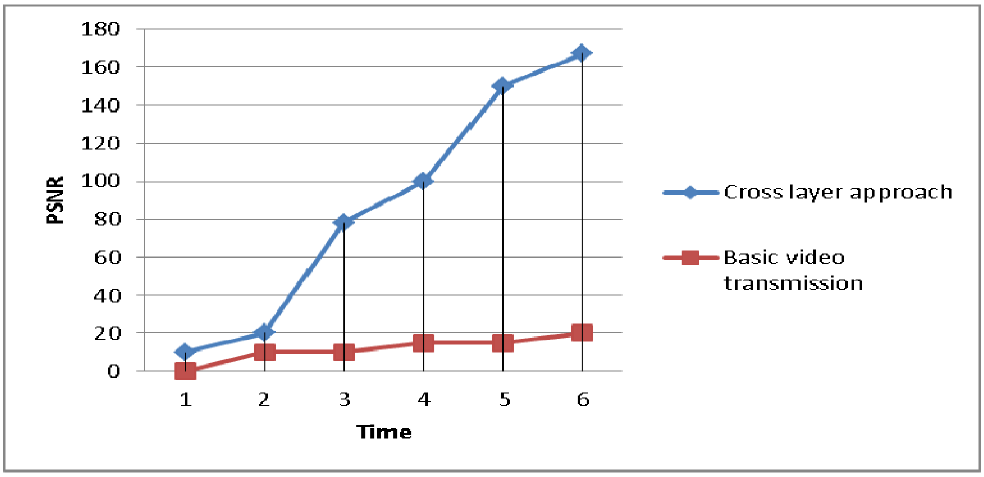

Figure 4: PSNR performance comparison

As presented in Figure 4, it is evident that horizontal axis represents simulation time while vertical axis shows PSNR values. The results showed two important trends. The first trend is that cross layered approach showed better performance in terms of PSNR when compared with basic video transmission approach. The second observation is that the PSNR performance is increased for both approaches as the simulation time increases. However, the PSNR of proposed method outperforms the basic video transmission.

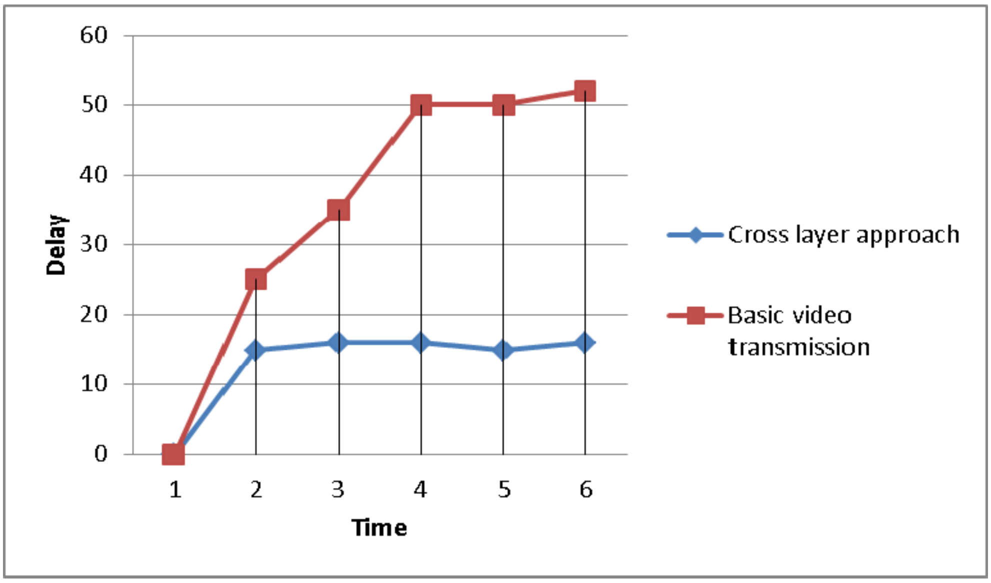

Figure 5: Delay performance comparison

As presented in Figure 5, it is evident that horizontal axis represents simulation time while vertical axis shows delay. The results showed two important trends. The first trend is that cross layered approach showed better performance in terms of reduction of delay when compared with basic video transmission approach. The second observation is that the delay is gradually increased for both approaches as the simulation time increases. However, after some tie, the delay stabilized and showed same for rest of the simulation.

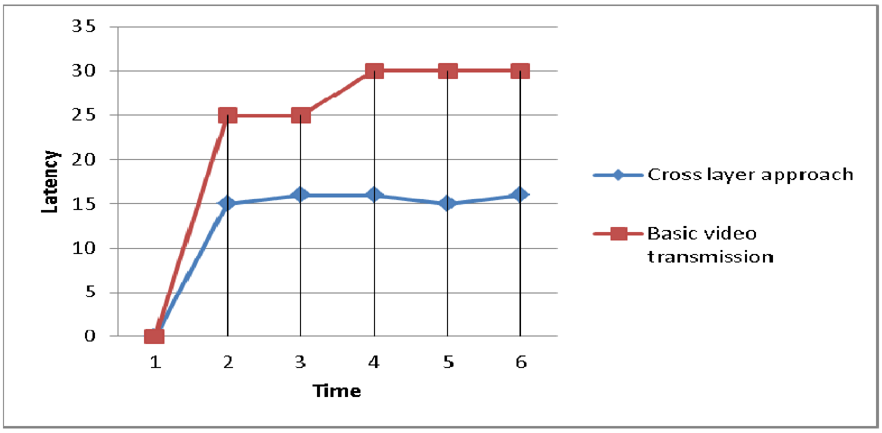

Figure 6: Latency performance comparison

As shown in Figure 6, the latency performance of the proposed system is far better than that of basic video transmission. As the simulation time increases, the latency is increased for some time. Later on same latency is observed for rest of the simulation with slight changes.

5. Conclusions And Future Work

In this paper, the problem of optimization of video transmission over wireless networks is investigated. There are many layers in OSI reference model. Each layer has its own purpose and it can be improved individually. When a layer is improved individually, it is called layered approach. Layered approach has limitations as it can only show the improvement pertaining to that layer only. Therefore, it is important to consider a cross layered approach in order to have better optimization. In this paper we used PHY and MAC layers for joint optimization. In PHY layer Scalable Video Coding (SVC) is employed in PHY layer in order to adapt to required transmission rates and based on the dynamic capacity assignment is made to other layer, the MAC layer. NS2 simulation study revealed the effectiveness of the proposed CLD. The results are compared with basic media transmission approach in terms of latency, throughput, delay and PSNR.

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