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Enhancing Video Streaming in Wireless Networks with Cross Layer Design Approach

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ABSTRACT

Wireless networks are growing in capabilities due to technological innovations and unprecedented growth of telecommunications. This is the reason, of late, video streaming applications exploit the power of mobile applications to render their services. However, mobile networks are known to various issues like channel fading, interference, and delay and so on. When multimedia content is being rendered through wireless network, the users of media expect high quality. Since video content is sensitive to delay, it is important to ensure the quality of service (QoS) in providing multimedia content through wireless networks. The existing solutions focused on different layers of OSI for solving problems. In this paper, we proposed a cross layer design that for joint optimization of network for ensuring high quality video streaming over wireless networks. We proposed a framework and implemented it. Our NS2 simulations provide proof of the concept.

Keywords: Wireless network, cross layer design, video streaming

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ABSTRACT

Wireless networks are growing in capabilities due to technological innovations and unprecedented growth of telecommunications. This is the reason, of late, video streaming applications exploit the power of mobile applications to render their services. However, mobile networks are known to various issues like channel fading, interference, and delay and so on. When multimedia content is being rendered through wireless network, the users of media expect high quality. Since video content is sensitive to delay, it is important to ensure the quality of service (QoS) in providing multimedia content through wireless networks. The existing solutions focused on different layers of OSI for solving problems. In this paper, we proposed a cross layer design that for joint optimization of network for ensuring high quality video streaming over wireless networks. We proposed a framework and implemented it. Our NS2 simulations provide proof of the concept.

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1. INTRODUCTION

Due to the innovations in wireless technologies and recent developments in electronic circuits, there is ever increasing trend in the usage of mobile devices that are part of wireless networks. People of all lifestyles are using different kinds of mobile devices. In this context, there has been increased research in the multimedia applications that run over wireless networks. As the multimedia applications are resource intensive, they are to be used with certain optimizations. The wireless networks are not optimized for such applications. The OSI model was also not designed by keeping multimedia applications in mind. Therefore, individual layers of OSI model can be optimized or jointly they can be optimized. The joint optimization is known as cross layer design (CLD) approach. The cross layer design approach considers two or more layers to be improved for different parameters. Each layer needs inputs from the application layer and then needs to have an optimizer. Once optimizers are designed for each layer, then the cross-layer optimization is done which in turn applied to the corresponding layers for enhanced functionality in video streaming.

As explored in [2] and [10] there is error concealment approaches to minimize issues in the cross layered approach. They focused on improving region of interest of videos in order to render high quality service in wireless applications. They tried to optimize different layers jointly and perform well in transportation of media content. Various approaches came into existence for cross layer design. The main difference among them is to have different combinations in joint optimization. The parameters used for improvement may also differ.

Improving layers in the OSI reference model is an open problem that can be addressed. The layers when improved for enhancing video transmission quality can gain an optimizer that can boost the performance of the layers when they work together jointly. Thus joint optimizations are synonymous to cross-layer design approaches. The existing cross layer design approaches are studied in this project in order to know their insights in terms of advantages and limitations. This know how helps the researcher to have a new CLD that can leverage the performance of video streaming

applications in wireless networks. Boundary matching algorithm (BMA) and Outer Boundary Matching Algorithm (OBMA) are existing algorithms that focused on video error concealment [2]. The error concealment algorithms focused on improving video quality in wireless networks. They are also used in combination of region of interest concept in order to have better video quality in the region of video expected by the recipient. A motivating example considered by those kinds of researches is healthcare domain where a remote physician can obtain vital signs of patients such as ultrasound video on the required part to be rendered with high quality.

In this paper, a new CLD is proposed and implemented using NS2 simulations. The simulation study is expected to reveal the performance improvement over traditional approaches when cross layer design is used. The observations are interpreted and conclusions are made.

2. RELATED WORKS

As explored in [2] made a good review of cross-layer design (CLD) approaches for improving Quality of Service (QoS) in multi-hop wireless networks. They explored about many trends in wireless networking such as real system performance evaluation, opportunistic transmission, and cooperative communication. QoS-Aware MAC and QoS Routing are discussed as they are very important components. Initially there was layered approach in which individual layers are enhanced in order to achieve QoS. However, this approach proved to be suboptimal as there was not joint optimization. To overcome this problem, cross-layer design was realized. Internet Engineering Task Force (IETF) also studied the need for CLD approaches. CLD is the new paradigm shift in performance improvement of multi-hop wireless networks. The rationale behind this is that the CLD approach uses joint optimization of layers in order to enhance the QoS in cooperative fashion. Operations such as channel management and scheduling in MAC layer help in reusing space and time in wireless networks [2].

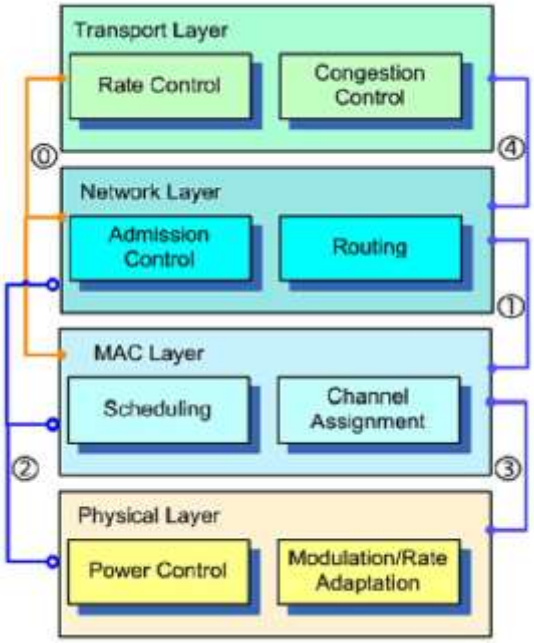

Figure 1: Framework of CLD with Interaction among layers [2]

There are different layers as shown in Figure 1. The physical layer has provision for power control, modulation or rate adaptation. The MAC layer supports channel assignment and scheduling. The network layer takes care of admission control and routing while the transport layer supports rate control and congestion control. Interaction among multiple layers, network capacity planning with CLD, joint rate allocation and routing for QoS in video streaming, joint approach for routing and channel assignment, opportunistic transmission through joint rate adaptation and scheduling, joint scheduling, admission control and rate control, and joint routing, scheduling and power control are possible CLD approaches that can improve media transmission in wireless networks [2]. In [5], it explored CLD solutions for wireless mobile networks. They opined that an attempt to change Open Systems Interconnect (OSI) reference model is considered to be CLD. The cross layer coordination is shown in Figure 2. There is possible coordination among different layers in OSI model such as application layer, transport layer, network layer and link layer. The coordination among the layers is possible in terms of security, QoS, mobility and wireless link adaptation.

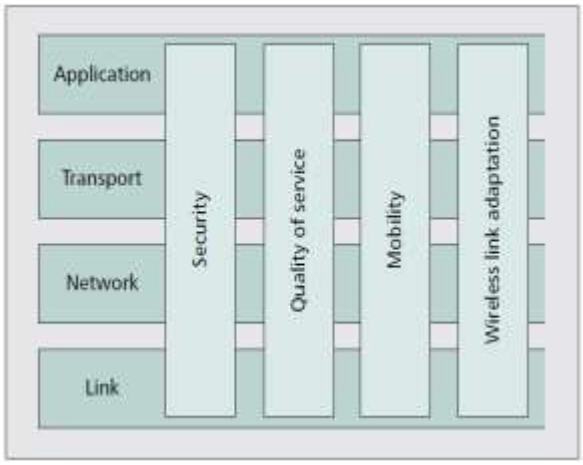

Figure 2: Shows cross-layer coordination [1]

The application layer can be used for video construction and adaptation, data link layer is used for error correction, queuing control with RED, retransmissions, and MAC layer scheduler. Physical layer enhancements include adaptive modulation and coding, power control, multi-user diversity, and co-channel interference controller. Cross layer designs when incorporated into wireless standards, it is possible to have end to end QoS in video streaming [5]

In [3] explored cross layer design protocols for enhanced QoS of multimedia transmission in wireless networks. They used encoding parameters in application layer, adaptive transmission rates for transport layer, QoS for network layer, QoS, FEC and ARQ for MAC layer, and signal modulation for physical layer. There are different approaches for cross layer design. They are known as integrated approach, MAC-centric approach, top-down approach, and bottom-up approach. The integrated approach is used to do jointly with all layers in the network. MAC-centric approach MAC layer takes care of optimization by taking QoS needs from application layer. In case of top-down approach, the application layer informs other layers to know the importance of quality. The other layers follow the QoS criteria as the higher layers optimize parameters and lower layers. With respect to bottom approach, the lower layers provide optimization to upper layers. It can exploit the channel situation to meet the requirements of application layer [3]. There were many other efforts on CLD as found in [3], [4], [6], [7], [8], and [9] to have improved QoS in wireless networks for video streaming. In this appear we proposed a CLD model by improving PHY and MAC layer for joint optimization.

OSI Reference Model

According to OSI reference model, there are different layers involved. The layers play vital role in functionality of applications in a network. The layers are shown in Figure 1. The application layer is responsible for providing its need for network and quality requirements as well. The physical layer is meant for data transmission. MAC layer or data link layer is responsible for control flow.

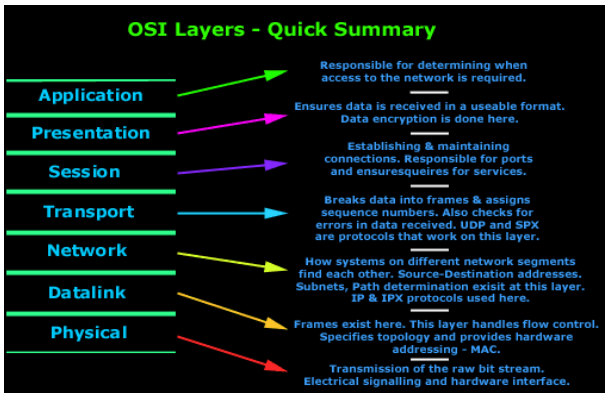

Figure 3: Different Layers in OSI Model and the Purpose of them [11]

The presentation layer is responsible for data format and encryption. The session layer is for providing connections. The transport layer supports SPX and UDP kind of protocols for breaking data into frames. Network layer is meant for addressees of nodes in network and path determination.

Different Approaches for Cross-Layered Design

There are different approaches that can be used for cross-layer design. They are known as top-down approach, bottom-up approach, application-centric, MAC centric and integrated. In top-down approach the QoS strategy is determined by upper layers and that is used by lower layers. The optimizer built in this scheme makes use of QoS needs provided by application layer. The results of reconfiguration of physical layer are then given to MAC layer. This is used in many implementations it is simple to implement.

In bottom-up approach there is insulation of upper layers from lower layers which is taken care of by

optimizer. Based on the state of lower layers, the upper layers are configured. As per the status of MAC layer, the application parameters are configured. In application-centric approach the optimizer is located in the application layer and other layers are reconfigured in top-down approach or bottom up approach. This is based on the needs of application layer. This approach is not adaptive to real time changes. In MAC-centric approach the procedure is similar to application-centric approach. The needs of application layer are taken by MAC layer and the MAC layer optimizes itself and then optimizes physical layer. The integrated approach is an optimal decision is taken based on the parameters and other information obtained from different layers. Here all layers are involved in the determination of quality.

Proposed Cross Layered Design for Optimizing Video Streaming

Video streaming in wireless networks has become a reality. However it needs to be optimized for quality of services. In this project a cross layered approach is proposed and implemented using two layers known as physical layer and MAC layer. The proposed architecture for the cross layer design is shown in Figure 4.

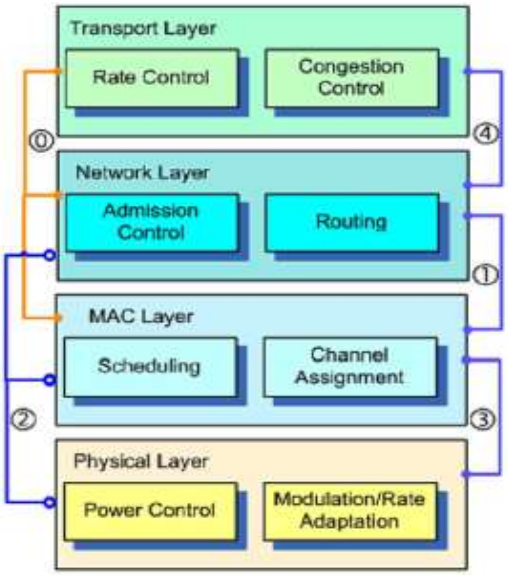

Figure 4: Cross Layered Design for Video Streaming Optimization

As shown in Figure 4, the application layer is able to determine the Quality of Service (QoS) needs to the other two layers such as the physical layer and the MAC layer. The physical layer is optimized based on the QoS needs. Then the MAC layer is optimized based on QoS needs. A combined approach that optimizes cross layer is implemented. The combined approach takes care of modulation, duplex mode, channel bandwidth, TX power and RTS/CTS dynamics in wireless network. The optimizations of cross layer approach are reflected back into the underling layers such as MAC layer and physical layer. The video streaming quality needs are provided by the application layer. The abstraction of MAC and physical layers is made for capturing status of the layers jointly. The cross layer optimizer is responsible for optimizing MAC and physical layers jointly based on the QoS needs of the application layer. The final cross layer strategy is de-abstracted and applied to MAC and physical layers besides application layer. Thus the application layer is able to acquire the Quality of Service (QoS) expected for video streaming. The video quality is enhanced in terms of frame size, frame rate, and Peak Signal-to-Noise Ratio (PSNR).

Physical connectivity of different stations is taken care of by physical layer. This layer takes care of determination of wiring, hardware, pulses, cabling, frequencies, and binary signals. It also provides its services to other layer known as data link layer. Two layers in OSI model make up of data link layer. MAC layer is one of them. It is meant for moving to Network Interface Card (NIC) and from NIC to other in a channel which has been shared. By subjecting physical layer and MAC layers to have optimizations, the resultant optimizations work on the application layer to have intended QoS.

The cross-layer optimization considers modulation, duplex mode, channel bandwidth, TX power and RTS/CTS. Modulation is the process of changing properties of waveform in the network for improved data transfer. Duplex mode is the mode which supports transmission of data in both directions. Between transmitter and receiver there is medium to transfer data. This medium is known as channel. Channel bandwidth is the frequency range supported by the channel. TX power refers to signal strength. Request to Send/Clear to Send (RTS/CTS) is a mechanism in order to reduce

frame collisions. It is supported by IEEE 802.11 standard for wireless networks. By using the aforementioned parameters and optimizing them in the cross-layer optimizer, the optimizations are applied to MAC and physical layers and finally the application layer can have better QoS for video streaming in wireless networks.

3. SIMULATION RESULTS

NS2 simulations are made to demonstrate the proposed CLD approach in wireless networks. The results are presented here.

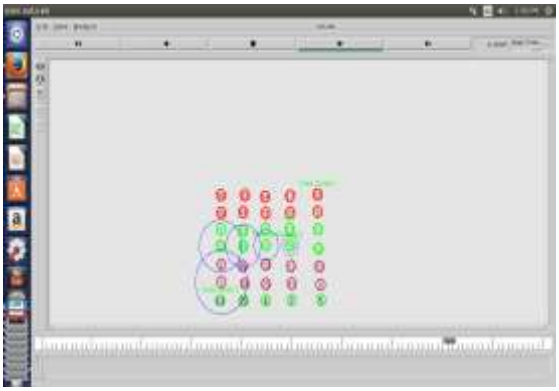

Figure 5: Shows Simulation with Wireless Network

As shown in Figure 5, the wireless network is presented using NS2 simulations. There are nodes designated as video sender and video receiver with many intermediate nodes.

Figure 6: Simulation with Protocol Propagation

As shown in Figure 6, it is evident that the simulation shows protocol propagation among the nodes in the network.

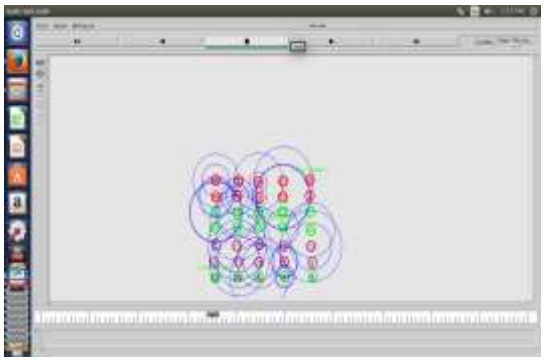

Figure 7: Data Transmission Simulation

As shown in Figure 7, data transmission with cross layer design approach is simulated between sender and receiver.

Figure 8: Data Transmission Simulation Continued

As shown in Figure 8, data transmission with cross layer design approach is simulated between sender and receiver.

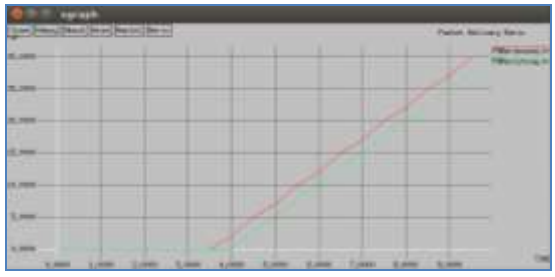

Figure 9: Packet Delivery Ratio

As shown in Figure 9, the packet delivery ratio performance of the system is presented.

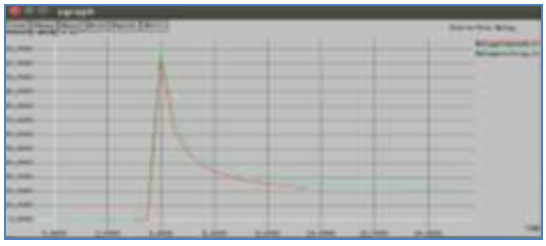

Figure 10: End to end delay Performance

The end to end delay performance is presented in Figure 10. The results revealed that the delay is

more at certain time but later it is decreased gradually and significantly.

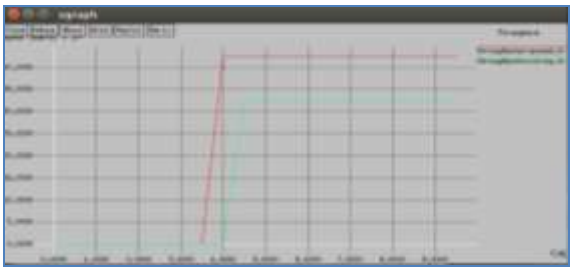

Figure 11: Throughput Performance

As can be seen in Figure 11, the throughput performance is presented. The throughput of the proposed system is high as simulation time is increased.

4. CONCLUSIONS AND FUTURE WORK

In this paper, we studied the problem of deterioration of video streaming quality in wireless networks. There are plethora of reasons for this. Some of the reasons is connectivity, mobility, interference, delay and channel fading. In order to overcome these issues, it is essential to improve the network for high quality video transmission over wireless networks. The existing approaches focused on improving different layers of OSI model. In this paper we proposed a joint optimization of PHY and MAC layers to have enhanced quality in video streaming over wireless networks. Our experiments are made with NS2 simulations where the proposed methodology is employed. The results revealed that the video streaming quality is improved due to joint optimization of layers in wireless network. The coordinated effort among layers of the network yielded better performance. In future, we intend to continue our research on working with other layers of OSI model for optimization.

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