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Layered Implementation Solutions for Video Transmission over Wireless LANs

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Abstract: In the current networking scenario, there is an availability of huge bandwidth capacity for transmission of data of any kind and also the connections are unconstrained in nature. In this kind of situation, the wireless LANs are providing an ideal infrastructure for ubiquitous audiovisual content transmission and sharing. But still, the ability to achieve high performance in the delivery of video content over the wireless LANs is still a challenging task. In this paper, we present a survey on the solutions that are developed to improve the Quality of Service characteristics of video delivery and streaming over the WLANs based on the implementation layer of the solutions. These solutions mainly concentrate on the three major layers namely, Application layer (APP), Physical layer (PHY) and the Medium Access Control layer (MAC). There are also cross layer implementations that were developed on the recent years to take the advantage of the interactions between these network layers which helps in improving some parameters of the quality being delivered as a whole. Also, some major issues like security and energy are being discussed in this work. We conclude that the technologies and application of video over WLANs will attain a new peak in the near future.

Key words: layered solutions, Quality of Experience, video streaming, robust video transmission.

I. Introduction

The usage of networking remains inevitable in the recent decades. Since the parameters like mobility and portability are of major concern in the current enterprise environment, the usage of IEEE 802.11 wireless LANs is growing in an exponential fashion. These networks are an extension to the wired network and in some cases they are the replacements of the wired networks [1]. Another most important reason for this improved usage is the fall in pricing of the WLAN products. As there is an availability of high bandwidth for transmission, these technologies are wide open for multimediatransmissions. Still, there are some key obstacle parameters like variations in bandwidth, data loss, power efficiency, security, scalability and so on. Among the multimedia data transmission, videodata is considered to be the most vital one to consider.

There can be three cases in the receiving of a video packet [3]. The most expected case is that, it is received correctly. The second case is receiving with some errors. Finally case is loss of video packet by the network. The technologies that are being developed recently, aims to consider these cases and some technologies succeed in rectifying the errors and losses. If there are some errors in the received video packet, then decoding failure will happen because of the presence of error bits. In this scenario, the decoder will often discard the packet and continue the decoding process by jumping to the next packet. Buffer overflow and the congestion in the network are the major reasons for the packet losses. In the real time video applications, there is significant delay constraint in the video transmission. Before the scheduled playback time, the video packet has to reach the decoder. But there are significant delay experienced by the video data that is transmitted along the shared multihop wireless networks. The packet will be considered to be lost, if it reaches the decoder after the scheduled time. Both the discarded and the lost video packets will cause distortion in the picture and this will also affect the subsequent frames in the motion path since the video data is compressed. This will accumulate for a long time and will degrade the video presentation quality due to the propagation errors. The video transmission that is caused by the transmission errors is called *transmission distortion*[4].

A wide number of new applications are emerging over the recent years to enable the emerging multimedia delivery over the wireless Local Area Networks from VoIP to mobile gaming, video streaming and video conferencing. In these kinds of scenarios, Quality of Service perceived by the user is a most important point of concern [2]. Video delivery is considered to be a challenging task over the WLANs when the services need to guarantee the desired level of QoS for its consumers. The most important and inevitable reason for this is that the wireless channel is error-prone and dynamic in nature. The compressed video data is time critical and also error sensitive. The compression algorithms used for the compression of video data tries to reduce the bandwidth consumption by creating complex dependencies among the video blocks and frames.

Over the recent years, there has been a significant advancement in the video over wireless LANs. The continuous enhancement in the standards of IEEE 802.11 facilitated several new applications. Of these, the major concern is for high capacity transmission. The throughput of the Physical layer is continuously increasing to provide enough bandwidth for such high capacity transmissions. There is a need to provide careful designs and innovative ideas for channel access mechanisms and error recovery for Medium Access Control layer (MAC). These are the individual single layer solutions in the implementation point of view [7]. There are also some non-standard mechanisms recently developed to enhance the performance of the video transmission like application layer rate control, admission control, cross layer optimization and so on. Among all the recently developed technologies, the cross layer solutions are of major concern and remain to be attractive. There are a large number of research people working in the cross layer solution domain to provide considerable improvement in the focused area. In this survey, we focus and summarize several technologies in video transmission over wireless LANs. These solutions are classified based on their layer of implementation in the wireless network.

II. Video Transmission And Streaming

In wireless LANs, there are two different scenarios in video applications: video transmission and video streaming. In the case of real-time video transmission, multiple users of the WLAN in the same network or using Access Point (AP) transmit their contents to reach the remote users. This scenario may include video conferencing, video content sharing in smartphones, or any other interactive video applications that are in need of immediate play-out at the receivers. These applications demand for on demand and onboard video coding and at the same time rigorous delay constraints [8].The consumers of the service may use any type of communicating device like a portable smartphone or a laptop and the configuration and display parameters vary among the devices being used for communication. The solutions developed for this kind of scenarios should also consider this.

In the video streaming scenario, a server system is provided to deal with the video which is usually attached at the wired network and that wired network is considered to provide enough bandwidth and produces negligible effects on the delivery of the video streams [10]. This includes the applications like video download and playing, video-on-demand and television content sharing. In the receiver end, it will use a buffer to store the video contents and the play. At the server side, it does offline encoding and hence it could tolerate some delay. In both cases the transmission of video streams can be either unicast or multicast.

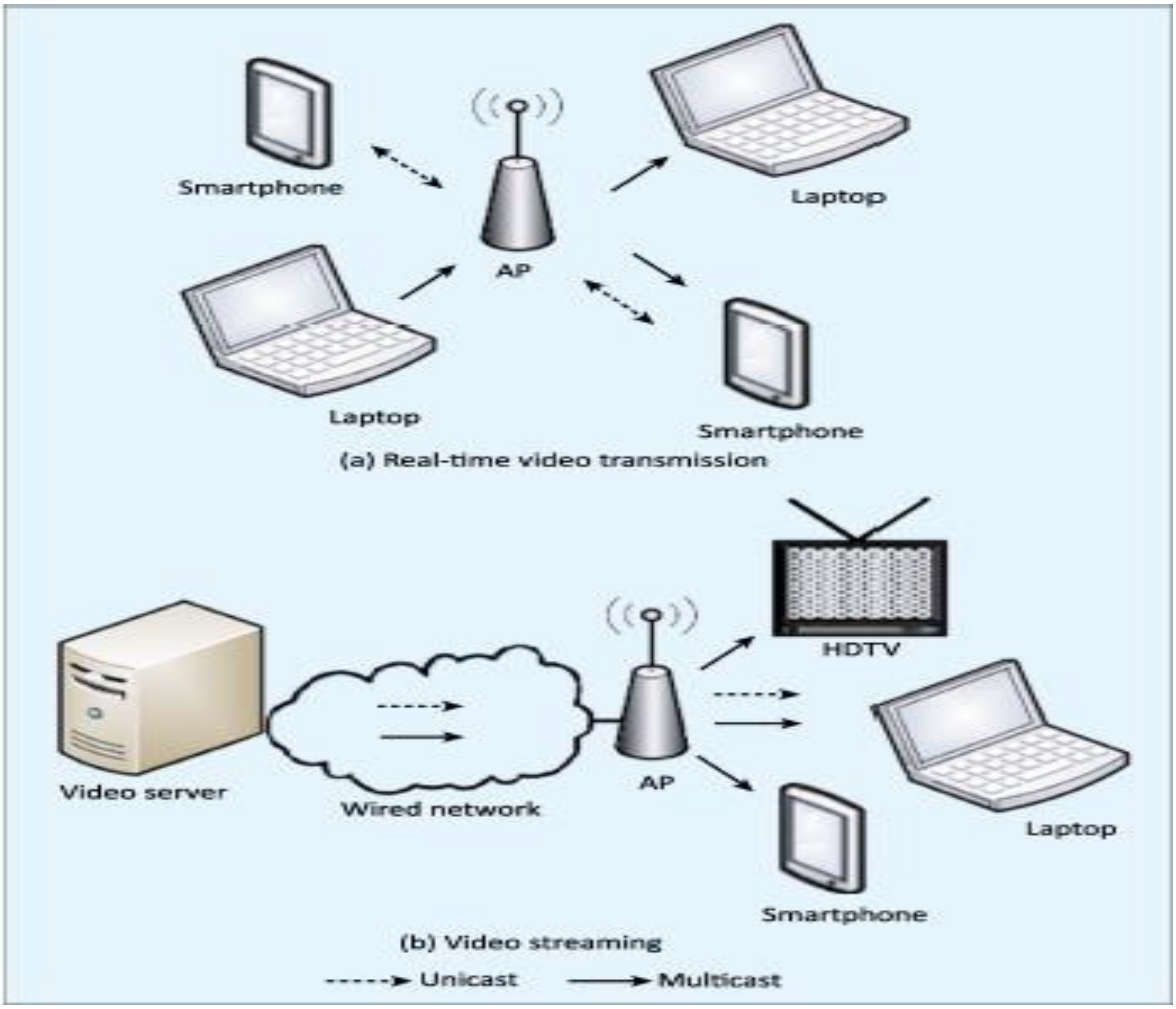

Figure 1: video application scenarios

III. Solutions Based On Implementation Layer

The video transmission and delivery over the wireless LANs is mainly concerned with the three layers of the communication network: APP layer, MAC layer and PHY layer. The APP layer conveniently facilitates the characteristics for video stream information like coding parameters, frame priority status, etc [9]. This layer is mainly involved in storage of pre-coded video content or online encoding. The MAC layer is concerned with the error recovery and channel access mechanisms. These factors have a direct impact on the performance of the video stream transmission. The channel information is provided by the PHY layer which can be properly utilized to improve the efficiency of the video transmission.

In the following section, we consider the various solutions for video transmission in correlation with the associated layers. We start with the discussion of the single layer implementation solutions and then followed by the recent advancements in the cross layer solutions.

A. Single Layer Solutions

1) APP layer solutions

The solutions based on this layer are more concerned with the techniques associated with video coding in order to generate the bitstreams for video. The particular video codec algorithms employed for this purpose decides the performance of the solutions. This is critically important for the real time video transmission where the QoS performance is guaranteed only by the use of appropriate onboard coding techniques at this layer. This kind of APP layer solutions can be readily applied for both wired and also wireless networks. These solutions can be able to adopt on to a few parameters of the transmission channel like rate of transmission or the error probability of transmission. The major APP layer solutions use H.264/AVC standard for video coding [13].

The H.264/AVC standard enforces a greater impact on the video content transmission due to the error resilience tools provided for particular transmission in different types of networks. The error resilience tools include Slice structuring, Error concealment and partitioning of data. The Slice structuring aims at avoiding propagation of error. Data partitioning and other such tools work in a similar way to improve the quality of transmission by avoiding or minimizing the error in the video transmission. This standard also has some impact on the optimization of rate distortion.

2) PHY layer solutions

The advantage that is provided by the physical layer of IEEE 802.11 is its ability to allow for the usage of multiple transmission rates for different coding and modulation schemes. This is called *Adaptive Modulation and Coding (AMC)*. The advanced standard of IEEE 802.11n allows sixty two different rates for transmission. This helps the mobile devices in selecting the suitable link for the corresponding channel conditions and the QoS needed for that system performance. There is a technology called *Multiple Input and Multiple Output (MIMO)*that was introduced in the physical layer to provide complicated techniques for signal processing. This can be used to achieve increased throughput or improved reliability.

The important factor to consider in the usage of physical layer solutions is the rate adaptation, that is, more transmission rates can be made available for the mobile users to select that is suitable for their transmission criteria. But the task of designing efficiently to make the rate adaptation scheme for achieving increased throughput is highly difficult and challenging. One such design is to use an algorithm that bases the rate adaptation on the signal strength received in the current state [15]. Another algorithm based on RTT-decision approach that can detect the channel conditions pro-actively and lead to the development of a more practical algorithm due to its easy implementation nature.

3) Mac Layer Solutions

The MAC layer is associated with the access control functions that it can provide to the wireless network like coordinating the channel access, retransmission of the frames when necessary, and generation of check sequence. There are several research works recently in the aim of extending the MAC layer protocols. In the original MAC of IEEE 802.11 there are two coordination functions for access control: Distributed Coordination Function (DCF) and Point Coordination Function (PCF). The DCF is a mandatory one while the other is optional.

The DCF uses Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) mechanism to eliminate collision when there is a concurrent access to a shared medium. And the vital parameter in this DCF function is the Contention Window size. Using DCF only a best effort service is provided to the MAC users.

PCF was introduced with the aim to support the transmission of multimedia traffic. This can only be a centralized control unit that is being implemented at the Access Point of the WLAN [14]. When the PCF is enabled in a WLAN system setup, then the access to the channel is divided into Beacon intervals which are periodic in nature. This beacon interval consists of a Contention-free period and Contention period where both DCF and PCF are applied in each period. In the Contention-free period, the Access point maintains a list of the users who are registered and then polls them as per the list.

B. Cross Layer Solutions

In order to overcome the limitations in the single layer solutions, the cross layer solutions have been developed. The single layer solutions are limited because there is negligible or no interaction between different layers of the network [12]. Even though the layers of the network are well defined, they need some relations because several layers are dependent on cooperation from others to achieve a greater potential. This factor is used as a base for the development of the cross layer solutions and hence they sustain in the current networking environment.

1) MAC-APP cross layer solutions

This cross layer solution contributes to the majority of all other cross layer solutions. For the Contention-based mechanism for accessing the channel, this solution focuses on video priority frames to the priority queues. Data partitioning technology can be utilized to achieve this by generating different priorities of the video packets. For Contention free mechanism of channel access, this solution focus on utilizing the limited bandwidth for scheduling as many high priority video streams as possible for transmission. There is another important tactic along with the access control mechanism called *Auto Repeat reQuest(ARQ)*and the *Forward Error Correction (FEC)*. Several retry limit algorithms have been proposed in this area.

2) PHY-MAC cross layer solutions

In the design of this cross layer solution the characteristics of the video data has to be taken into account. The main objective of the PHY-MAC cross layer solution is attaining maximized throughput. There is an approach of joint adaptation of the MIMO technology of PHY layer and Contention window sizing of the MAC layer in order to improve the performance. The cross layer solutions enable improved throughput to be attained for all types of traffic along WLAN, especially video data, which demands for a higher throughput because of its volumetric characteristic.

3) PHY-APP cross layer solutions

As stated earlier, there are two important characteristics in the case of physical layer of WLAN: AMC and MIMO technologies. This cross layer solution aims in mapping video data characteristics of the APP layer and transmission rate adaptation of the PHY layer. The mapping of rate variation and rate adaptation has been developed in the recent days [16][17][18]. One such work assigns the various layers of the video stream to the different rates [16]. Another approach uses the rate waveform of video streaming to guide the adaptation in the rate selection [17]. In the third approach, the error resilient coding combined with the rate adaptation of the PHY layer to achieve maximized performance [18].

4) PHY-MAC-APP cross layer solutions

Theoretically, the possibility of combining more than two layers of the network can be combined to enhance the throughput and the transmission performance of the video applications over the WLANs. But this has been tried out in the recent years practically. In that way, the researchers could face an exponential increase in the state parameters for the solutions of the cross layer interaction. The success of the PHY-MAC-APP cross layer solutions lies in efficiently overcoming the risks in this exponential increase of state parameters. An approach based on neural networks has been proposed in [19]. The QoS metric of the APP layer can be combined with the feedback mechanism of the cross layer. This approach uses the estimation of the channel status information from the PHY layer and the maximum retry limit from the MAC layer to improve the performance of the transmission.

An optimization architecture scheme for cross layer has been designed more recently using the three layer solution. This uses the priority structure of the APP layer, adaptation of rate modes of the PHY layer and the selective retransmission mechanism for multicast error frames of the MAC layer. These parameters were efficiently integrated to attain enhanced performance for video transmission when compared to the corresponding single layer or two layer solutions.

IV. Evaluation Parameters

The major concern in the development of any type of solution is the QoS parameters which includes packet loss ratio, delay and variation in delay. The main focus of both the single layer solutions and the cross layer solutions is achieving the desired level of QoS and a guaranteed QoS service for the error sensitive video applications. There are also non-QoS metrics that are also playing a vital role in the determination of the performance of the video content being transmitted over the wireless LANs.

The most frequently noted issue among the non-QoS metrics is the energy efficiency in the transmission of the video content. The low consumption of the energy is a critical factor in most of the mobile applications and since the mobile devices are the receiving ends in most of the video delivery applications, this issue needs to be considered in all the implementation solutions. But in case of WLANs, provision of better QoS would consume a little more energy. So there should be an appropriate trade-off between these two parameters. Another issue concerned is the security and the privacy in the video applications. This is to be considered more vital in case of social media applications. There should be authentication and security mechanisms enforced along with the implementation. This should be done for both stream-based and content-based methods. Now the focus of the research is quality performance and the authentication performance of the video over the error prone wireless channels since the security aspects will demand more resources which in turn leads to degraded performance of the video.

V. Conclusion

In this paper, we have presented on a brief survey of the developments in the techniques for video transmission over the wireless LANs. This includes single layer and cross layer solutions that were implemented using the three major layers of the network namely, the APP layer, MAC layer and the PHY layer. We focused on the major issues related to achieving the desired level of QoS. The unique characteristics of each approach were focused and the solutions to improve the performance were taken care. There are several key open problems like optimization criteria, low cost implementation architecture in design, the advantages and disadvantages which can be taken towards future research.

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