# Cross Layer (Application and Medium Access Control) Design and Optimization of Wireless Network for Real Time Video Transmission

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***ABSTRACT* - Robust streaming of video over 802.11 WLANs poses many challenges, including packets losses caused by network buffer overflow or link erasures, time-varying wireless channel and video content characteristics etc. To improve the performance of real-time video transmission over 802.11 WLANs, the use of cross layer design approach is required which allows communication between layers by permitting one layer to access the data of another layer, thereby facilitating the exchange of information. One of such design approach includes Application (APP) and Medium Access Control (MAC) layers considerations and is explored in this paper. This survey paper describes a detailed study of the APP and MAC layer considerations for good wireless video transmission. The solution for the problem of real time video transmission is to study the different methods/Mapping algorithms of adapting parameters for achieving the delay constraints in real time environment. This study focuses on H.264/MPEG4-AVC, the most widely accepted video coding standard and provides better quality compressed video and flexibility in compressing and transmitting video at APP layer and the retry limit settings of the MAC layer can be optimized in such a way that the overall packet losses that are caused by either link erasure or buffer overflow are minimized. Our proposed cross layer design for optimizing the wireless network's APP and MAC layer parameters is proposed in this work.**

***Keywords* — H.264/MPEG – 4 – AVC, IEEE 802.11e, AIFS, CW, Backoff counter, TXOPlimit.**

## I. INTRODUCTION

Video transport over wireless networks usually requires retransmissions to successfully deliver video data to a receiver in case of packet loss, leading to increased delay time for the data to arrive at the receiver side. Delay constraint is, one of the most important requirements in real-time applications [1]. To support the varying QoS requirements of emerging application such as those involving continuous media, a new standard IEEE 802.11 is specified. This standard aims to support QoS by providing differentiated classes of service at the MAC layer. The designing of cross-layer for video transmission over WLANs, it is necessary to study of APP layer and MAC layer characteristics along with the network behaviour. The main advantage of cross layering is to maintain the functionalities associated to the original layers but to allow coordination, interaction and joint optimization of protocols crossing different layers.

At APP layer, H.264/MPEG-4 AVC is a recent video compression standard jointly developed by the ITU-T VCEG and the ISO/IEC MPEG standard committees. This standard provides much higher compression than earlier standards. It allows not non-interlaced video coding but also interlaced video coding very efficiently, and also offers not only high-quality service in high-bandwidth network but also acceptable quality service in low-bandwidth network. Coding of video is performed by picture by picture. Each picture is first partitioned into a number of slices. Slice consists of sequences of macroblocks with each macroblock consisting of luminance (Y) and associated two chrominance (Cb and Cr). The hierarchy of video data as –

**Picture[slice{macroblocks(sub-macroblock(blocks(pixels)))}]**

IEEE 802.11e was proposed to prioritize packets into different categories for priority scheduling. The IEEE 802.11e EDCA is designed to enhance the 802.11 DCF mechanisms by providing a distributed access method that can support service differentiation among different classes of traffic aiming to better deliver multimedia traffic over the IEEE 802.11 WLANs. The EDCA of 802.11e standard defines four ACs. These four ACs which are proposed to carry four different types of traffic specifically voice, video, best effort and background traffic and have different transmission priorities as shown in Table I.

TABLE I Priority Value and corresponding AC's [2]

| User Priority | Access Categories | Destination |
|---|---|---|
| 3 | AC_VO | Voice |
| 2 | AC_VI | Video |
| 1 | AC_BG | Best Effort |
| 0 | AC_BE | Background |



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In the framework Transport layer receive the slice type and deadline from APP layer and encapsulates it into packet header. MAC layer then retrieves the encapsulated information from the packet header as shown in Fig. 1.

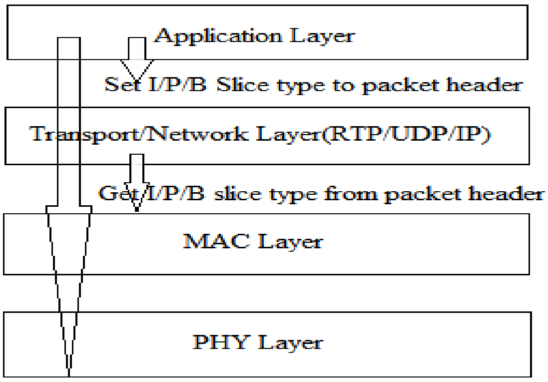


Fig. 1 Cross Layer Architecture [2]

Section II defines APP layer considerations, H.264/MPEG4-AVC video coding standard. Section III describes MAC layer considerations for real time video transmission. This evaluates the EDCA behaviour propose an appropriate video Section I describes the IEEE standards. Section II defines APP layer considerations, H.264/MPEG4-AVC video coding standard. Section III describes MAC layer considerations for real time video transmission. This evaluates the EDCA behaviour propose an appropriate video transmission techniques. Section IV introduce a cross-layer design approaches to achieve optimized video transmission over WLANs. Section V discusses the conclusions of this survey work.

## II. APP LAYER CONSIDERATIONS

In WLANs, video applications can be classified into two different scenarios: real-time video transmission and video streaming [3].

*In real-time video transmission scenario*, multiple users transmit their video contents to each other within one WLAN cell or via the WLAN Access Point (AP) to connect them to remote users e.g. mobile video conferencing, smart phone video content sharing.

*In video streaming scenarios*, the video server located in the wired network side delivers the video content to multiple users that connect to a WLAN AP e.g. video-on-demand, video download and play, and home HDTV sharing. At the receiving end, such scenario usually would buffer video frames for a while before the play-out starts.

The H.264/AVC video codec used for video transmission over various networking environments also known as MPEG_4 Part 10 or MPEG-4 AVC. H.264/AVC can offer not only high-quality service in high-bandwidth network but also acceptable quality service in low-bandwidth network and converts the digital video into a format that takes up less capacity when it is stored and transmitted i.e. codewords/binstring. The picture in H.264 is a collection of one or more slices which are sequences of macroblocks. The different types of slices in H.264 include: I slice, P slice, B slice and two derived slice type called SI- and SP- slice [4]. A macroblock is the basic coding block of H.264/AVC and can be encoded in intra or inter mode. Typically, I-slices contain more video information and the coding reference frame for other frames (P and B frames) and Frame I - the first level of priority, Frame P - second level of priority and B frame belongs to the lowest level of priority.

*Video coding solutions for APP layer are:*

There are different video coding solutions for APP layer are: [3].

*1) The error resilience tools:* These are the tools are required in a wireless transmission environment are Slice structuring, FMO, Data partitioning and Error concealment. The objective of slice structuring is to avoid error propagation while the aim of FMO is to avoid error accumulation in a frame. Data partitioning is designed to encapsulate the syntax elements with different importance levels into separate NALU. It enables the unequal error protection according to the importance of syntax elements.

*2) RDO mode:* It can be used for rate control in APP layer to adapt the video traffic to the network bandwidth.

*3) JSCC schemes:* It attempt to develop APP layer solutions that consider both source coding rate as well as channel coding rate simultaneously. Channel coding is introduced to combat the transmission errors to improve the quality of received video. However, since the channel coding is competing for the limited channel bandwidth. JSCC can efficiently utilize the UEP algorithm to increase the transmission robustness of the video bit streams and therefore can be considered as application layer FEC.

*4) H.264/AVC video coding :* APP layer solution based on H.264/AVC video coding standard. The H.264 standard use two layers namely, VCL and the NAL [10]. VCL contains specifications of the video-encoding engine including motion compensation, transform coding of coefficients, quantization and entropy coding. NAL is responsible for the encapsulation of the coded slices into transport entities of the network. Building Block of NAL design are NAL units, parameter sets and access units. Cross-layer design involves the mapping of H.264 video slices (packets) to appropriate access categories of IEEE 802.11e according to their information significance [1].

There are two kinds of entropy encoding mode, CAVLC and CABAC. For transform coefficient coding AVC includes CAVLC and CABAC entropy coding methods for coding quantized coefficient of transform. The CABAC mode has higher compression rate, the computation complexity is higher, takes lot more processing power than CAVLC [5].

*Profiles:*

The H.264/AVC standard defines subsets of coding tools intended for different classes of applications called Profiles. A decoder may choose to implement only one subset (profile) of tools [4].



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*1) The Baseline profile* includes I- and P-slice coding, enhanced error resilience tools (flexible macroblock ordering (FMO), arbitrary slices and redundant slices), and CAVLC. It was designed for low delay applications, as well as for applications that run on platforms with low processing power and in high packet loss environment. Among the three profiles, it offers the least coding efficiency.

*2) The Extended profile* is a superset of the Baseline profile. Besides tools of the Baseline profile it includes B-, SP- and SI-slices, data partitioning, and interlace coding tools. It however does not include CABAC. It is thus more complex but also provides better coding efficiency. Its intended applications were streaming video.

*3) The Main profile* includes I-, P- and B-slices, interlace coding, CAVLC and CABAC. It shares common tools such as I- and P-slices, and CAVLC with both the Baseline and Extended profiles. In addition it shares B-slices and interlaced coding tools with the Extended-profile. The Main profile was designed to provide the highest possible coding efficiency.

*CAVLC Entropy Encoding[5]:*

The CAVLC is used for encoding the residual data. Run-Length coding is performed to encode run and levels separately. After the 4x4 data block is predicted, converted and quantised, low frequency domain coefficients are mainly non-zero and most high frequency coefficients are zeros. If magnitude of NZ lies within the range of that VLC table, it is coded by regular mode, otherwise escape mode is used as shown in Fig. 2.

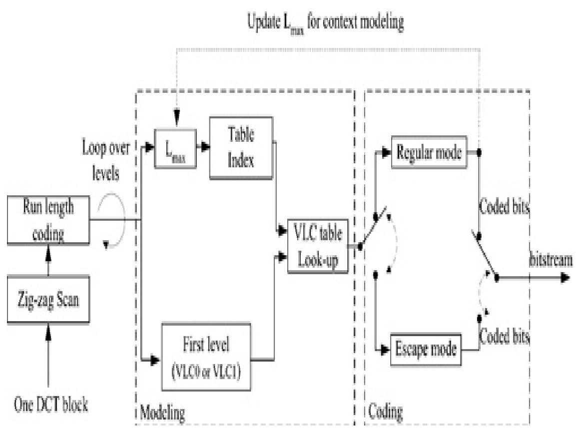


Fig. 2 Block diagram of level coding in CAVLC of H.264/AVC [5].

In CAVLC, five syntax elements are used to code levels and runs as shown in Fig. 3

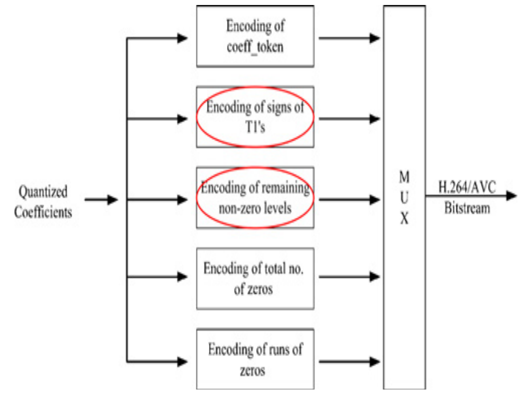


Fig. 3 Encircled syntax elements are used for SE-CAVLC [5].

*CABAC Entropy Encoding [4][5]:*

The design of CABAC involves the key elements of binarization, context modeling, and binary arithmetic coding as shown in Fig. 4(a).

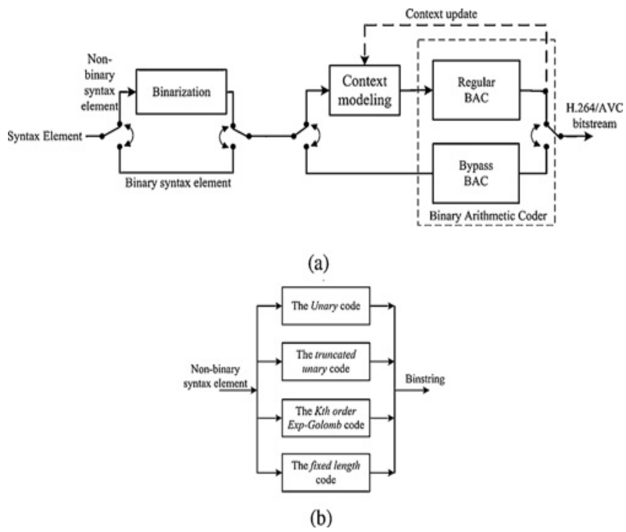


Fig. 4 (a) Block diagram of CABAC of H.264/AVC. (b) Binarization stage [5].

Run-length coding has been replaced by significant map coding which specifies the position of NZs in the 4×4 block. Binary arithmetic coding (BAC) module of CABAC uses many context models to encode NZs.

*1) Binarization*:

A binarization scheme defines a unique mapping of syntax element values to sequences of binary decisions, so-called *bins*, which can also be interpreted in terms of a binary code tree. It is done on non-binary syntax elements which are converted to binary form called binstring. There are four basic code trees for binarization steps. as shown in Fig. 4(b).

*2) Coding-Mode Decision and Context Modeling:*

By decomposing each syntax element value into a sequence of bins, further processing of each bin value in CABAC depends on the associated coding-mode decision which can be either chosen as the *regular* or the *bypass* mode. In the regular coding mode, each bin value is encoded by using the regular binary arithmetic-coding engine. In context modeling, model is selected



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based on previous encoded binstring which is generated in binarization stage.

*3) Adaptive Binary Coding Engine:*

The Arithmetic coding engine used is based on the probability of symbol to be coded. Complexity reduced by allowing a simpler coding mode called "Bypass mode".
CABAC offers 10% better compression than CAVLC [5].

## III. MAC LAYER CONSIDERATIONS

The IEEE 802.11 MAC layer aims to provide access control functions to the wireless channel such as access coordination, frame retransmission and check sequence generation. By adjusting the MAC parameters dynamically according to varying channel conditions and delay considerations one can achieve the improvements in the video transmission.

The objective of [8] is to investigate the effects of main parameters in a WLAN communication system, the effects of modulation modes at the physical layer, retry limits at the MAC layer and packet sizes at the application layer over the quality of media packet transmission. To maintain the delay as low as possible and high throughput, use lower retry limits in higher modulation modes, good channel condition with high SNR and in case of low SNR, lower modulation modes, higher retry limits, smaller packet size to achieve better performance.

The fundamental building block of the IEEE 802.11 architecture is the Basic Service Set (BSS) is under the control of a DCF makes use of CSMA/CA as access method. The IEEE 802.11e replaces DCF and PCF standard with HCF. In HCF, two channel access methods are used: HCCA and EDCA. EDCA was designed to enhance the DCF mechanism that can support service differentiation among different classes of traffic. EDCA supports QoS by introducing AC. Each AC within a station behaves like an individual virtual station: it contends for access to the medium and independently starts its backoff procedure after detecting the channel being idle for at least an AIFS period. When a collision occurs among different ACs within the same station, the higher priority AC is granted the opportunity to transmit, while the lower priority AC suffers from a virtual collision, similar to a real collision outside the station as shown in Fig. 5.

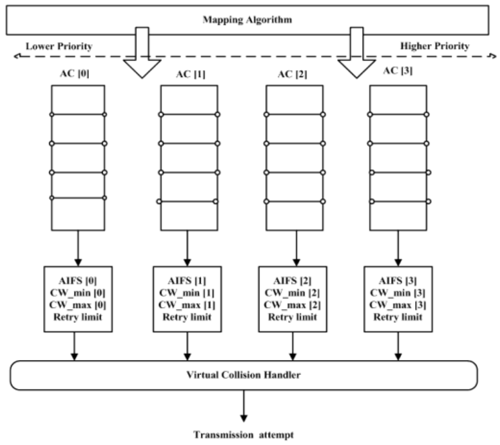


Fig. 5 Priority based AC's [9]

*EDCA Collision [9]:*

The ACs with higher priority has small CW will suffer from higher rate of collision. Two types of collisions in the wireless channels are internal collision and external collision.

*1) Internal collision:* When more than one EDCF in the same station count their backoff timers to zero and try to transmit at the same time it leads to a station like internal collision OR

If two ACs finish their backoff at the same time in a station, then the station has an internal collision called virtual collision. To avoid such virtual collision a node selects one AC having the higher priority

*2) External collision:* External collision occurs if backoff timers of the EDCFs at two or more stations reach zero at the same time and win access to the medium.

*Different MAC-Layer Adaption Techniques for Retry-Limit:*
*A. Adaptation of Retry limit*

Retry limit parameter of IEEE 802.11 standard directly effects on the packet reliability whereas other parameters mostly effect on packet delay. According to the IEEE Standard 802.11 MAC when a transmitted packet is not acknowledged properly retries can be performed and repeated until a certain limit is reached. Packets are dropped when they reach their retry limits. Retry is an efficient parameter to improve the reliability of the link. By varying the Retry limit value of the ACs, the QoS optimization- throughput stability and minimum delay is achieved. Advantage of EDCA is that, it fully utilizes the channel bandwidth. By assigning a high value to the Retry limit, it gives the AC a high priority. There are different techniques to adapt the retry limit studied further.

*1) Content-Aware Technique :* In [1], proposed cross layer content aware retry limit adaptation (CA-RLA) scheme for wireless video transmission over IEEE 802.11 WLAN where transmitter retrieves the side information associated with the video bit stream as well as estimates the client channel conditions according to the estimated channel state information (CSI) and actual estimated back-off waiting statistics.


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*2) Priority queuing :* The way a node manages delayed packets in its buffer, such as the order of receiving service or dropping, is called a queuing mechanism. PQ is referred to the type of service discipline in which multiple queues are maintained and associated with different priority levels. By combining the retry limit adaptation with priority queuing, performance of the transmitted video over WLANs is improved [11]. This technique uses the feedback from decoder side so it leads to delay which is not suitable for real time video transmission.

*3) M/M/1 model :* The effect of delay constraint on the quality of received packets is analyzed by "expired-time packet discard rate" (Pex). In the retry-limit adaptation the optimum retry-limit is obtained in order to minimize the "total packet loss rate" (PT) by virtue of the fact that increasing retry-limit will decrease "packet link loss rate" (PL) and increases both Packet overflow drop rate (POV) and expired-time packet drop rates. In this scenario each packet may be lost either due to drop from the queue at the wireless access point or due to channel errors at the wireless link. Packet dropping from the queue in turn can take place when the number of packets in the queue exceeds the buffer length or some packets become expired [12]. This technique is good which increases the throughput as it adapts the retry limit according to total packet loss rate and expired time packet discard rate. For real time video transmission the total packet loss rate can be calculated with the help of estimated CSI from the receiver.

*4) Adaption of contention window, backoff timer/counter, AIFS in both DCF and EDCA:* When the channel is sensed idle the transmission begins otherwise the station executes a backoff procedure after waiting a period of AIFS [AC]. The backoff mechanism of EDCA is different from the DCF. The EDCA is selected from[1,CW], instead of [0,CW −1] as the DCF. If two ACs finish their backoff at the same time in a station, then the station has an internal collision called virtual collision. To avoid such virtual collision a node selects one AC having the higher priority.In [13], CW is adjusted based on number of collisions. Both DCF and EDCA use random contention window to determine bakeoff intervals. Once a transmission is failed, it results in a larger contention window. This may cause two problems. First, video packets are still transmitting while deadlines were due. This will waste network bandwidth in transmitting invalid packets. Second, I-slice is the most critical slice for P/B-slice to refer to. As the number of stations increases, the number of collisions, average delay time and packet loss rate increase [2]

In [9], the proposed Cross-Layer (CL) scheme, an MAC-Centric Architecture considers the co-design of APP and MAC layer in IEEE 802.11e network. CWmin, CWmax, PF (Persistence Factor) together determines a new CW after unsuccessful transmission. IEEE 802.11e updates the value of CW after each unsuccessful transmission using the fixed value known as persistence factor (PF). In IEEE 802.11e draft version 6.0 the PF is equal to 2. The new CW caculated as-

$$CW_{new} = (CW_{old} + 1) * PF - 1$$

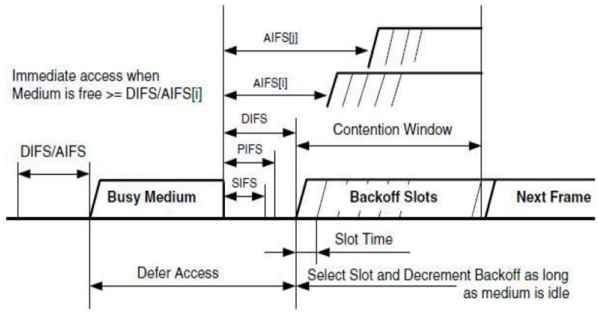


Fig. 6 Different IFS values in IEEE 802.11e EDCA [9]

The IEEE 802.11 standard specifies four types of Interframe Spaces (IFS) utilized to define different priorities, namely Short Interframe Spaces (SIFS), Point Coordination IFS (PIFS), Distributed IFS (DIFS), and Arbitrary IFS (AIFS) as shown in Fig.6. In [13], The algorithm for collision avoidance by adaptive CW enable each station to tune the size of the min CW used in its backoff algorithm for real time applications. The AIFS differentiation introduced in the algorithm determine the starvation point of different AC's at a given traffic load at given channel access parameter, such as the AIFSN to each AC.

## IV. CROSS LAYER OPTIMIZATION ISSUES AND SUGGESTIONS

A layered architecture is the cross-layer optimization approach, which refers to protocol design by exploiting the dependence between protocol layers to obtain a better system performance. In cross layer technique as shown in Fig. 7, instead of considering a layer as a completely independent functional entity, information can be shared among layers in both senses: upper to lower layers and lower to upper layers. This information exchange can be used to optimize the overall performance of the system in a holistic way, by adapting the protocols functionalities in the presence of changing networking conditions.

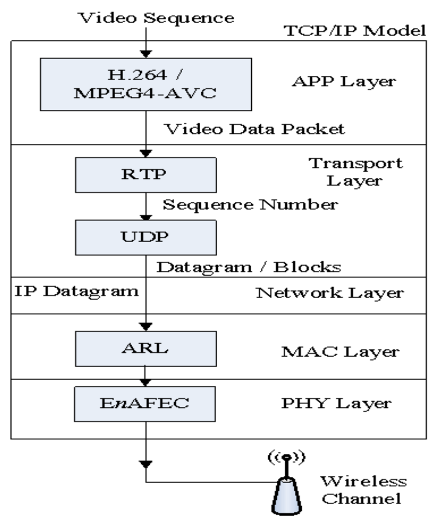


Fig. 7 Cross Layer Mechnism

In [14], a CAVP (Cross Layer Adaptive Video Prioritization) provides the combination of two mechanisms to implement the real testbed are: VFP (Video Frame prioritization) on APP layer, MAP


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(MAC-Layer Adaptive Prioritization). Video Frame Prioritization (VFP) prioritizes packet according to PSNR influence level, and MAC-layer Adaptive Prioritization (MAP) estimates the delay time i.e. access waiting time of each AC and chooses the faster one. From graph i.e. Fig. 8, both EDCA and the QoS scheme show a sudden drop immediately after the background traffic is larger than 200 kbps.

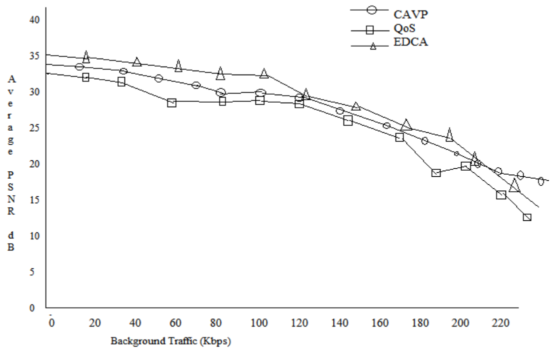


Fig. 8 The PSNR result (CAVP, QoS and EDCA) [14]

In [2], proposed combination of the calculation of queuing probability maintain the end-to-end queuing delay at a desired level and the active queuing algorithm assigns the video packets to different AC according to packet type, current queuing delay and calculated queuing probability, reducing the loss of important packets under heavy n/w traffic to provide higher PSNR values of video. In [1], the authors discuss various possible cross layer approaches for video transport over wireless network to achieve QoS into five categories summarized as follows.

1. *Top-down approach* relies on the higher layers to optimize their parameters and the parameters of their next lower layer in a top-down manner.
2. *Bottom-up approach* lets the lower layers insulate the higher layers from losses and bandwidth variation.
3. *Application-centric approach* uses either top-down or bottom-up approach to allow the application layer optimizing the lower layer parameters one at a time. However, due to the slower timescales in the application layer operation, this approach may not be optimal at all time.
4. *MAC-centric approach* considers the passing of traffic information and requirements from the application layer to the MAC layer allowing the MAC layer to optimize the transmission.
5. *Integrated approach* mixes and matches the above approaches to provide a combined strategy for cross-layer QoS design.

In [15] proposed CL design based on top-down approach, involves the mapping of H.264 video slices (packets) to appropriate access categories of IEEE 802.11e according to their information significance. The drawback with this approach is that when the video stream increases the AC_[2] queue gets full and unnecessary drops will occur. The RED approach is congestion avoidance algorithm used as a queuing management mechanism to prevent packet drop and much better than the drop tail algorithm. It uses a low pass filter to calculate the average queue size. In [1], proposed a hybrid design framework which consists of a MAC-centric cross-layer architecture to allow MAC layer to retrieve video streaming packet information, a hybrid retransmission deadline and retry limit to save unnecessary packet waiting time and a single-video multi-level queue to prioritize I/P/B slice (packet) delivery as shown in Fig. 9, 10.

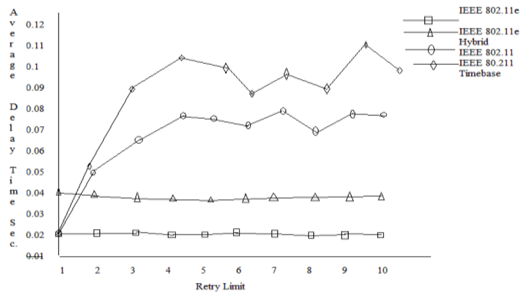


Fig. 9 Average delay time against retry limit [1]

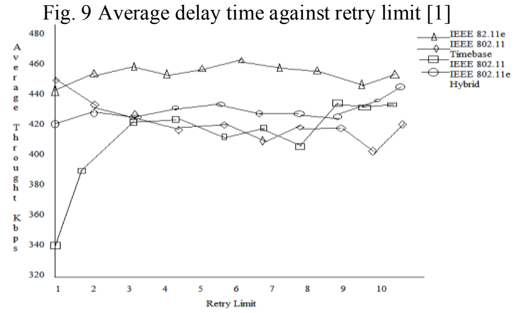


Fig. 10 Average throughput against retry limit [1]

At the Application layer, the last step of H.264/AVC encoding process is entropy encoding, which converts the DCT quantisation coefficients into codewords / binstring. After that, the codeword combines some header information (such as quantisation coefficients of prediction mode, motion vectors) to form compressed bitstream, which is used for transporting or storing through NAL (Network Abstraction Layer). In the MAC layer retry limits are used for reducing delay. While adapting the retransmission mechanism is effective for the delay sensitive applications requires employing alternative protection mechanisms by using a cross-layer protection strategy.

## IV. CONCLUSIONS

Different MAC layer parameters are identified in this study such as contention window, Arbitrary Inter Frame Space and Retry limit with their adapting techniques in real time environment. But Retry limit is most suitable for real time video transmission. The retry limit adaptation scheme is able to quickly track the optimal retry limits corresponding to the different states of the selected time-varying channel model. In APP, H.264/AVC video coding technique to generate the video bit streams and IEEE 802.11 at MAC layer for retry limit adaptation are the two techniques which are good for real time video transmission. These two techniques are jointly needed to be considered to optimize cross layer strategies.

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