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Ph.D. Research Proposal

Doctoral Program in "Department Name"

Refining Path & Buffer Management for Real-Time Video Transmission Over 5G Multi-RAT Systems

by

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I. INTRODUCTION / BACKGROUND

With the advancement of technologies, the demands of user also increase every day. Especially in the field of networking, people expect fast data transmission with both upload and download of information. Any user would aspire to watch the video in a good quality. Also, watching video in poor quality affects the eyesight and increases the stress with the impatience of the viewer. Many researchers have conducted experiments in this section and tried to bring many novel approaches. But, most of them suffer from certain drawbacks. But with the deployment of 5G network, this problem is completely removed. 5G network has many unique features out of which the speed is main significant characteristics. Some of the other vital features of 5G networks are given in Fig. 1.

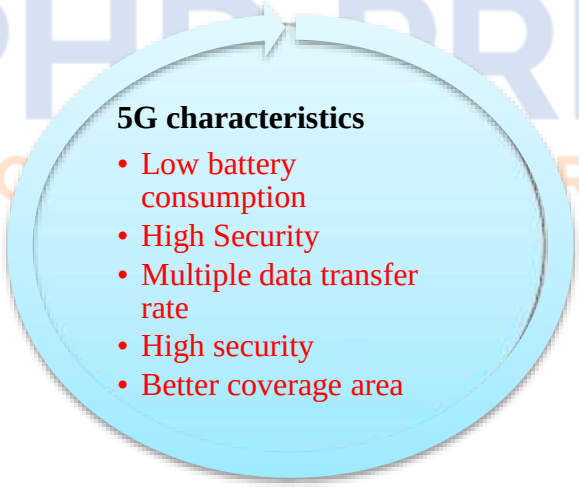

Figure 1 Characteristics of 5G network

5G network is a new kind of network platform that allows for innovations that will not only enhance today's mobile broadband services but also expand the support to a vast diversity of devices and services. This network will connect new industries with improved performance, efficiency and cost. 5G will refine a broad range of industries with connected services for every

firm that exist in present. Also, research works and reports show that 5G is full economic efficient and supports a wide range of industries in the growth of their business. Similarly, 5G hold a lot of beneficial information that is yet to be explored. It is evident that the 5G technology has improved technological features than the existing network technologies.

In general, video streaming is a type of media streaming in which the data from a video file is continuously delivered through the Internet to a remote user. It allows a video to be viewed online without being downloaded on a host computer or device. Video streaming works on the data streaming principles, where the data of the video file is compressed or encoded and sent to the requesting device in forms of small chunks. But this will not be reflected at the end of the receiver and the video will be played continuously. Sometimes, the video gets buffered and then plays continuously. As in computer memory, the buffering process will collect the set of chunks and ensures to play the video in a smooth and continuous manner. A typical video streaming process with 5G communication is given in Fig. 2.

Figure 2 Video Streaming with 5G Network

Video streaming typically requires a compatible video player that connects with a remote server, which hosts a prerecorded or pre-stored media file or live feed. The server uses specific algorithms to compress or encode the video file for the process of transmission over the network or internet connection. The size of each data stream depends on various factors including actual file size, bandwidth speed and network latency. In turn, the user or client player decompresses

and displays the streamed data, allowing a user to begin viewing the file before the entire video data or file is received.

Advantages of Video Streaming

- Increases the potential of interactive applications for the video search
- Monitoring the time the video is watched by the requestors
- Efficient usage of bandwidth
- Video is played and discarded. Thus saving the memory of the viewer's computer
- Easily portable and can be obtained from any destination
- Readily available, free and premade

1.1 Research Outline & Scope

Our main aim is to refine the cross layer with adaptive rate control in the video transmission in the 5G multi RAT wireless networks. This paper scope is to reduce the packet loss rate, delay and improve the QoE performance during video transmission in the cross layer based network.

1.2 Research Objectives

The objective of our proposed work is discussed as follows:

- To enhance the video encoding performance by performing the adaptive rate control mechanism in order to increases the video quality.
- To manage the buffer of the 5G wireless device in order to reduce the latency during the video transmission.
- To provide best QoE performance to the user during the video transmission via selecting the optimal access point in 5G multi-RAT networks.

II. RESEARCH GAPS

2.1 Common Problem Statement

Transmitting video over 5G is not a challenging task. Since wireless network has multipath fading and interference issues that tends to reduction in video quality, packet losses and delay during video transmission. Most of the works have utilized H.264 to encode the video packets. However, these methods consume more bandwidth and require high processing power. Thus introduces difficulties during video transmission. In wireless network, video packet is transmitted through the air medium which is highly affected by the network environment factors such as bit error rate, SINR and more. These network environment factors affect the video transmission greatly such as quality reduction and packet losses. However, most of the works doesn't utilized network environmental and user preference factors for video transmission. Thus reduces the QoE performance and also video quality.

2.2 Problem Definition

The authors of this paper [16] proposed the multipath based concurrent video streaming over 5G networks. In this paper, two different concurrent transfer techniques are proposed that are fast concurrent transfer (FCT) and reliable concurrent transfer (RCT). Here, the paths are selected based on the propagation delay, processing delay, transmission delay and round trip time parameters. Here, reliable concurrent transfer method transmits packet in both main and backup path. These two mechanisms are performed based on the adaptive transmission scheme by considering the status of the destination buffer.

Problems

- Here, H.264 encoding scheme used where the QP and bit rate are not adaptively changed based on the essential factors. Thus affects the quality of the video and result in low PSNR.
- This paper doesn't select the optimal RAT network to provide better QoE performance in the video transmission. Since, it frequently use cellular and wifi network during video transmission for two different paths respectively. However, high QoE require user may use the wifi network thus result in poor QoE results.
- Even though this paper reduces the delay during the multi path selection, it doesn't provide optimal path for video transmission. Hence, this paper doesn't considers the

parameters such as link stability, number of hops and buffersize. Thus result in more packet losses during the video transmission in 5G multi-RAT network.

Proposed Solutions

- In our work, we have selected best RAT network using the Red Deer Algorithm which is one of the significant heuristic algorithm. It selects the best RAT network for the video transmission.
- In our work, we have utilized H.265 encoding algorithm where we adaptively change the bit rate and QP value parameters effectually with the use of significant parameters. Thus increases the quality of the video and PSNR performance.
- In our work, we have performed path selection using Artificial Bee Colony algorithm with the aid of the number of hops, link stability and buffer size.

The authors in this paper introduced [17] the preference aware multipath video streaming over the MPTCP. Here, the two links are used to transfer the video chunks to the destination. Here, the chunks are the H.264 encoding method. Here, the buffer capacity and bandwidth is estimated before transmitting chunks via link. Based on the estimated buffer capacity and the bandwidth, it increases the chunks dead line constantly until the transmission condition satisfied. This paper utilized the backward and forward based algorithms to transmit the chunks.

Problems

- Here, the two links are utilized to perform the multipath video streaming in wireless networks. However, second link is used less and doesn't able to transmit the high quality level videos. Thus result in high packet overhead and also increases the delay during the video transmission. Since, all video chunks are most of the time transmit through the link 1. This paper utilized the available path to transmit the video packet thus tends to increase the packet loss rate. Since, path with higher delay and worst channel conditions affects the video transmission.

Proposed Solutions

- In our work, we have utilized the multiple links to transmit the encoded videos into the multipath to the destination. Hence, our work doesn't face any packet overhead and delay during transmission
- In our work, we have utilized H.265 encoder which provides better performance under the high resolution video. Thus provides better QoE since it is highly resilience to errors during the transmission.

In [18], the partially reliable transfer based high definition video is streamed in wireless networks. This paper utilized the H.264 method to encode the video packet. Here, the buffer rate is controlled adaptively by considering the reliability adaptation model. The buffer is controlled through proactive substitution mechanism for high priority packet frames. Herein, the both sender ad received buffer is adaptively controlled based on the ACK and NACK packets received. In receiver buffer, it also maintains the deadline constrained sliding window.

Problems

- This paper follows the partial reliability based video transfer in order to satisfy the high retransmission behavior of sender node. However, partial reliability based video transfer tends to ineffective results in achieving the better QoE performance i.e. low video quality score, high Mean of Score (MoS) and low Peak to Signal Noise Ratio (PSNR). In this paper, buffer is controlled by dropping the low priority packets via executing the high proactive substitution methods. Thus tends to increase the packet loss rate for the low priority video packets.
- In this paper, UDP protocol is utilized for video transfer however it is highly suitable for the best effort packets. Hence, it is not apt for the video transmission that tends to increase the packet loss rate.

Proposed Solutions

- In our work, we have transfer video transmission with high reliability via transmitting video with high quality. Thus increases the QoE results such as MSE and PSNR performances.

- In our work, we have controlled buffer by maintaining three different queues and we also schedule the packets using the APDRR algorithm.
- We have utilized the RTP protocol which is highly suitable for the video packet transmission over the wireless network. Thus avoids the packet loss during the video transmission.

Author proposes [19] the video data transmission in the cross layer based wireless networks. This paper concentrates on the bit rate adaptation and error control mechanisms. Here, bit rate is controlled adaptively by considering the available bandwidth in the channel. And, it also dynamically changes the quantization parameter by considering the estimated bandwidth. The available bandwidth is estimated based on the physical layer transmission rate and packet loss rate from the application layer. Here, the H.264 encoding mechanism is utilized to encode the video packet.

Problems

- Here, the lower and upper limit value of QP is adaptively changed between the 23 and 51. However, the lower the QP value (<23) provides high quality video during transmission. Since QP value starts from 0 to 51 where lower the QP value provides better video quality during transmission. Thus degrades the high QoE performance in video transmission in cross layer based wireless network.
- The video packets have different priorities; however this paper doesn't schedule the video packets with effective mechanism. Since, it delivers packets one by another without considering its priority. Thus tends to increase in the delay during the video transmission.
- The bit rate is adaptively controlled without considering the strong network environment characteristics. Since, the network environment parameters (attenuation, bandwidth) greatly affect the video transmission thus result in high packet loss rate.

Proposed Solutions

- In our work, we have selected the optimal QP value based on the decision making algorithm by considering the significant features such as distortion, previous QP and CSI. Thus increases the QoE performance.
- In our work, we have prioritized the packets using the APDRR algorithm where it monitors the three different queues based on the video traffic.
- We have adaptively changed the bit rate of the video packet by considering the strong network environment factors such as attenuation, SNR, throughput, bandwidth and bit error rate information.

In [20], the novel rate control mechanism is applied on the multi view based video encoding model. Here, the high efficiency based video coding model is utilized where the bit rate is adaptively controlled. It is achieved through the multi objective based optimization algorithm. Along with the bit rate control, it also controls the layer rate such as frame and view parameters during the video encoding process. Here, the similarities between the different frames are considered for the adaptive rate control process.

Problems

- The highly significant network environment factors (SNR, throughput) are not considered during the video encoding process thus affects the video quality during the transmission processes.

Proposed Solutions

- In our work, we have considered SNR, attenuation, bandwidth, throughput and bit error rate parameters during video encoding process thus evades low video quality during transmission.

III. RESEARCH CONTRIBUTIONS

Network Model

Our proposed approach involves the process of streaming the video files by using the 5G multi-RAT system. This multi-RAT is an effective approach for transmission over multichannel

and ensured to improve the throughput and reliability of the real-time video streaming over 5G networks. Multi-RAT supports connectivity to more than one network transmission and so it has been implemented in our approach.

Therefore the implementation of 5G technology for video streaming is ensured to provide better streaming and QoE of the video. Also, this approach is proved to increase the packet delivery rate during the frame transmission. Due to this approach, our system is guaranteed to provide reliable transmission of the video files. Our cross layer based 5G multi-RAT network comprises of 5G base station, LTE access point, wimax access point, wifi access points and also 5G wireless devices.

SYSTEM ARCHITECTURE

In our work, we have concentrated on four different processes such as

- Best access point selection
- Dynamic video encoding
- Optimum Path Selection
- Buffer management

These processes are discussed in detail as follows:

Best Access Point Selection

In our work, each user in the network selects the optimal access point in order to attain the better QoE performance in the 5G multi-RAT wireless network. For this purpose, we have employed Red Deer Algorithm (RDA). It is one of the optimization algorithms which select the optimal access point through three significant parameters. They are data rate, Signal to Interference Noise Ratio (SINR) and Received Signal Strength Indicator (RSSI). With the aid of these parameters, RDA selects the optimal access point for each user in the network.

Dynamic Video Encoding

Initially, the source will encode the video file for transmission. For the purpose of encoding, the H. 265 encoding algorithm is implemented in our approach. In this approach, the video file is first split into separate frames. In our approach, there is no fixed number of separations. These frames are further split into packets that will be transmitted through the 5G network. Our approach is designed to transfer the packets of the video file in parallel to the destination. this process, we adaptively controlled the bit rate and QP parameter of the video encoder. Here, the bit rate is adaptively controlled using the Deep-Q algorithm. Here, bit rate is controlled by considering the network environmental factors and the user preference factors. The network environment factors are bit error rate, attenuation, bandwidth, throughput and Signal to Noise Ratio (SNR). And, the user preference factors are high quality/low quality and processing speed of user device. The optimal QP parameter for each video packet is selected using the WASPAS decision making algorithm. Here, WASPAS algorithm considers the three different parameters that are distortion, previous QP value and CSI. Based on these processes, our work encodes the packet effectually by considering both user preference and network environment factors. By performing video encoding process based on these procedures enhance the video quality during the video transmission.

Optimum Path Selection

If users in the 5G multi-RAT network require video packets, then it broadcast the video packet request along with its preference that need to be in the transmitted video packet. 5G wireless device that receives the video request transmits the response to the destination device. After receiving the response from the multiple source device, destination device selects one response based on the Round Trip Time (RTT). Then, it transmits the acknowledgement to the selected source device. The source device selects the best path between the source and destination devices. For this purpose, we adopt the Artificial Bee Colony (ABC). The parameters considered for the path selection are *number of hops, link stability and buffer size.* It selects the best path after checking the threshold conditions.

Buffer Management

In order to reduce the latency during video transmission, we have proposed adaptive buffer management in the cross layer based 5G multi-RAT network. In each device buffer, we have maintain three different queues that are real time, interactive and video on demand. Here, the Adaptive Pre-order Deficit Round Robin (APDRR) algorithm is utilized to maintain these three different queues. In each queue, it prioritizes the received packet based on the four different parameters that are *layer information, dead line, packet size and arrival time.* After prioritizing the packets in each queue, during the transmission, it transmits the packet adaptively in order to reduce the waiting time of the packet in queues. For this purpose, it considers the queue length and average packet size. Based on these parameters, it monitors the queue and schedules the packet adaptively which reduces the packet waiting time and packet drops.

Performance Evaluation

Finally, the performance of the proposed work is measured through the following performance metrics,

- PSNR (db) w.r.t number of devices
- MoS w.r.t number of devices
- Throughput (Mbps) w.r.t number of devices
- Delay (ms) w.r.t number of devices
- Packet Drop Rate (%) w.r.t number of devices
- Goodput (Mbps) w.r.t number of devices

IV. RESEARCH NOVELTIES

- The proposed encoding algorithm high error resilience and consumes less bandwidth during encoding process.
- In our work, we have utilized the H.265 encoding algorithm which provides better video quality and consumes low bandwidth.
- We enhance the QoE performance through the optimal selection of the access point which is done through the effective optimization algorithm RDA.

V. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title - QoE-Aware Scheduling Algorithm for Adaptive HTTP Video Delivery in Wireless Networks

Concept

This paper proposed the QoE based scheduling process based on the video delivery based wireless networks. For the scheduling purpose, this paper utilized the maximum buffer filling algorithm. Here, the buffer scheduling process is performed based on the channel quality index. In this, channel quality index is measured from the wireless networks along with this constraint it also considers the current buffer capacity to schedule the packets the in each device exists in the wireless network.

Limitations

- The video transmitted over HTTP doesn't provide optimal result in receiver end hence, this paper has less QoE results and video quality.

Paper 2

Title- 5G-QoE: QoE Modelling for Ultra-HD Video Streaming in 5G Networks.

Concept

This paper proposes the ultra HD based video streaming in the 5G networks. In this paper, path is investigated between the source and destination in order to reduce the packet loss. For this purpose, it estimates the congestion index between the source and destination along the available path. During congestion index estimation, it estimates the both measured congestion index between sender and receiver and also expected congestion index between sender and receiver. Based on the estimated congestion index, it performs the video streaming process between source and destination.

Limitations

- During path selection, congestion index alone considers thus tends to induce high packet losses and delay during the video transmission

Paper 3

Title- Streaming high-definition real-time video to mobile devices with partially reliable transfer

Concept

In this paper, the author presents an application-layer solution dubbed Partial Reliability based Realtime Streaming (PERES) to perform partially reliable transfer and to strike an effective balance between delay and reliability in real-time video transmission. First, this paper develops an analytical framework to model the delay-constrained partial reliability for acknowledgement (ACK) and negative acknowledgement (NAK) based real-time video streaming. Second, this paper proposes scheduling algorithms for video-aware reliability adaptation and network-adaptive buffer control.

Limitations

- If the acknowledgement is not received on-time, then re-transmission increases
- Increase in redundant data and congestion of network.

Paper 4

Title - Optimal multipath TCP offloading over 5G NR and LTE networks

Concept

In this paper, the author proposes a framework for optimal multipath TCP offloading over 5G NR and LTE networks. Multipath TCP (MPTCP) is one of the key technologies that can improve the throughput performance by exploiting multiple path communications. This paper proposes an offloading by restriction (OBR) scheme to enhance the throughput by offloading data traffic optimally when fifth generation (5G) new radio (NR) and LTE communication paths

are aggregated. The proposed OBR scheme also considers interaction with MPTCP congestion control and scheduling algorithms

Limitations

- Limited and also insignificant parameter consideration
- Poor QoE achievement

Paper 5

Title- A quality-of-experience index for streaming video

Concept

In this paper, the author proposes a quality-of-experience index for streaming video. In this work, this paper first build a streaming video database and carry out a subjective user study to investigate the human responses to the combined effect of video compression, initial buffering, and stalling. This paper then propose a novel QoE prediction approach named Streaming QoE Index that accounts for the instantaneous quality degradation due to perceptual video presentation impairment, the playback stalling events, and the instantaneous interactions between them.

Paper 6

Title- Multi-RAT dynamic spectrum access for 5G heterogeneous networks: The SPEED-5G approach

Concept

In this paper, the author presents a detailed survey on the speed of the 5G approach considering the multi-RAT dynamic spectrum access for 5G heterogeneous networks. The objective of this article is to present a new framework for MAC and RRM layers for supporting eDSA and requirements of the next-generation network. The solutions proposed by SPEED-5G through extended dynamic spectrum access (eDSA) address traffic allocation over heterogeneous

wireless technologies, better load balancing across available spectrum bands, and capacity boosting through aggregation of available resources while ensuring fair coexistence.

Paper 7

Title - Quality-aware energy optimization in wireless video communication with multipath TCP

Concept

In this paper, the author presents an energy-distortion-aware MPTCP (EDAM) solution to enable the energy-efficient and quality-guaranteed video streaming. First, this paper develops an analytical framework to characterize the energy-distortion tradeoff for multipath video transmission over heterogeneous wireless networks. Second, this paper proposes a video flow rate allocation algorithm to minimize the energy consumption while achieving target video quality based on utility maximization theory.

Limitations

- QoE is very poor
- Increase in Delay

Paper 8

Title- Energy-efficient bandwidth aggregation for delay-constrained video over heterogeneous wireless networks

Concept

In this paper, the author presents an Energy-quaLity aware Bandwidth Aggregation (ELBA) scheme to address the critical problem. First, this paper develops an analytical framework to model the delay-constrained energy-quality tradeoff for multipath video transmission over heterogeneous wireless networks. Second, this paper proposes a bandwidth aggregation framework that integrates energy-minimized rate adaptation, delay-constrained unequal protection, and quality-aware packet distribution.

Limitations

- Reduced throughput reduced the lifetime of the wireless network
- Not suitable for resource constrained network

Paper 9

Title- Energy-minimized multipath video transport to mobile devices in heterogeneous wireless networks

Concept

In this paper, the author proposes an energy-video aware multipath transport protocol (EVIS) to enable the energy-efficient and quality-guaranteed live video streaming over heterogeneous wireless access networks. First, this paper presents a mathematical framework to analyze the frame-level energy-quality tradeoff for delay-constrained multihomed video communication over multiple communication paths. Second, this paper develops scheduling algorithms for prioritized frame scheduling and unequal loss protection to achieve target video quality with minimum device energy consumption. EVIS is able to effectively leverage video frame priority and rateless Raptor coding to jointly optimize energy efficiency and perceived quality.

Limitations

- Computational overhead is increased as too many metrics have to be calculated
- Highly time consuming approach

Paper 10

Title- Receiver-side TCP countermeasure to bufferbloat in wireless access networks

Concept

In this paper, the author addresses the bufferbloat problem in resource-competitive environments such as Wi-Fi, and designs a receiver-side countermeasure for easy deployment that does not require any modification at the sender or intermediate routers. Exploiting TCP and AQM dynamics, the proposed scheme competes for shared resource in a fair manner with

conventional TCP flow control methods and prevents bufferbloat. Bufferbloat has drawn much attention in the network community for its negative impact on TCP delay performance and user QoE.

Limitations

- Routing is not optimized and so there is high chance of packet loss
- Very low QoE of the data transmission

Paper 11

Title- 5G-QoE: QoE Modelling for Ultra-HD Video Streaming in 5G Networks

Concept

In this paper, the author proposes a 5G-QoE framework to address the QoE modeling for UHD video flows in 5G networks. Particularly, it focuses on providing a QoE prediction model that is both sufficiently accurate and of low enough complexity to be employed as a continuous real-time indicator of the "health" of video application flows at the scale required in future 5G networks. The model has been developed and implemented as part of the EU 5G PPP SELFNET autonomic management framework, where it provides a primary indicator of the likely perceptual quality of UHD video application flows traversing a realistic multi-tenanted 5G mobile edge network testbed.

Limitations

- Path of transmission is not selected accurately
- Not adaptive for all type of video qualities

Paper 12

Title- CASH: Content- and Network-Context-Aware Streaming Over 5G HetNets

Concept

The proposed CASH fundamentally works in a multi-step process. First, the CASH comes with an integrated architecture that includes a media server, a flow scheduler, and a single radio controller (SRC). The SRC and the user equipment (UE) of interest cooperatively prepare a metadata file that contains the network-context. Second, based on the metadata file, which can be accessed from the SRC in the media preparation server, we analyze and cluster the contents based on the content-context, e.g., the actual bitrate of each scene. The metadata file is then updated by adding the content-context information. Third, the flow scheduler basically controls the flow of the clusters of the contents in the server-push mode.

Paper 13

Title- Optimal Video Streaming in Dense 5G Networks With D2D Communications

Concept

In this paper, we design an optimal rate allocation and description distribution for high performance video streaming, particularly, achieving high QoE at high energy efficiency while limiting co-channel interference over D2D communications in 5G networks. To this end, we allocate optimal encoding rates to different layers of a video segment and then packetize the video segment into multiple descriptions with embedded forward error correction before transmission.

Paper 14

Title- The K-hop Cooperative Video Streaming Protocol Using H.264/SVC Over the Hybrid Vehicular Networks

Concept

This work proposes the k-hop cooperative video streaming protocol using H.264/SVC over the hybrid vehicular networks which consist of 3G/3.5G cellular network and Dedicated Short-Range Communications (DSRC) ad-hoc network. In order to smooth video playback over the DSRC-based ad-hoc network, this work proposes: (1) one streaming task assignment scheme that schedules the streaming task to each member over the dynamic vehicular networks, and (2)

packet forwarding strategies that decide the forwarding sequence of the buffered video data to the requested member hop by hop.

Paper 15

Title- Video Quality-aware Traffic Offloading System for Video Streaming Services over 5G Networks with Dual Connectivity

Concept

The proposed system achieves a good balance between fairness and social welfare in terms of the video quality by allocating the radio resource of the macrobase station. The data flow is split into two parts toward the macrobase station and small cell AP, and the users simultaneously receive their data from both. In the proposed system, fountain code is employed to achieve dual connectivity enhancement by overcoming frequent packet loss in error-prone mobile networks and practical issues in the dual connectivity architecture. Furthermore, software-defined networking (SDN) technology is adopted not only to quickly react to time-varying network status but also to control network resources efficiently.

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