Multimedia Transmission Mechanism for Streaming Over Wireless Communication Channel

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***Abstract*—With the evolution of wireless communication technologies (i.e., 4G/5G), the explosion of multimedia transmission of content sharing has become an integral part of users' daily lives. It expects further growth in Quality of Service (QoS) and Quality-of-Experience (QoE) performance. Therefore, multimedia service providers are developing new technologies to offer higher video streaming quality content along with video compression standards, which is highly demanded by the receivers. Thus, inventing precise and efficient quality-based media transmission protocol will significantly help to improve the multimedia QoS over wireless networks. This comprehensive research study discusses standard research work progress in multimedia transmission protocol for wireless communication networks. It also investigates the limitations of such literature found some challenging factors that play a significant role in managing the superior signal quality for digital or video content transmission over heavy traffic conditions. The final section provides a briefing on crucial open research issues to develop a multimedia transmission model that can seamlessly communicate multimedia content irrespective of adverse traffic conditions.**

Keywords—Multimedia transmission; video encoding; multimedia streaming; quality of service; quality of experience; video compression standards

I. Introduction

The evolution of media communication systems (i.e., 4G and 5G) has led to increased digital services and applications, such as IPTV, social networking, video conferencing, multimedia games, educational digital presentation, etc. These multimedia applications are becoming an integral part of our daily lives and are provisioned to grow exponentially. Various multimedia service providers, e.g., subway system [1], chroma-keying [2], 2D and 3D animation industries, etc., are discovering differing technologies to offer a higher quality of experience, which end users are progressively insisting. In the current scenario, almost all users having/utilizing smart devices for multi-purpose like generating data, communicating, or sharing information from person to person or device to device anywhere and anytime. Most of the users spending time viewing and sharing multimedia content from the internet. At present, viewing video content over the internet is almost free for public users. It is also studied that there will be a phenomenon increase in user base for using multimedia streamed contents over the internet [3]. Apart from this, it is also figured out that it reaches up to 80% by 2020. In the future, most of the multimedia access traffic will be transmitted wirelessly. Nowadays, video transmission has become common for all internet users.

Despite the increasing growth of advanced technologies, the audio-video transmission process suffers from impairments by lossy transmission and source encoding over the network channels, thereby degrading the quality of multimedia content [4]. For example, the user may receive a sample video file that may group different quality ranges due to rendering errors or another transmission. However, other technologies and network standards have been developed that facilitate a high communication range among digital devices. Such standard networks are; IEEE 802.15 WPAN [5], IEEE 802.11 WLAN [6], IEEE 802.16 WMAN [7], and 4G telecommunication networks [8]. The high-speed network availability and video transmission with high speed and minimum cost provide a new era for video communication that has not been implemented over the past decades. Video communication technology dominates the high traffic over the wireless networks and is envisioned for multiple applications. The deployment of high-standard networks like 3G and 4G and advancements in intelligent device development had led to the massive demand for digital media transmission over wireless channels. The increasing requirement for multimedia content creates challenges for all digital media streaming systems, such as wireless network service providers [9], content providers, and mobile device makers.

The mobile network service providers and content providers strive to enhance their services while adopting advanced technologies—for example, improving processing power and high-quality displays. Ultimately, the common goal of all service providers is to improve the quality of experience (i.e., QoE) for end-users. The objective of QoE is t evaluate the video streaming quality by end-users. It can be assessed in-display smoothness, streaming bit-rate, video quality range like PSNR, etc. Therefore, in [10], the authors provided a comprehensive survey study on existing video transmission methods and offered a research direction towards defining high QoE and new transmission methods for 3D video streaming. Video streaming or video transmission over wireless channels remains challenging, for example, signal interference between nodes, unreliable quality due to multi-path fading, and dynamicity in connectivity. Routing problems always influence the end-to-end QoS of video applications; an example is finding an optimal route that could help for video transmission with high quality. The conventional routing protocols rely on packet delay and packet loss metrics to achieve the high perceived video quality. The case study shows that multiple techniques exist to address the routing issues for real-time video transmission over wireless networks to enhance the quality of video at the end user. The practical use of these theoretical results of existing studies offers better guidelines toward formulating new studies for better QoS and QoE performance in routing strategies.

Therefore, most research was carried out on developing optimal routing for video transmission in wireless networks, mainly focused on network-oriented QoS (i.e., delay, throughput, and packet loss) and less concentrated on application-oriented QoS perceived video quality. Thus, the present survey study overviews different challenges in designing a multimedia transmission protocol to improve the signal quality in heavy traffic over wireless networks. From the prior research study, it can be observed that very little research has been done towards multimedia compression, which does not have an explicit module of wireless networks and its associated problems. The transmission protocols designed to date seriously lack multi-level optimization, showing that the existing algorithms can provide a one-way solution and cannot go beyond that. Since multimedia transmission protocols play a significant role in delivering the requirements of WSN applications, there is less work done that needs to extend the conventional real-time communication systems. Multimedia transmission protocols must be upgraded to be suitable for wireless environments. The significant challenge in implementing multimedia transmission protocol involves real-time data streaming over wireless networks with high QoS. Another challenging task is the compression technique, where a slight increment in the compression level causes data quality to decrease. Hence, the present study's contribution presents the relevant prior research study towards multimedia transmission protocol over wireless channels that have been recently introduced. Also, investigate such literature's limitations and find some challenging factors that play a significant role in managing the superior signal quality for digital or video content transmission over heavy traffic conditions. With the increasing usage of streaming-based services over various commercial applications for different causes, a smoother streaming experience is needed. This streaming is eventually carried out using different variants of the wireless network. Adoption of wireless network offers cost-effective utilization towards the user, but it also introduces various challenges. There are multiple archives of research-based solutions for dealing with the difficulties in data transmission over a wireless network. However, the challenges still exist, and there is yet evolving research work.

Hence, the biggest problem is a snapshot of the existing transmission methods for multimedia contents over a wireless network. Therefore, this manuscript contributes towards more detailed insight into the strength and weaknesses of existing multimedia transmission in a wireless network. The overall organization of the current manuscript is as follows; Section II briefs about multimedia transmission standards. Section III discusses different researchers who have introduced various theoretical and implementation research studies. Section IV presents the other multimedia transmission protocols that help improve QoS in the streaming process concerning compression standards. Section V reviews current research challenges found from existing studies. Finally, in the last Section VI, the summary of the study is presented in the form of a conclusion.

II. Multimedia Transmission Protocols

The multimedia transmission means forwarding data packets that usually consist of audio, video, or audio-visual streaming. Multimedia transmission is the fundamental process for sending media content to mobile users. The scalable transmission process will need efficient and robust routing protocols which provide high-quality output video content. Therefore, effective and scalable video streaming protocols intend to transmit multimedia content through the internet while enabling users to access it without completing the transmission process. Generally, all video transmission protocols preferred a transport layer where transmission occurs via live video streaming. The functionality of the transmission protocol is to offer real-time, sequential, less packet loss, low delay, minimum energy consumption for video/digital data streaming. This section discusses the most common and frequently adopted multimedia transmission protocol.

- Real-Time Messaging Protocol (RTMP): RTMP is best and significantly utilized for media streaming technology in all listed transmission protocols. Macromedia developed RTMP to stream digital data over the internet. It is a TCP-based protocol that provides low latency communication with a persistent connection. It contains multiple features such as; it is very flexible and enables audio, video, audio-visual streaming, even text content in several formats to various devices. Another significant feature is the multiplatform transmission protocol; users can access the media content using any platform (i.e., Android, Mac, Windows, etc.).

- Nevertheless, one of the drawbacks of this protocol is that users need to consider it before selecting it for video streaming activities. RTMP is an old protocol and well-proof multimedia streaming technology that has been adopted for years now. The Flash-Player helps in viewing media streams via RTMP, which is very famous and utilized over the globe [11].

- Real-time Transport / Control Protocol (RTP/RTCP): A transport layer protocol built on UDP enables real-time multimedia content transport. It may be exploited for single-way transport services like video on demand and internet telecalls. One of the features of RTP is closely associated with RTCP, which performs at the session layer of the ISO model. It offers feedback for the quality of content distribution. RTP is mainly designed to utilized UDP/IP protocols at the transport layer. Both RTP & RTCP are compressed in UDP/IP packets.

- Real-time Streaming Protocol (RTSP): Primarily, RTSP is utilized to control real-time media streaming applications such as HD-video streaming. It is a network control protocol that establishes communication sessions among the endpoints. This protocol uses TCP protocol to balance the end-to-end session, and RTP is utilized to deliver the media content over the UDP. Additionally, RTSP protocol may interact with HTTP server such that hand over devices is specified among the media and web server. This makes, as, the delivered file content to be requested via HTTP or RTSP. "VOCAL" optimized software is utilized for media transmission, which supports RTSP protocol [12].

- HTTP Streaming: In the current multimedia streaming technique, HTTP streaming is the new trend that supports adaptive bit rates. Specifically, HTTP plus TCP/IP protocol is designed for reliable transmission to maintain the transmission flow. APPLE's company developed HTTP streaming for IOS, and it does not apply to other products, i.e., it supports only Apple's products [13].

- Adobe HTTP Dynamic Streaming (AHDS): AHDS is a proprietary solution for real-time on-demand streaming of high-quality content. It mainly operates on HTTP. Like RTMP protocol, AHDS is associated with flash. However, unlike RTP, AHDS utilizes an adaptive bit-rate mechanism to transfer the MP4 media files over HTTP servers. Additionally, it supports encrypted files and can be used for HD quality video content delivery up to 1080 pixels with a 6MBps bit rate. It also supports different compression algorithms, for example, H.264, VP6, AAC, and MP3 video [14].

- Microsoft Smooth Streaming (MSS): Microsoft invented it in 2008 to develop silver light architecture [15]. It was primarily utilized to deliver the on-demand video clips of the 2008 Olympics. The MSS technology can optimize the media playback by switching real-time video quality. Now, this technology goes beyond, and it can be utilized to reach different types of devices/clients like as browsing with Xbox, Silver light, Apple devices, TV set-top boxes, etc. typical example is the Xfinity TV application for iPhone, which has been operated on top of MSS and transmits media content to IOS devices. MSS is generally utilized for television and premium media content delivery. MSS can also host on Apache web server and support advanced operations like rewind, fast-forward, etc.

- Shout-Cast: It is one of the popular technologies which delivers broadcast streaming. Shoutcast utilizes its protocols, and it was developed by Nullsoft and named ICY; at present, Ultravox is using for ShoutCast-2. This protocol can operate over either UDP or TCP. The major drawback of this protocol is only applicable for broadcasting, not for on-demand video delivery.

- Moving Picture Expert Group-DASH: (MPEG-DASH): Generally, MPEG was developed for multimedia streaming with multiple standards, i.e., MPEG-2, MPEG-4, and MPEG-7. The dynamic adaptive streaming standard over HTTP is the MPEG-DASH, which can solve media delivery problems to several devices with a unified standard [16].

Above discussed, all multimedia protocols have different methods and formats as well as unique features. Therefore, a dynamic supportable protocol must be needed to deliver or receive media content from servers to users. However, all these standard protocols can provide multimedia content over wireless channels. Apart from this, there are some recent studies carried out in this direction. The study presented by Li et al. [17] has implemented a parallel coding scheme to improve multimedia transmission considering turbo coding. Reinforcement learning is another scheme that offers better video transmission performance considering a case study of the internet of things, as seen in the analysis of Xiao et al. [18]. Ta et al. [19] have developed a cooperation scheme of image transmission considering sensor networks as a wireless medium. Huang et al. [20] have presented a Q-Learning scheme over the cognitive network for improving multimedia transmission. Liu et al. [21] have used the beamforming approach for enhancing multimedia transmission in 5G, harnessing the potential of the relay network. The following section discusses existing strategies for multimedia transmission over different variants of the wireless network.

III. Existing Approaches

Different theoretical and implementation research studies have been introduced by other researchers that achieved multimedia transmission over other network technologies. Therefore, this section discusses relevant research studies on multimedia transmission protocols in wireless networks. At present, various wireless protocols are claimed to offer the quality of service for multimedia transmission. Table I highlights this comparative analysis of these standards.

TABLE I. Comparison of Performance of some Existing Standards

	H1	H2	H3	H4	H5
[22]	Delay	No	Yes	No	No
[23]	Delay	Limited	No	Limited	No
[24]	Delay	No	Yes	Yes	Yes
[25]	Delay	Yes	Yes	Yes	Yes
[26]	Delay	No	Yes	Yes	Yes

H_1: QoS Metric, H_2: Energy-Aware, H_3: Location-aware, H_4: Scalability, and H_5: Service differentiation

At present, most online users are widely utilizing multimedia content for various reasons to ensure public and personal services. The multimedia content is transferred or distributed over different networks, i.e., ranging from classical wireless networks to IoT (Internet of Things). However, the deployment of the network has multiple reasons: ensuring high QoS and QoE with minimum latency reduction specific to traffic concerns. To tackle this challenging task, Bennis et al. [27] introduced a cross-layer protocol that handles the video transmission procession over WSN's. The proposed approach also cooperated with the application layer to frame an aware strategy for queuing policy that solves the various functions (i.e., enqueuing, dequeuing) to optimum latency reduction and enhances the video streaming quality. Asha and Mahadevan [28] adopted the exact cross-layer mechanism, which addressed QoS challenges in mobile networks for multimedia applications. To enhance the QoS for the mobile web, the authors proposed a combined approach that improves the network lifetime. This represents three objectives; network modeling, threshold-based packet transmission, and queuing model on physical-layer, which support the QoS.

Current cloud computing environment, multimedia transmission via IoT technology presents lots of challenges to nodes' diversity. Said et al. [29] explored adaptive real-time transport and control protocols over IoT environments. The experimental study considered the heterogeneous network for transmission, threshold value, and various multimedia sources. The primary intention was to split the scalable multimedia sessions into multiple sessions with network status awareness. The proposed technique can decrease network overload under critical traffic conditions. Also advantageous for an end-to-end delay, minimum packet loss, and energy consumption. Another research study by Huang et al. [30] focused on the concept of improving QoE over multimedia IoTs for network users. First, the author introduced a Quality-of-Experience (QoE) optimization mechanism for multimedia IoTs that leverages the data fusion technique. Initially, the proposed method involves two core phases; the data fusion model builds a QoE mapping among the un-controllable streaming data with controllable network system data. Then, another automatic QoE optimization model was designed to automatically adjust the network systems and achieve higher optimization results.

Multiple approaches have been proposed which ensures the energy trade-off for network performance [31][32]. However, the routing challenge has been considered a significant problem and needs to resolve to support future communication technologies. Therefore, in the context of work carried out by Khernane et al. [31], who have addressed the different routing problems based on a routing matrix. As a solution, a single selective routing protocol has been introduced. The solution strategy allows the end-to-end routing for each video sensor without any path discovery. Therefore, it is named as a change of dynamic network topology.

Another challengeable issue in the transmission process is the security because voluminous data content is quite impossible by conventional methods to encrypt the video content fully. Almasalha et al. [32] presented a scalable model for securing multimedia content on low energized mobile devices. The proposed technique is mainly applicable to the compressed video stream and will not require any decoding. The system encrypts 3% of packet load and offers equivalent security by doing bit-stream encryption. This phenomenon has experimented on laptops, desktops, notebooks, and mobile phones. Canovas et al. [33] have proposed a multimedia distribution system that delivers the video streams over the IP network. The proposed mechanism adopted a heuristic decision method and a probabilistic distribution system that provides the media streams among the service providers. Clients can upload and download the media files. The proposed approach takes into account energy conservation as well as enhances the QoE of end-users. However, the wireless multimedia transmission process contains multiple constraints and faces several problems: bit rate, storage problem, power consumption, bandwidth, and processing rate. Hassan et al. [34] explored an advanced multimedia compression technique that lacks such challenges, i.e., H.264 has been developed jointly with MPEG. The proposed compression standard offers multiple tunable parameters which tailor the video encoding operation as per the provisions. Additionally, the proposed framework to resolve the multi-objective problems achieved relevant results in bit-rate improvement, power consumption, and quality enhancement in multimedia content.

Due to wireless sensor technology's advanced improvement, sensor nodes can perform multimedia data processing, but the significant challenge is the real-time routing system over wireless multimedia networks [35]. Therefore, Ahmed et al. [35] introduced a real-time routing protocol for video streaming over next-generation wireless multimedia sensor networks. This study elaborates an algorithm to accomplish adaptive traffic shaping for video streaming. It exploits a multi-route forwarding approach with dynamic cost computation for a section of the next node. The author mainly focused on video streaming and real-time routing. Majeed et al. [36] have provided a comprehensive survey study on several problems in the art of information-centric networking systems and discussed respective architectures and literature concerning multimedia streaming.

Additionally, a roadmap is provided on the research community studying in a similar domain. Huang et al. [30] introduced analytical modeling for multimedia data flow scheduling systems over SDNs (software-defined networks). This study author presented a hybrid data flow scheduling system by integrating priority-based queuing packets and offering QoS for multimedia applications in SDN. Several researchers provided different multimedia transmission methods. Some of them addressed multimedia transmission over VANETs. For example, Xu et al. [37] have explored an information-centric networking model that delivers multimedia content over mobile vehicular networks. The proposed mechanism implements two significant factors, data mobility, and provider supply-demand balance. They also formulated an optimized mixed-integer programming module that is cost-effective concerning QoS multimedia. In another research study, author Moussaoui et al. [38] have adopted VANETs technology to implement cost-free and efficient multimedia content sharing among the two vehicles and their passengers. In this study, the authors proposed an improved cross-layer protocol that deals with routing challenges over VANETs. Yang et al. [39] have presented a movie recommendation model based on user scores. From the viewpoint of the movie formulation system, the level of access control & media security are analyzed, along with cloud storage security architecture was implemented. The primary objective is to ensure the safety of multimedia content during the data transmission process. Dien et al. [40] have presented cross-layer architecture to implement a security-based routing protocol for multimedia transmission on the wireless sensor network. The primary focus was on energy consumption during packet transmission and path scheduling. The authors concluded that the proposed framework is suitable for enhancing real-time video quality and prolonging the network performance from the implementation results.

Rapid advancement in wireless technology infrastructure and smart devices, video streaming like cloud gaming, live sports watching, YouTube video uploading and downloading, etc., has dominated the harmful applications over the web. With the increasing rate in emerging multimedia applications, providing a better quality of video services (e.g., YouTube and many more) provides multimedia streaming up to sixty frames in a second. Therefore, Wu et al. [41] mainly focused on real-time video transmission problems on mobile devices like the example video conferencing or calls, video games, etc. hence, nowadays, it is becoming a highly challenging issue for the service providers to provide and ensures about high-quality content delivery as well as high-quality video streaming. For that purpose, the authors proposed a frame scheduling and error resilience model for mobile devices over heterogeneous wireless networks. Hameed et al. [42] have introduced an energy-efficient video quality prediction model for wireless communications. The entire work mainly consists of two components: real-time video quality with low complexity. Another is the content and energy-aware model to balance the video quality during packet transmission over the network. The authors showed that the proposed prediction model achieves ~ 90% accuracy, and as compared to conventional techniques, the proposed communication model reduces the network overhead by 41%. With the growth of new generation networks and communication technologies, video services are becoming pervasive for large-scale heterogeneous wireless networks. More and more uploading, downloading, and accessing video information with the help of various devices (PCs, tablets, smart TVs, smartphones, etc.) is becoming very common for all users. Offering heterogeneity with QoE, which supports a wide range of multiple multimedia devices, is crucial and challenging to broadcast the video over new generation wireless networks. Chen et al. [43] have reviewed different existing video broadcasting technologies and founds present requirements ranging from homogeneous to heterogeneous transmission network technologies. Also presented is a typical modeling approach for video broadcasting with large-scale heterogeneous network support that enables QoE, joint coding, cross-layer transmission, optimal and dynamic adaptation to enhances the receiving quality of heterogeneous devices.

One of the challenging factors for digital media transmission over multimedia WSN is the spectrum scarcity with high radio interference in the current digital world. In that context, Bradai et al. [44] proposed a solution mechanism for multimedia transmission over multimedia WSNs which exploit radio interferences for spectrum scarcity and clustering method for energy efficiency. Also highlighted significant issues and challenges of multimedia WSNs, i.e., high bandwidth requirements, energy efficiency, QoS, data processing cross-layer routing issues, and compressing techniques. On the other hand, Gur [45] has mainly focused on QoE and QoS requirements over multimedia applications or services deployed over mobile networks. Also defined the network performance parameters utilized to balance the service performance like; throughput, latency, packet loss, reliability, and availability. Han et al. [46] have investigated the new concept of a fast directional hand-off mechanism that helps to enhance or improves the quality of multimedia over WSN. Also introduced is a lightweight retransmission protocol that reduces the packet loss on WiFi without generating any acknowledgment. The proposed mechanisms can be applied on android based smart devices, and their performance has been evaluated in the indoor wireless LAN environment. The experiment results demonstrated that the proposed mechanism balances the seamless quality for video streaming under hand-off operation. Some studies have analyzed the challenges facing multimedia transmission in the IoT environment. Alvie et al. [47] have introduced a novel of the internet of multimedia things where smart multimedia devices can cooperate and interact with each other and connect with the internet to provide multimedia-based services to global users. Jiang and Meng [48] have designed an IoT-based multimedia platform that improves real-time multimedia transmission protocol quality. The following Table II highlights a summary of the existing multimedia transmission techniques that different authors have proposed.

TABLE II. SUMMARY OF THE PRIOR RESEARCH STUDY TOWARDS MULTIMEDIA TRANSMISSION TECHNIQUES

Author	Problem	Technique	Application	Performance
Bennis,[27]	To ensure better QoE with Low latency for multimedia transmission	Cross-layer scheme	Enhance the video quality and reliability	Bit-rate, delay, and packet loss rate.
Asha et al.[28]	Improve the QoS for mobile applications	Channel modeling	Able to select the transmission channel through the threshold. Less resource utilization	Throughput, bandwidth, delay
Said et al. [29]	Multimedia Transmission over IoT environment	RTP/RTCP protocols	End to end delay, minimum energy consumption	Delay jitter, packet loss, throughput.
Huang et al. [30]	Increase QoE in multimedia IoT	Machine learning	Optimize the QoE by adjusting network parameters, automatic bandwidth allocation	Comparative analysis with different topologies
Khernane et al. [31]	To improve network performance	Video encoding method	It consumes less amount energy and increases the network lifetime	Energy cost, network lifetime.
Almasalha et al. [32]	Secure media streaming technique for low energized mobile nodes	Selective encryption method, RTP protocol	It is suitable for laptop, desktop, tablet, and Nokia N-series platform	Speed and streaming rate
Canovas et al.[33]	To ensure high quality of experience for IP multimedia with minimum resource allocation	Heuristic and probability distribution model	Can upload multimedia files with high speed	Delay jitter, packet loss, and energy consumption
Hassan et al.[34]	To achieve a high bit rate for H.264 encoding	joint parameter cost-function	Maintain good video quality with low energy consumption	Bit-rate, PSNR, processing delay
Ahmad et al. [35]	Real-time data routing for media streaming	Dynamic routing mechanism for wireless multimedia applications	The packet can switch from single path to multi-path, balance the traffic load	Limited bandwidth, minimum processing power
Majeeb et al. [36]	Multicast delivery, security, QoS, and mobility	Information-centric networking mechanism	Multimedia streaming	Comparative analysis with existing methods.
Xu et al. [37]	Provide high-quality media streaming with a minimum cost of mobile vehicular networks	Information-centric networking mechanism	Reduce the economic cost, caching enhancement, and less resource utilization	Delay, jitter, QoE, playback continuity.
Moussaoui et al. [38]	Multimedia Data Dissemination over VANET's	Cross-Layer technique	Maintain the road traffic, mitigate traffic congestion and reduce air pollution	Decrease the packet control overhead.
Yang et al. [39]	To ensure multimedia security and access control	Hybrid cloud storage security model	Mitigates the attacks	Downloading time Vs. user request
Din et al. [40]	To improve the QoS for multimedia applications	Cross-layer approach, packet, and route scheduling algorithm	Can improve the network lifetime through packet scheduling	Loss ratio Vs. Lost frames, Energy usage per nodes
Wu et al. [41]	To achieve high-quality video frames via mobile devices	Frame scheduling approach	Can reduce the intraframe probability, outperformance w.r.t video transmission	End to end delay Vs. overdue frames
Hameed et al. [42]	Maintain the video quality with good QoE	Decision tree-based QoE support model	Predict the high quality of real-time video content with minimum complexity	Prediction accuracy about ¬ 90%, Network overhead by an average of 41%
Chen et al. [43]	Large video streaming with QoE over large-scale heterogeneous networks	Video broadcasting method, experimental analysis	Can improve the QoE of heterogeneous devices	PSNR, PSPNR, and SSIM
Bradri et al. [44]	Multimedia Transmission in an urban area using wireless multimedia sensor network	Cognitive radio spectrum technique, the clustering approach	Perform high video quality, minor transmission delay, less frame loss ratio	PSNR Vs. several channels and several media sources.
Gur et al. [45]	Multimedia transmission over WSN	Theoretical analysis	real-time communications	Comparative study between existing methods
Han et al. [46]	To provide high-quality services with minimum packet loss.	Hand-off mechanism, the retransmission protocol	Minimizes the packet loss ratio using WiFi, implemented over Android platform applications	The rate of packet loss during the hand-off process
Alvie et al. [47]	Multimedia streaming over IoT environment	Theoretical approach	Heterogeneous intelligent devices can interact and cooperate	NA
Jiang et al. [48]	Real-time multimedia streaming over IoT	Efficient communication protocol (i.e., UDP & TCP) is called control over UDP.	Rate control and retransmission	The result was calculated in terms of PSNR.

IV. Multimedia Compression Standards

Multimedia compression is a technique that transmits the media content over a wired or wireless channel by encoding digital video content. The compression for media content transmission offers multiple benefits like fewer storage requirements and minimum bandwidth requirements. The compression technique typically involves deletion of information not considered critical to viewing the video content and a good video codec technique that provides multiple benefits mentioned above: without significant degradation in the visual content experience, post-compression, and without requiring significant hardware overhead achieve the compression. Even within a particular video compression technique, different levels of compression standards can be applied. Hence, the more aggressive compression, high storage space and transmission bandwidth efficiency, and the higher computing power required. However, ISO/IEC and ITU-T are the influential international organizations that classified the multimedia compression standards into two major categories; i.e., ISO/IEC includes MPEG standards like MPEG-1, 2, 3, 4, MPEG-4(AVC), and Motion-JPEG [49]. At the same time, ITU-T has H.26x series standards, viz. H.261, H.263, H.264, and H.265 (HEVC) [50].

Most video retailers utilize few standard compression techniques (i.e., M-JPEG, MPEG-4, and H.264). However, such standards techniques are mainly relevant to video compression since video can be used for several purposes, such as video surveillance. Therefore, this section has briefly discussed work in state of the art in standard video compression techniques. Additionally, Fig. 1 illustrates the media transmission process at a different layer of the IOS model. Motion-JPEG: M-JPEG is a digital video sequence that contains a series of JPEG images. An image in the video file has equal quality determined from the compression level selected for the video encoder. The high compression level lowers the video file size as well as quality. Some image files require more bandwidth and memory during the compression process since the file size is more significant. Thus, to prevent more storage and bandwidth requirements, video retailers allow the users to set up the file size range for the image frame. The higher quality video content requires additional bandwidth and more storage for file transmission. The mezzanine image compression technique reduces the file transmission capacity and provides higher resolution with high-quality video content [51].

Additionally, the authors introduced a term called JPEG-XS which addressed the requirement for interoperable video over IP. In another research study, Willeme et al. [52] adopted a similar approach to JPEG-XS for image buffer compression. The proposed research aims to reduce the frame buffers' bandwidth and make HEVC more reliable for energy-aware applications.

Moving Pictures Experts Group (i.e., MPEG) is the traditional video compression technique that can compress the media contents like images and audio and combine both files. Several MPEG compression standards are currently available, i.e., MPEG-1, 2, 3, and MPEG-4. All MPEG versions have their features concerning the data rates variation. For example MPEG-1 intended for intermediate data-rates (i.e. 1.5 Mbit/sec), whereas MPEG-4 intended for very less data rates (i.e. <64 KB/sec). The study of Hameed et al. [53] has introduced a decision-tree-based media quality prediction model using the MPEG-4 compression standard. This technique extracts frames from the compressed bit-streams and predicts the video quality based on resultant features. The proposed model provides high video quality content with low complexity.

Meanwhile, Seethram et al. [54] investigated a scheduling algorithm to deliver a multimedia stream from the server to mobile users. Also introduced is an epoch-by-epoch model which allocates the transmission slots for video streaming. The experimental results were validated by applying the MPEG-4 compression technique and trace the wireless channel.

3G mobile video services were widely based on MPEG-4 and H.263 compression standards. Still, from the recent advancement in wireless transmission technology, almost all video service providers exclusively utilize the H.264 media transmission technique, providing a better video streaming quality. Thus, nowadays, all mobile operators are widely exploiting efficient video streaming applications for multimedia broadcasting. Several researchers have introduced multiple approaches that intended the different features with different H.264/AVC compression standards. For example, Hassan et al. [55] have introduced advanced video compression techniques (i.e., improved H.264) to overcome wireless networks' bit rate overhead challenge. Authors developed video compression standards jointly, i.e., H.264/MPEG-4, which reduces the cost function and maintains good video quality without performing compression. Many researchers developed the H.264/AVC compression technique [56]-[59] to reduce and delete the redundant media content such that compressed video files can be successfully transmitted over the wireless network. However, the significant challenge of any technique is to reduce the content size and provide high visual quality without any packet loss. Therefore, Chang et al. [56] presented a multi-pooling control access scheme that ensures low latency during the transmission of video frames and reduces transmission overhead. At the same time, Wu et al. [57] presented a video frame scheduling mechanism that reduces the total distortion. The result performance can be evaluated in terms of analyzing video PSNR values.

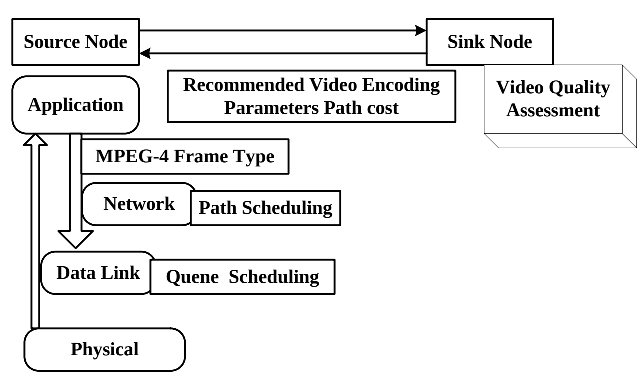

Fig. 1. Multimedia Transmission Process at different Layers.

V. Research Gap

Despite continuous progress and usage of multimedia content quality assessment, some challenges are addressed to some extent. Therefore, this section has discussed some significant research challenges in multimedia transmission over wireless networks.

- Media specific QoE demands: Generally, a multimedia file contains different types of media with other characteristics. For example, real-time video streaming, i.e., video, audio, or audio-visual, is delay-sensitive and error-resilient. On the other hand, non-real-time media files, i.e., web data, have minor delays but need an end-to-end transmission. Hence, due to the scalability in multimedia encoding technologies, different media content is essential for their users QoE. At present, there is no generalized scheme to offer benchmarked QoE for multimedia transmission over a wireless network.

- The trade-off between improvements in the physical layer and network technologies: Due to the greater demand for higher quality multimedia content, there is a provision to improve the network efficiency with available bandwidth. In this context, the role of media compression remains of core importance, ensuring that media transmission at a particular layer with appropriate quality while staying compatible with available bandwidth over the transmission channel. Furthermore, in the context of the growing requirement of multimedia streaming at higher QoS and QoE, there is a provision to introduce a transformational mechanism to solve the media compression problems and perform well beyond the conventional coding standards. Hence, more advancement in network technologies and lower supportability by its physical medium are translated. This demands more computational modeling.

- Less Efficient network coding for successful transmission: The massive requirement for multimedia streaming from the receiver devices to wireless channels faces multiple difficulties in which the bandwidth demand is limited. The efficient network coding allows the content transmitted over the network to be improved compared to conventional routing systems. However, there are several theoretical approaches have been introduced to assess the network capacity. For example, Zhang et al. [60] presented a physical layer network coding scheme for wireless transmission intending to improve the network performance with a high degree of freedom for media transmission. However, implementing a physical network coding system faces multiple practical problems that need to be solved, such as bandwidth issues, spectral efficiency, etc.

- High Media Content Loss Rate and Bit Error Rate: In wired transmission, there are more chances of content loss caused by the congestion of intermediator nodes. Meanwhile, wireless networks have a high bit error rate owing to multi-path fading and interference. The increasing packet loss rate or content loss and the bit error rate can directly affect media quality. Hence, there is a need to discover a reliable routing protocol to improve media quality with minimum loss.

- Energy Consumption Rate: As compared with fixed devices, there is good battery life in mobile devices. Usually, maintaining a media quality with minimum power consumption, i.e., transmitting and processing media content on mobile devices, are conflicting tasks. These trade-offs are valid, especially for wireless networks, i.e., wireless multimedia sensor networks. From the viewpoint of media coding, generating high-quality multimedia content usually consumes high power processing. Meanwhile, from the perspective of network performance, interference and multi-path fading require high transmission energy. So that, there is a need to design a reliable network that performs multimedia transmission with a minimum power consumption rate.

- Inadequacies of transport layer protocols performance: The existing transport layer protocol analyzes the primary reason behind the packet loss: congestion and unusual delay in the network. These two factors, i.e., packet loss and delay rate, affect the transmission process and media quality. However, in the wireless communication system, packet loss may occur due to network errors. Therefore, a QoS and transmission viewpoint should focus on designing a reliable transport protocol because the transmission process mainly occurs at the transport layer.

- Heterogeneity between the receivers and networks: The end-user is in the multimedia transmission process is quite different in QoS requirements, latency reduction, power consumption, processing capabilities, bandwidth demand, etc. Additionally, multimedia may deliver to varying networks with non-similar characteristics (i.e., delay, jitter, reliability, many more) and MAC (medium access control) mechanism.

- Lack of performance in the video compression standard: Existing multimedia transmission standards do not emphasize the signal quality, and the techniques lack a decision mechanism to perform compression. Moreover, existing methods do not ensure the perceptual quality of the multimedia framework to support higher pixel resolution. Although used more frequently in current times, HEVC is a new protocol; currently, no standard and potential studies exist in literature archival to further improve it. Very few works were found to adopt HEVC on a wireless mobile networking platform to check the efficiency of the HEVC algorithm and its potential to mitigate the loading impact of a dynamic traffic system (especially in a wireless environment).

Discussion: Apart from the points mentioned above, Table III highlights the contribution of the proposed survey work with some of the existing survey work. It is seen that existing review papers do not possess discussion of the research gap. At the same time, their emphasis is particular, while the proposed study intends to offer a clear discussion about research challenges and contributes towards a simplified debate on the strength/weaknesses of related work.

TABLE III. COMPARISON WITH EXISTING REVIEW WORK

	Research Gap	Emphasis
Proposed Manuscript	Yes	Strength & weakness of existing schemes
Pal et al. [61]	No	Application
Wang et al. [62]	No	Mobile internet
Barakabitze et al. [63]	No	Quality of experience

The review findings show that multiple aspects can be classified into two parts, viz. i) standard protocol for wireless transmission and ii) research-based protocol for wireless transmission. There is a significant trade-off between this two. The first standard methods are meant for the theoretical formulation of transmission, while the second research part is particular and narrowed in its applicability process. Hence, not much higher scope is witnessed in the existing system. The existing literature is found with highly scattered technique implementation where multiple methods have been used to improve the performance. However, apart from this, a potential research gap exists, which requires immediate attention for future research work.

VI. CONCLUSION

The extreme growth in the various wireless communication technologies, the convergences of standard protocols, availability of small-sized hardware devices, software tools, and collaborative frameworks have paved a solid basis to visualizing real-time multimedia content, including; audio, video, and audio-visual applications in future endeavors. Furthermore, the advancement in the emerging wireless network technologies (i.e., 4G/5G) leads to having many multimedia-based new applications in the direction of augmented reality. However, order to perform transmission of multimedia content over the wireless channel is always a challenging factor. Various studies have focused on multimedia contents transmission over wireless sensor networks, mobile ad-hoc networks, using IEEE standard, etc. However, the mechanism adopted mainly applies conventional encoding techniques evolved from conventional discrete cosine transform, which does not hold much validity in upcoming encoders, e.g., HEVC (High-Efficiency Video Coding) standards. Therefore, from the comprehensive research study, there is a provision to investigate the better and reliable multimedia transmission proclaiming for wireless channels. The contribution of the present research study is to provide a dept investigational research study on understanding different existing techniques, challenges over multimedia transmission, and its significant impact on perceptual quality and traffic rate in wireless communication. The novelty of the study is in terms of its findings as research gap, i.e., i) The trade-off between improvements in the physical layer and network technologies, ii) Less Efficient network coding for successful transmission, iii) High Media Content Loss Rate and Bit Error Rate, iv) Energy Consumption Rate, v) Inadequacies of transport layer protocols performance, vi) Heterogeneity between the receivers and networks, vii) Lack of performance in the video compression standard.

Therefore, for the future, there is an aim to develop a multimedia transmission model that can perform seamless transmission of multimedia content irrespective of any adverse traffic conditions. Additionally, there is a need to design a novel and efficient compression mechanism using H.265 for next-generation wireless networks.

REFERENCES

[1] D. Striccoli, G. Piro and G. Boggia, "Multicast and Broadcast Services Over Mobile Networks: A Survey on Standardized Approaches and Scientific Outcomes," in IEEE Communications Surveys & Tutorials, vol. 21, no. 2, pp. 1020-1063, Second quarter 2019, doi: 10.1109/COMST.2018.2880591.

[2] P. Lestari, S. Niyas and D. Krisnandi, "Depth Data based Chroma Keying using Grab-cut Segmentation," 2018 International Conference on Computer, Control, Informatics and its Applications (IC3INA), 2018, pp. 118-123, doi: 10.1109/IC3INA.2018.8629501.

[3] A. Nauman, Y. A. Qadri, M. Amjad, Y. B. Zikria, M. K. Afzal and S. W. Kim, "Multimedia Internet of Things: A Comprehensive Survey," in IEEE Access, vol. 8, pp. 8202-8250, 2020, doi: 10.1109/ACCESS.2020.2964280.

[4] N. Minallah, I. Ahmed, M. Ijaz, A. S. Khan, L. Hasan, and A. Rehma, "On the Performance of Self-Concatenated Coding for Wireless Mobile Video Transmission Using DSTS-SP-Assisted Smart Antenna System", Hindawi-Wireless Communication and Mobile Computing, 2021.

[5] Kütner, Thomas. "Turning THz Communications into Reality: Status on Technology, Standardization, and Regulation." In 2018 43rd International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), pp. 1-3. IEEE, 2018.

[6] M. C. Caballé, A. C. Augé, E. Lopez-Aguilera, E. Garcia-Villegas, I. Demirkol, and J. P. Aspas, "An Alternative to IEEE 802.11ba: Wake-Up Radio With Legacy IEEE 802.11 Transmitters," in IEEE Access, vol. 7, pp. 48068-48086, 2019, doi: 10.1109/ACCESS.2019.2909847.

[7] M. Jia, W. Liang, Z. Xu, M. Huang, and Y. Ma, "QoS-Aware Cloudlet Load Balancing in Wireless Metropolitan Area Networks," in IEEE Transactions on Cloud Computing, vol. 8, no. 2, pp. 623-634, 1 April-June 2020, doi: 10.1109/TCC.2017.2786738.

[8] Santos, Raul Aquino, ed. Broadband Wireless Access Networks for 4G: Theory, Application, and Experimentation: Theory, Application, and Experimentation. IGI Global, 2013.

[9] Huan Chen, Lei Huang, Sunil Kumar, C.C. Jay Kuo, Radio Resource Management for Multimedia QoS Support in Wireless Networks, Springer Science & Business Media, pp. 256, 2012.

[10] Su, Guan-Ming, Xiao Su, Yan Bai, Mea Wang, Athanasios V. Vasilakos, and Haohong Wang. "QoE in video streaming over wireless networks: perspectives and research challenges." Wireless networks 22, no. 5 (2016): 1571-1593.

[11] Hasan, Mohammed Zaki, Hussain Al-Rizzo, and Fadi Al-Turjman. "A survey on multi-path routing protocols for QoS assurances in real-time wireless multimedia sensor networks." IEEE Communications Surveys & Tutorials 19, no. 3 (2017): 1424-1456.

[12] Stokking, Hans Maarten, Mattijs Oskar Van Deventer, Fabian Arthur Walraven, and Omar Aziz Niamut. "Method and system for transmitting a multimedia stream." U.S. Patent 9,654,330, issued May 16, 2017.

[13] Kua, Jonathan, Grenville Armitage, and Philip Branch. "A survey of rate adaptation techniques for dynamic adaptive streaming over HTTP." IEEE Communications Surveys & Tutorials 19, no. 3 (2017): 1842-1866.

[14] Robert, Antoine, Omar Alvarez, and Gwenaël Doërr. "Adjusting bit-stream video watermarking systems to cope with HTTP adaptive streaming transmission." In Acoustics, Speech and Signal Processing (ICASSP), 2014 IEEE International Conference on, pp. 7416-7419. IEEE, 2014.

[15] Chan, K. M., and Jack YB Lee. "Improving adaptive HTTP streaming performance with predictive transmission and cross-layer client buffer estimation." Multimedia Tools and Applications 75, no. 10 (2016): 5917-5937.

[16] Lim, Seong Yong, Joo Myoung Seok, Jeongil Seo, and Tag Gon Kim. "Tiled panoramic video transmission system based on MPEG-DASH." In Information and Communication Technology Convergence (ICTC), 2015 International Conference on, pp. 719-721. IEEE, 2015.

[17] Z. Li, M. Miao and Z. Wang, "Parallel Coding Scheme With Turbo Product Code for Mobile Multimedia Transmission in MIMO-FBMC System," in IEEE Access, vol. 8, pp. 3772-3780, 2020, doi: 10.1109/ACCESS.2019.2958482.

[18] Y. Xiao, G. Niu, L. Xiao, Y. Ding, S. Liu and Y. Fan, "Reinforcement learning-based energy-efficient internet-of-things video transmission," in Intelligent and Converged Networks, vol. 1, no. 3, pp. 258-270, Dec. 2020, doi: 10.23919/ICN.2020.0021.

[19] V. K. Ta and H. Oh, "A Pipelined Cooperative Transmission Protocol for Fast and Reliable Image Delivery in Wireless Sensor Networks," in IEEE Access, vol. 8, pp. 142758-142771, 2020, doi: 10.1109/ACCESS.2020.3013738.

[20] X. -L. Huang, Y. -X. Li, Y. Gao and X. -W. Tang, "Q-Learning-Based Spectrum Access for Multimedia Transmission Over Cognitive Radio Networks," in IEEE Transactions on Cognitive Communications and Networking, vol. 7, no. 1, pp. 110-119, March 2021, doi: 10.1109/TCCN.2020.3027297.

[21] F. Liu, Y. Liu, Y. Liu, and J. Yu, "Secure Beamforming in Full-Duplex Two-Way Relay Networks With SWIPT for Multimedia Transmission," in IEEE Access, vol. 8, pp. 26851-26862, 2020, doi: 10.1109/ACCESS.2020.2970612.

[22] T. He, J. Stankovic, C. Lu, T. Abdelzaher, SPEED: a stateless protocol for real-time communication in sensor networks, in Proc. IEEE International Conf. Distributed Computing Systems, 2003, pp. 46–55.

[23] K. Akkaya, M. Younis, Energy and QoS aware routing in wireless sensor networks, Cluster Comput. 8 (2–3) (2005) 179–188.

[24] E. Felemban, C. Lee, E. Ekici, MMSPEED: multi-path multi-SPEED protocol for QoS guarantee of reliability and timeliness in wireless sensor networks, IEEE Trans. Mobile Commun. 5 (2006) 738–754.

[25] S. Sanati, M.H. Yaghmaee, A. Beheshti, Energy-aware multi-path and multi-speed routing protocol in wireless sensor networks, in Proc. of 14th International CSI, CSICC 2009, Tahran, December 2009, pp. 640–645.

[26] S. Darabi, N. Yazdani, O. Fatemi, Multimedia-aware MMSPEED: a routing solution for video transmission in WMSN, in Proc. of 2nd International Symposium on Advanced Networks and Telecommunication Systems, Mumbai, India, December 2008, pp.1–3.

[27] Bennis, Ismail, Hacène Fouchal, Kandaraj Piamrat, and Marwane Ayaida. "Efficient queuing scheme through cross-layer approach for multimedia transmission over WSNs." Computer Networks 134 (2018): 272-282.

[28] Mahadevan, G. "A combined scheme of video packet transmission to improve cross-layer to support QoS for MANET." Alexandria engineering journal 57, no. 3 (2018): 1501-1508.

[29] Said Omar, Yasser Albagory, Mostafa Nofal, and Fahad Al Raddady. "IoT-RTP and IoT-RTCP: adaptive protocols for multimedia transmission over the internet of things environments." IEEE Access 5, no. 16 (2017): 757-16.

[30] Huang, Xiaohong, Kun Xie, Supeng Leng, Tingting Yuan, and Maode Ma. "Improving Quality of Experience in multimedia Internet of Things leveraging machine learning on big data." Future Generation Computer Systems 86 (2018): 1413-1423.

[31] Khernane, Nesrine, Jean-François Couchot, and Ahmed Mostefaoui. "Maximum network lifetime with optimal power/rate and routing trade-off for Wireless Multimedia Sensor Networks." Computer Communications 124 (2018): 1-16.

[32] Almasalha, Fadi, Farid Naït-Abdesselam, Goce Trajcevski, and Ashfaq Khokhar. "Secure transmission of multimedia contents over low-power mobile devices." Journal of information security and applications 40 (2018): 183-192.

[33] Cánovas, Alejandro, Miran Taha, Jaime Lloret, and Jesús Tomás. "Smart resource allocation for improving QoE in IP Multimedia Subsystems." Journal of Network and Computer Applications 104 (2018): 107-116.

[34] Hassan, Hammad, Muhammad Nasir Khan, Syed Omer Gilani, Mohsin Jamil, Hasan Maqbool, Abdul Waheed Malik, and Ishtiaq Ahmad. "H. 264 Encoder Parameter Optimization for Encoded Wireless Multimedia Transmissions." IEEE Access 6 (2018): 22046-22053.

[35] Ahmed, Adel A. "A real-time routing protocol with adaptive traffic shaping for multimedia streaming over next-generation of Wireless Multimedia Sensor Networks." Pervasive and Mobile Computing 40 (2017): 495-511.

[36] Majeed, Muhammad Faran, Syed Hassan Ahmed, Siraj Muhammad, Houbing Song, and Danda B. Rawat. "Multimedia streaming in information-centric networking: A survey and future perspectives." Computer Networks 125 (2017): 103-121.

[37] Xu, Changqiao, Wei Quan, Athanasios V. Vasilakos, Hongke Zhang, and Gabriel-Miro Muntean. "Information-centric cost-efficient optimization for multimedia content delivery in mobile vehicular networks." Computer Communications 99 (2017): 93-106.

[38] Moussaoui, Boubakeur, Soufiene Djahel, Mohamed Smati, and John Murphy. "A cross layer approach for efficient multimedia data dissemination in VANETs." Vehicular Communications 9 (2017): 127-134.

[39] Yang, Jiachen, Huanling Wang, Zhihan Lv, Wei Wei, Houbing Song, Melike Erol-Kantarci, Burak Kantarci, and Shudong He. "Multimedia recommendation and transmission system based on cloud platform." Future Generation Computer Systems 70 (2017): 94-103.

[40] Mohammed Ezz El Dien, Aliaa AA Youssif and Atef Zaki Ghalwash, "Energy-Aware Cross-Layer Framework for Multimedia Transmission over Wireless Sensor Networks", International Journal of Sensor Networks and Data Communications, Vo. 5(1), 2016

[41] Wu, Jiyan, Bo Cheng, Ming Wang, and Junliang Chen. "Delivering high-frame-rate video to mobile devices in heterogeneous wireless networks." IEEE Transactions on Communications 64, no. 11 (2016): 4800-4816.

[42] Hameed, Abdul, Rui Dai, and Benjamin Balas. "A decision-tree-based perceptual video quality prediction model and its application in FEC for wireless multimedia communications." IEEE Transactions on Multimedia 18, no. 4 (2016): 764-774.

[43] Chen, Bo-Wei, Wen Ji, Feng Jiang, and Seungmin Rho. "QoE-Enabled Big Video Streaming for Large-Scale Heterogeneous Clients and Networks in Smart Cities." IEEE Access 4 (2016): 97-107.

[44] Bradai, Abbas, Kamal Singh, Abderrezak Rachedi, and Toufik Ahmed. "EMCOS: Energy-efficient mechanism for multimedia streaming over cognitive radio sensor networks." Pervasive and Mobile Computing 22 (2015): 16-32.

[45] Gür, Gürkan. "Multimedia transmission over wireless networks fundamentals and key challenges." In Modeling and Simulation of Computer Networks and Systems, pp. 717-750. 2015.

[46] Han, Sangyup, Myungchul Kim, Ben Lee, and Sungwon Kang. "Fast Directional Hand-off and lightweight retransmission protocol for enhancing multimedia quality in indoor WLANs." Computer Networks 79 (2015): 133-147.

[47] Alvi, Sheeraz A., Bilal Afzal, Ghalib A. Shah, Luigi Atzori, and Waqar Mahmood. "Internet of multimedia things: Vision and challenges." Ad Hoc Networks 33 (2015): 87-111.

[48] Jiang, Wei, and Limin Meng. "IOT real-time multimedia transmission over CoUDP." International Journal of Digital Content Technology and its Applications 7, no. 6 (2013): 19.

[49] Mohammed, Anthony Olufemi Tesimi Adeyemi-Ejeye, Abdulrahman Alreshoodi, Geza Koczian Michael C. Parker, and Stuart D. Walker. "Ultra-High-Definition Video Transmission for Mission-Critical Communication Systems Applications." Multimedia Services and Applications in Mission Critical Communication Systems (2017): 115.

[50] Rao, K. R., Do Nyeon Kim, and Jae Jeong Hwang. "Video coding standards." The Netherlands: Springer (2014): 51-97.

[51] Richter, Thomas, Joachim Keinert, Siegfried Foessel, Antonin Descampe, Gaël Rouvroy, and Jean-Baptiste Lorent. "JPEG-XS—A

High-Quality Mezzanine Image Codec for Video Over IP." SMPTE Motion Imaging Journal 127, no. 9 (2018): 39-49.

[52] Willème, Alexandre, Benoit Macq, Antonin Descampe, and Gaël Rouvroy. "Power-Aware HEVC Compression Through Asymmetric JPEG XS Frame Buffer Compression." In 2018 25th IEEE International Conference on Image Processing (ICIP), pp. 3598-3602. IEEE, 2018.

[53] Hameed, Abdul, Rui Dai, and Benjamin Balas. "A decision-tree-based perceptual video quality prediction model and its application in FEC for wireless multimedia communications." IEEE Transactions on Multimedia 18, no. 4 (2016): 764-774.

[54] Seetharam, Anand, Partha Dutta, Vijay Arya, Jim Kurose, Malolan Chetlur, and Shivkumar Kalyanaraman. "On managing quality of experience of multiple video streams in wireless networks." IEEE Transactions on Mobile Computing 3 (2015): 619-631.

[55] Hassan, Hammad, Muhammad Nasir Khan, Syed Omer Gilani, Mohsin Jamil, Hasan Maqbool, Abdul Waheed Malik, and Ishtiaq Ahmad. "H. 264 Encoder Parameter Optimization for Encoded Wireless Multimedia Transmissions." IEEE Access 6 (2018): 22046-22053.

[56] Chang, Che-Yu, Hsu-Chun Yen, Chun-Cheng Lin, and Der-Jiunn Deng. "QoS/QoE support for H. 264/AVC video stream in IEEE 802.11 ac WLANs." IEEE Systems Journal 11, no. 4 (2017): 2546-2555.

[57] Wu, Jiyan, Bo Cheng, Ming Wang, and Junliang Chen. "Delivering high-frame-rate video to mobile devices in heterogeneous wireless networks." IEEE Transactions on Communications 64, no. 11 (2016): 4800-4816.

[58] Khalek, Amin Abdel, Constantine Caramanis, and Robert W. Heath Jr. "Loss Visibility Optimized Real-Time Video Transmission Over MIMO Systems." IEEE Trans. Multimedia 17, no. 10 (2015): 1802-1817.

[59] de Miranda Regis, Carlos Danilo, Italo de Pontes Oliveira, Jose Vinicius de Miranda Cardoso, and Marcelo Sampaio de Alencar. "Design of objective video quality metrics using spatial and temporal informations." IEEE Latin America Transactions 13, no. 3 (2015): 790-795.

[60] S. Zhang, S. C. Liew, and P. P. Lam, "Hot topic: Physical-layer network coding," in Proc. 12th Annual Int. Con! Mobile Computing and Networking (MobiCom '06). New York, NY. USA: ACM, 2006. pp. 358-365

[61] Pal, Kunwar, Mahesh Chandra Govil, Mushtaq Ahmed, and Tanvi Chawla. "A Survey on Adaptive Multimedia Streaming." In *Recent Trends in Communication Networks*. IntechOpen, 2019.

[62] Wang, Mu, Changqiao Xu, Shijie Jia, and Gabriel-Miro Muntean. "Video streaming distribution over mobile Internet: a survey." *Frontiers Comput. Sci.* 12, no. 6 (2018): 1039-1059.

[63] A. A. Barakabitze et al., "QoE Management of Multimedia Streaming Services in Future Networks: A Tutorial and Survey," in IEEE Communications Surveys & Tutorials, vol. 22, no. 1, pp. 526-565, Firstquarter 2020, doi: 10.1109/COMST.2019.2958784.