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Analysis of Video Transmission Over 4G Network Using Wi-Max and High Efficiency Video Coding

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Abstract-: This paper examines the performance of video transmission over 4G networks, which are witnessing a surge in demand. High Efficiency Video Coding (HEVC) also known as H.265 and MPEG-H Part 2, is a draft video compression standard, a successor to H.264/MPEG-4 AVC (Advanced Video Coding), currently under joint development by the ISO/IEC Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG). MPEG and VCEG have established a Joint Collaborative Team on Video Coding (JCT-VC) to develop the HEVC standard. The main motivation behind the HEVC is to improve video quality and double the data compression ratio compared to H.264. Wi-Max is engineered to cover Metropolitan Area Networks (MAN), aiming for a range of approximately 50 kilometres with speeds exceeding 1 Gbps, accommodating a large number of users. It is required to support HD quality video and other data traffic simultaneously for all users. Therefore, video compression is essential to deliver HD quality video at lower data rates. This paper concentrates on transmitting high-quality video over 4G networks while minimizing data rates. Wi-Max is design to serve over MAN, targeting approximately 50KM range with the approximately speed more than 1 Gbps with large number of users. It must support the HD quality video and all other data traffic at the same time to all users. Hence, the video must be compressed in such a way that HD quality video should be passed at lower data rate. This paper is focused on transmitting high quality video over the 4G Network with low data rate.

Key Words: HEVC, HEVC Encoder, HEVC Decoder, 4G Wireless Networks, WIMAX-OFDMA, HD quality.

1. INTRODUCTION

WiMAX is referred to as Worldwide Interoperability for Microwave Access. The IEEE 802.16 group's wireless Metropolitan Area Network (MAN) specifications serve as the foundation for WiMAX. It functions in the 2-11-GHz and 10- 66-GHz licensed exempt and licensed spectrums, respectively [1].It was created to link to the Internet and offer cable and DSL internet users a last-mile wireless extension. Users can remain connected even in the

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absence of a direct line of sight (LOS) to a base station (BS) with IEEE 802.16's 50 km of linear service area range. The technology also offers shared data rates of up to 70Mbps, which is more than enough bandwidth to support multiple users at the same time. The data stream is encoded into blocks and spread among time- and space-separated antennas in Space Time Block Codes (STBC).While this encoded data is delivered along multiple antennas at the transmitter side, multiple antennas at the receiver side receive multiple replicas of the similar signal and process it to extract as much information as possible. It offers a notable boost in both throughput and range while maintaining the same overall bandwidth and transmit power consumption. Additionally, by utilizing numerous antennas spaced apart in time and space, it improves the wireless system's spectral efficiency, or the amount of information bits per hour of bandwidth [2].Turbo codes, recognized as the closest approximation to the Shannon limit, play a crucial role in WiMAX. On the transmitter side, one bit is encoded into a sequence of bits based on the encoder's architecture. This encoding significantly reduces the probability of errors when the data is transmitted over the channel. Upon reaching the receiver side, the data undergoes decoding, reverting back to its original form for comprehension by the recipient.

2. WIMAX

A number of industry standards govern how wireless broadband equipment is designed and operates. The two main standards that pertain to wireless broadband are 802.16 and 802.16a, which were developed by the Institute of Electrical and Electronics Engineers (IEEE), a well-known American industry standards body.

A. *Physical Layers of Wimax*

The IEEE 802.16 standard exhibits flexibility in its physical specifications owing to its modular design. In its initial version, the standard exclusively supported single carrier modulation. Over time, as technology advanced, additional features such as Orthogonal Frequency Division Multiplexing (OFDM) and scalable Orthogonal Frequency Division Multiple Access (OFDMA) were incorporated, specifically for operation in the Non-Line-of-Sight (NLOS) environment, aiming to provide mobility. Subsequently, the standards underwent further enhancements to function in the lower frequency range of 2-11 GHz, in addition to the previously established 10-66 GHz band.

1) Orthogonal Frequency Division Multiplexing (OFDM): The concept of OFDM is derived from the Multi Carrier Modulation (MCM) transmission technique. MCM involves dividing the input bit stream into multiple parallel bit streams and utilizing them to modulate various subcarriers, as illustrated in Fig 1. A guard band is presented between each subcarrier to prevent overlap, aiding in the identification of individual subcarriers by the band pass filter on the receiver side.

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OFDM represents a specialized and spectrally efficient form of MCM. What sets it apart from its predecessors is the use of orthogonal subcarriers, eliminating the need for a band pass filter on the receiver side. The orthogonal environment of the subcarriers also addresses the issue of Inter-Carrier Interference (ICI), which was a significant concern in previous techniques. Additionally, the guard band previously employed is eliminated in OFDM, resulting in a reduction in bandwidth usage, as shown in Fig. 2.

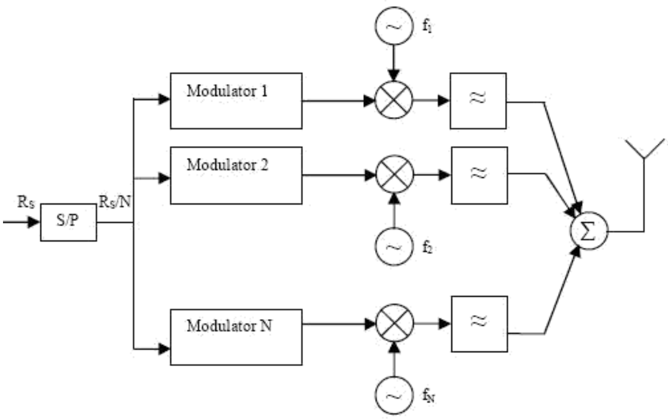

Fig. 1. OFDM Transmitter

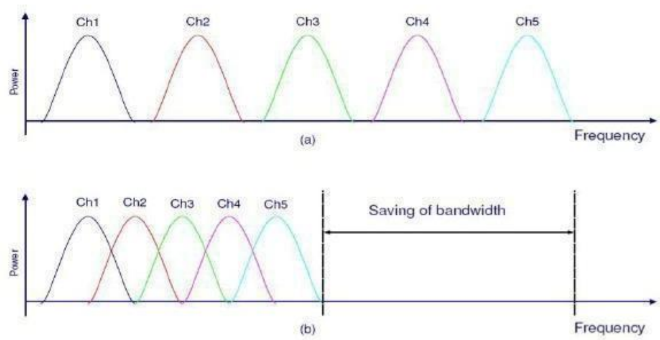

Fig. 2. OFDM Symbols

2. Adaptive Modulation and Coding (AMC): AMC enables WiMAX systems to dynamically choose the most suitable Modulation and Coding Scheme (MCS) based on the prevailing propagation conditions in the communication channel. For instance, in favourable propagation conditions, a higher-order modulation scheme with lower coding redundancy is used, thereby increasing the data rate of the transmission. Conversely, in the event of a signal fade, the system opts for a lower-order modulation scheme to maintain both connection quality and link stability without requiring an increase in signal power [3].

WiMAX employs four modulation schemes for this purpose:

- Binary Phase Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)

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- 16-Quadrature Amplitude Modulation (16-QAM)
- 64-Quadrature Amplitude Modulation (64-QAM)

3. SYSTEM MODEL

The prominent networking company Cisco projected that in 2014, video content accounted for about 70% of the total online traffic. Furthermore, it anticipates that this percentage is poised to increase to a range of 80% to 90% in the upcoming years. This surge in video traffic is attributed to a convergence of factors, including a rapidly growing demand for high-quality content. This trend shows no signs of reversal, and as we progress into the 21st century, video consumption is expected to continue its upward trajectory, necessitating the consumption of more bandwidth. Given the increasing diversity of services, the rising demand for High Definition (HD) video, and the emergence of formats beyond HD, such as 4k x 2k, there is a pressing need for enhanced coding efficiency and reduced bandwidth requirements. Therefore, there is a significant demand for video compression techniques that can deliver high quality while minimizing bandwidth utilization.

A. Introduction of HEVC in WiMAX System

H.265/HEVC represents a new video coding standard that outlines how video is decoded. This standard primarily focuses on two critical aspects: the enhancement of video resolution and the increased utilization of parallel processing architectures. HEVC is specifically designed to meet various requirements, including coding efficiency, resilience to data loss, and reduced memory requirements. The incorporation of HEVC in WiMAX systems aims to capitalize on these advancements to deliver improved video quality, efficient data transmission, and optimal utilization of parallel processing capabilities.

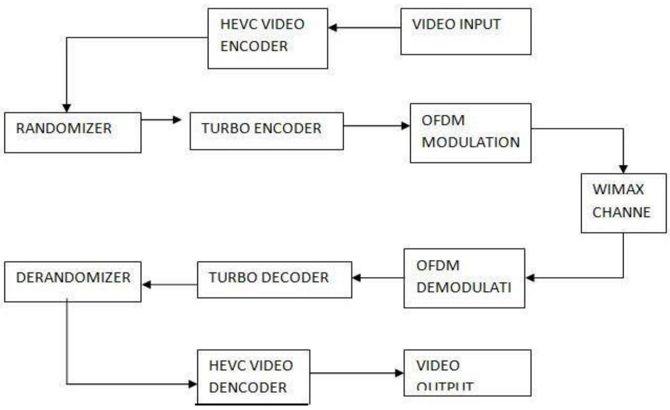

Fig. 3. WiMAX Module with HEVC

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B. HEVC – High efficiency video coding standard.

H.265/HEVC represents a modern video coding standard that outlines the decoding process for videos. It primarily addresses two main issues: increased video resolution and improved utilization of parallel processing architectures. These specifications aim to meet various needs such as coding efficiency, resistance to data loss, and reduced memory demands.

HEVC Video Encoder

Similar to H.264/AVC, HEVC comprises Inter-frame prediction, Intra-frame prediction, 2D transformation, entropy coding, and in-loop filters. A key distinction between H.264/AVC and HEVC is the utilization of a quad-tree coding structure in HEVC. In this framework, a frame is divided into multiple Coding Tree Units (CTUs), resembling the concept of macro blocks in the previous standard. Unlike the macroblock structure, where the maximum size is 16 x 16 luma samples, a CTU in HEVC supports larger sub-blocks of a picture, with a variable size up to 64 x 64 luma samples. A Coding Tree Unit (CTU) is further subdivided into Coding Tree Blocks (CTBs), and CTBs can be divided into smaller Coding Blocks (CBs). A coding unit (CU) comprises one luma CB and two Chroma CBs.

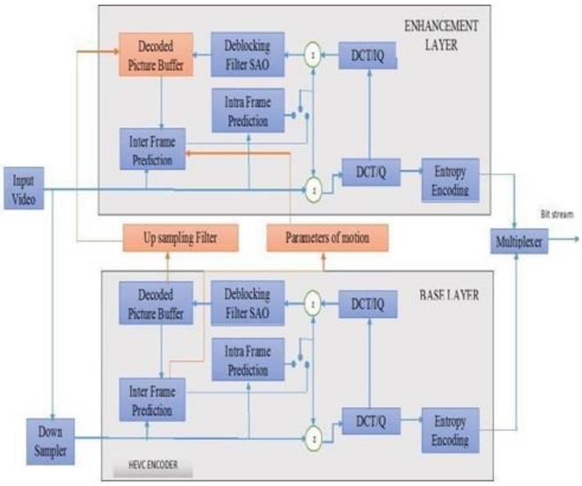

Fig. 4. HEVC Video Coder

Coding Unit (CU) in HEVC serves to define Prediction Units (PU) for making decisions regarding intra or inter-picture prediction, and Transform Units (TUs) that detail the block transform coding of the prediction residual. The Coding Blocks (CBs) within a CU may possess prediction blocks (PBs) and luma transform blocks (TBs) that are either identical or smaller in size. The residual of the luma CB can match the luma transform block (TB), or it may undergo further subdivision into smaller luma TBs. The same principles apply to Chroma TBs. Integer basis functions, akin to those in a discrete cosine transform (DCT), and are specified for square TB sizes such as 4×4, 8×8, 16×16, and 32×32. Additionally, for the 4×4 transform of luma intrapicture prediction residuals, an integer transform derived from a

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form of discrete sine transform (DST) is alternatively defined. Further insights and a performance evaluation of the emerging HEVC standard can be found in [1].

HEVC Video Decoder:

A video codec can be designed using a multi-loop decoding architecture or a single loop architecture. Techniques like residual prediction are crucial to achieving success in the case of inter-layer prediction schemes. In a multi-loop decoding architecture, motion compensation is executed in each reference layer, which is crucial for reconstruction of the target layer. Both inter-coded and intra-coded blocks are reconstructed in all reference layers, and the resulting samples from these layers can serve as additional predicted samples for the enhancement layer.The multi-loop decoding design is known for providing better coding efficiency than the single-loop decoding architecture, even though it may require more memory bandwidth and a larger decoded picture buffer on the decoder side, depending on the number of layers. The scalable codec based on the multi-loop decoding architecture can easily display any view inside a multi-view configuration, thus offering view scalability. This is another benefit of its intrinsic support for multi-view scaling. As a result, features like motion parameter prediction and inter-layer sample prediction are included in HEVC, which is built on a multi-loop decoding architecture [1].

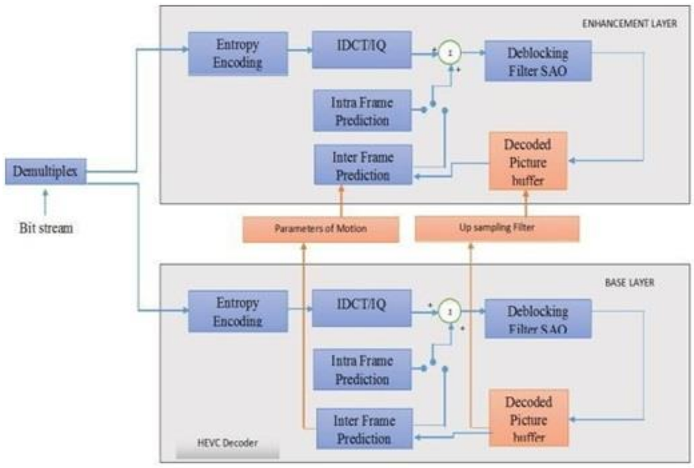

Fig. 5. HEVC Video Decoder

C. 4G WIRELESS NETWORK

WiMAX, or Worldwide Interoperability for Microwave Access, is an eagerly awaited technology designed to offer wireless broadband services for both business and consumers, specifically in the form of Metropolitan Area Networks (MAN). With a target range extending up to 31 miles and a transmission rate exceeding 100 Mbps, WiMAX aims to pose

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a challenge to expensive technologies like DSL and T1 lines, particularly in emerging markets. Initially, the IEEE 802.16 standard was crafted for communications with direct visibility in the frequency band ranging from 10 to 66 GHz. However, recognizing the challenges posed by non-line-of-sight transmissions at higher frequencies, the 802.16a amendment was introduced to operate in a lower frequency band, spanning from 2 to 11 GHz. WiMAX is a standardized technology by IEEE, ensuring interoperability in wireless MANs. Since its initial standardization efforts in IEEE 802.16, WiMAX has seen rapid development.
WiMAX stands out as one of the technologies that come close to meeting the criteria for true 4G, with the potential to surpass the 100MB/second benchmark, which is the standard for 4G [5][6][7].

Quality Factor (QF)

One simple measure to evaluate how compressed a video file is can be determined by its Quality Factor (QF). The QF reflects three aspects of video compression: bitrate, pixel count per frame, and the overall frame rate of the video. Essentially, QF is a way to measure "the data allocated per pixel in the video." However, this measure doesn't consider the compression profile, the number of encoding passes, or any adjustments made by the encoding engineer to enhance video quality. So QF or compression density serves as a fundamental reference for administrators overseeing transcoding or managing extensive video libraries. It provides a starting point for understanding the efficiency of video compression and aids in making decisions related to storage, transmission, and quality management.

$$\textit{Quality factor} = \frac{\textit{bit rate}}{\textit{pixels per frame} * \textit{frame rate}} \quad \text{----------------------(1)}$$

$$= \frac{\dfrac{\textit{bits}}{\textit{second}}}{\dfrac{\textit{pixels}}{\textit{frame}} * \dfrac{\textit{frames}}{\textit{second}}} \quad \text{------------------------(2)}$$

$$= \frac{\textit{bits}}{\textit{pixel}} \quad \text{-------------------------(3)}$$

Introduction of Turbo Codes in WiMAX System

The Turbo Encoder in WiMAX accepts bits from the MAC layer and employs a Recursive Systematic Convolution Encoder to encode them. Subsequently, the encoded bits are transmitted to the modulation scheme block. On the receiving end, the Log MAP decoder

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extracts bits from the demodulation block, decodes the data, and then forwards it to the MAC layer [5]. This entire process is depicted in Figure [6]

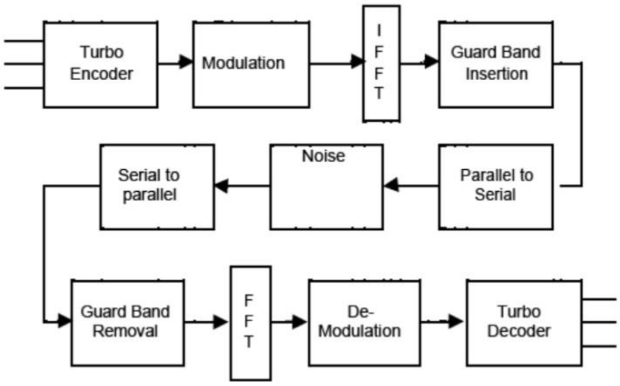

Fig. 6. WiMAX Module with Turbo Codes

1) Recursive Systematic Convolution Encoder (RSC):
This encoder operates on a bit-by-bit basis, producing a parity bit for each input bit based on its internal structure. It outputs the original input bit, referred to as the systematic bit, along with the generated parity bit. The implementation of this encoder involves the use of a Linear Feedback Shift Register (LFSR). The term "recursive" is aptly applied here, as the feedback loop, facilitated by these registers, creates a dependency on previous inputs. The encoder processes the input back into the output, with each new output being closely linked to the input before it. As seen in Figure 6, the registers (represented by D) begin in the known state of "00". Nevertheless, contingent upon the preceding input, they may be in any of the following four states following packet encoding:"00","01","10", or"11". The following packet is affected by these statuses. Memory Flushing, also known as Trellis Termination, is used to fix this problem and reset the registers to the well-known state of "00". In order to flush memory, Trail Bits are padded at the end of each packet according to the registers' current states.
Interleaver: The interleaver plays a crucial role within a frame. During the encoding phase, data is interleaved before being fed into the second encoder.

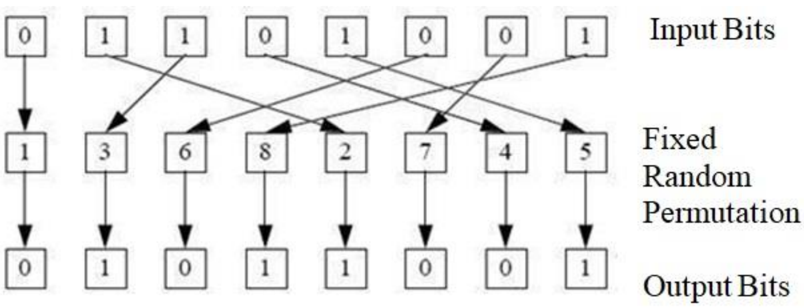

Fig.7 Random Interleaver

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2) To map the single input in accordance with that permutation order, the interleaver shown in Figure 8 uses a fixed random permutations. The input length is denoted by L in this case, and larger the L, better the performance. The Interleaver in Figure 8, produces [0 1 0 1 1 0 0 1] when L=8 and receives a sequence [0 1 1 0 1 0 0 1] as input.

3) Log Map Decoder: In turbo decoding to attain a soft decision, two Log Map Decoders are employed in tandem, operating iteratively using a symbol-by-symbol decoding approach.

4. SIMULATION RESULT

The results were gathered by simulating the model implemented in MATLAB 12. A packet size of 10^6 was used in the simulation, and it was transmitted 10^2 times to increase accuracy. The results of WiMAX performance using different modulation schemes are shown in Figure 10.

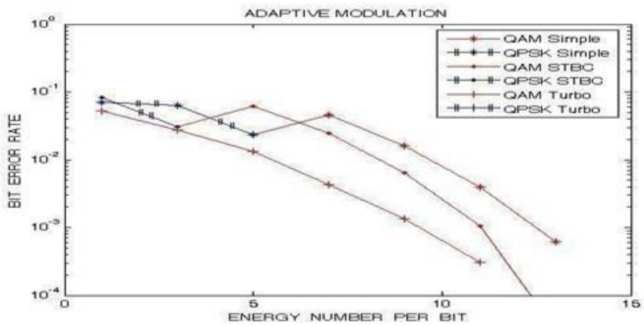

Figure. 8. Performance Graph of WiMAX

Initially, the packet was transmitted using a standard WiMAX design, and the graph labelled "achieved" illustrates its superior performance compared to other decoders. The Quality Factor is improved through advanced video compression, while the turbo decoder facilitates the simultaneous delivery of all other data traffic to all users.

5. CONCLUSION

The paper reported that the video transmission is achieved at the low data rate using HEVC with turbo decoder. The design of the HEVC coding layer is based on traditional block-based motion-compensated hybrid video coding principles, but it introduces notable distinctions compared to previous standards. Turbo codes play a vital role in mitigating residual intersymbol interference (ISI) and inter channel interference (ICI), consequently minimizing the necessary length of the Cyclic Prefix within an OFDMA system. The decrease in overhead related to the Cyclic Prefix results in enhanced bandwidth efficiency. The integration of Turbo codes into an OFDMA system for low-data-rate video transmission in wireless LANs, facilitated by HEVC, results in a significant improvement in terms of bit

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error rate performance and bandwidth efficiency. This approach is expected to be utilized in future 4G networks.

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