Video Transmission Using Scalable Video Coding For 4G Wireless Communications Systems

Muhammad Waqas Malik

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Approval of the Institute of Graduate Studies and Research

Prof. Dr. Serhan Çiftçioğlu
Acting Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science in Electrical and Electronic Engineering.

Prof. Dr. Hasan Demirel
Chair, Department of Electrical and Electronic Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Electrical and Electronic Engineering.

Assoc. Prof. Dr. Ali Hakan Ulusoy
Co-Supervisor

Prof. Dr. Hasan Amca
Supervisor

Examining Committee

1. Prof. Dr. Hasan Amca
2. Prof. Dr. Hasan Demirel
3. Prof. Dr. Hüseyin Özkaramanlı
4. Assoc. Prof. Dr. Ahmet Rizaner
5. Assoc. Prof. Dr. Ali Hakan Ulusoy

ABSTRACT

The technology foundation preferred by 4G wireless broadband networks is Long Term Evolution (LTE). This is because of its speed, robustness and lots of significant technological and business advantages. In recent years, applications based on video streaming have turned out to be immensely important. Due to the data-intensive nature of videos, alternatives for the delivery process have been investigated. In order to maximize throughput and video quality, Scalable Video Coding (SVC), combined with adaptive modulation and coding schemes and wireless multicast provides an excellent solution for streaming video to heterogeneous wireless devices. By choosing different modulation and coding schemes for different video layers, SVC can provide good video quality to users in good channel conditions while maintaining basic video quality for users in bad channel conditions. SVC provides three sorts of scalability, i.e. the spatial, temporal and quality scalability. Quality scalability in particular, plays an important role on the Quality of Experience.

In view of the above, the research in the thesis addresses the specific problem of the performance assessment of video traffic over a wireless communication link with varying channel conditions. The objective of the research is to mainly involve re-definition of system quality measures and parameters to adjust (such as modulation and video quality) for improvement of these quality measures and implement a successful SVC scenario where optimization of performance over varying channel conditions and scaling rate for the SVC is obtained.

Keywords: LTE, SVC, modulation and coding schemes, quality scalability

ÖZ

Long Term Evolution (LTE) teknolojisi 4G kablosuz geniş bant ağları tarafından tercih edilen teknolojidir. Bu tercih teknolojinin sağladığı hız, sağlamlık ve önemli teknolojik ve ticari avantajdan kaynaklanmaktadır. Son yıllarda, video akışı işlemlerine dayalı uygulamalar son derece popüler olmuştur. Videoların yoğun veri boyu nedeniyle, veri aktarım süreci için alternatif araştırmalar yapılmıştır. Veri hızını ve video kalitesini en üst düzeye çıkarmak için, değişken modülasyon ve kodlama düzenleri ile birlikte kullanılan Ölçeklenebilir Video Kodlama (ÖVK) kablosuz çoğa gönderim yöntemi ile heterojen kablosuz aygıtlara video akışı için mükemmel bir çözüm sağlamıştır. Farklı modülasyon ve kodlama şemaları seçimi ile ÖVK kötü kanal koşullarındaki kullanıcılar için temel video kalitesini korurken, iyi kanal koşullarındaki kullanıcılar için iyi video kalitesi sağlayabilmektedir. ÖVK uzamsal, zamansal ve nitelik olarak üç değişik türde ölçeklenebilirlik desteklemektedir. Özellikle nitelik ölçeklenebilirlik, deneyim kalitesi üzerine önemli bir rol oynar.

Yukarıdakiler ışığında, tezdeki araştırma değişen kanal koşullarına sahip kablosuz iletişim bağlantısı üzerindeki video akışında oluşacak sorunun giderilmesine yöneliktir. Araştırmanın amacı esas olarak sistemin kalite ölçüm ve parametre ayarlarının (örneğin modülasyon ve video kalitesi gibi) yeniden tanımını yaparak kalite ölçümlerinde iyileştirme sağlamak ve değişen kanal şartlarında başarılı bir ÖVK senaryosu oluşturabilmektir.

Anahtar Kelimeler: LTE, ÖVK, modülasyon düzeni, nitelik ölçeklenebilirlik

Dedicated to my late father, who always wants me to study further.

"It was your dream and my accomplishment"

I always love you and miss you in every part of life.

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LIST OF ABBREVIATIONS

3G	3^{rd} Generation
3GPP	3^{rd} Generation Partnership Project
4G	4^{th} Generation
5G	5^{th} Generation
AMC	Adaptive Modulation and Coding
AVC	Advance Video Coding
AWGN	Additive White Gaussian Noise
B4G	Beyond 4^{th} Generation
BER	Bit Error Rate
BL	Base Layer
BLER	Block Error Ratio
BS	Base Station
CDMA	Code Division Multiple Access
CGS	Coarse Gain Scalability
CIF	Common Intermediate Format
CQI	Channel Quality Indicator
CSVC	Combined Scalable Video Coding
DL	Downlink
EDGE	Enhanced Data rates for GSM Evolution
EL	Enhancement Layer
eNodeB	Evolved NodeB (LTE Base Station)
EPC	Evolved Packet Core
E-UTRAN	Evolved Universal Terrestrial Access Network

FDD	Frequency Division Duplex
FMDA	Frequency Division Multiple Access
FGS	Fine Gain Scalability
GOP	Group of Picture
GSM	Global System for Mobile Communications
HC-SDMA	High Capacity Spatial Division Multiple Access
HD	High Definition
HEVC	High Efficiency Video Coding
HSPA	High Speed Packet Access
HSPA+	High Speed Packet Access Plus
ITU	International Telecommunication Union
JSVM	Joint Scalable Video Model
JVT	Joint Video Team
LTE	Long Term Evolution
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Services
MBSFN	Multicast Broadcast Single Frequency Network
MCS	Modulation and Coding Scheme
MGS	Medium Gain Scalability
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MMOG	Multimedia Online Gaming
MPEG	Moving Picture Expert Group
MSE	Mean Square Error
OFDM	Orthogonal Frequency Division Multiplexing

OFDMA	Orthogonal Frequency Division Multiple Access
PDN	Packet Data Network
PDSCH	Physical Downlink Shared Channel
PGW	PDN Gateway
PRB	Physical Resource Block
PSNR	Peak Signal to Noise Ratio
QAM	Quadrature Amplitude Modulation
QCIF	Quarter Common Intermediate Format
QoE	Quality of Experience
QoS	Quality of Service
QP	Quantization Parameter
QPSK	Quadrature Phase Shift Keying
QS	Quality Scalability
QVGA	Quarter Video Graphic Array
RB	Resource Block
RNC	Radio Network Controller
RRM	Radio Resource Management
RTP	Real Time Transport
SC-FDMA	Single Carrier Frequency Division Multiple Access
SGW	Serving Gateway
SINR	Signal to Interference plus Noise Ratio
SNR	Signal to Noise Ratio
SVC	Scalable Video Coding
TDD	Time Division Duplex
TDMA	Time Division Multiple Access

UE	User Equipment
UL	Uplink
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunications System

Chapter 1

INTRODUCTION

This chapter presents a brief overview of video transmission and scalability, the objective and the organization of the thesis.

1.1 Video Transmission and Scalability

Towards 2020, a paradigm shift is expected in education, life style and business with video services playing a major role in the supporting technologies, which are expected to use significantly more power, bandwidth and be capacity hungry. The promise of 300 Mbps internet connection for every house, 30 Mbps wire and 20 Mbps wireless capacity per person to be offered by the Horizon 2020 project seems to be a remedy. However, with the current trends 3G, 4G, B4G [1] or similar technologies will not be capable of offering such capacities. Therefore 5G, as a competent for future wireless communications systems, is sought to have 1,000 times larger system capacity, 10 times more energy efficiency, data rate, and spectral efficiency and 25 times more mobile throughput than the 3G/4G/B4G networks in order to offer seamless communications, anywhere, at any time by just about any wireless device and between any people around the globe [1].

Video conversation and streaming is one of the biggest usages of smart phones nowadays. More users create a problem for less bandwidth available for each user. Video scalability is one of the most desirable features of the modern technology which stems from the heterogeneity of communication devices and varying communication channels. It had become compulsory to ensure Quality of Services (QoS) and transmission of data. Scalable Video Coding (SVC) method is used to transmit video at low signal quality at low bandwidth. SVC produces diverse layers from low to high which can be transmitted bestowing to available bandwidth and signal quality. SVC is an extension of H.264/AVC [2] designed to provide spatial, temporal and quality scalability. Scalability is provided by encoding the video signals into different layers. The first layer is called the Base Layer (BL) in which minimum details are present and can be transmitted in worst network conditions. The remaining layers are called Enhancement Layers (ELs) and contribute to increasing the video quality. Channel qualities of individual users in the form of Channel Quality Indicator (CQI) are available at the base station in the Long Term Evolution (LTE) system. For the unicast video transmission, CQI reports are used to decide which layers (only the BL or the BL together with EL(s)) will be transmitted using SVC. However for the multicast video transmission, all layers are simultaneously transmitted in the air but only the BL is decoded to contribute to the received video signal when the network conditions are bad. As the network conditions are improved, successive ELs will be decoded in order and added as the network conditions improve and dropped as the network conditions degrade.

1.2 Thesis Objective

The main aim in this work is to analyze quality scalability [2] keeping other spatial scalability and temporal scalability factors fixed. The thesis discusses the methods to create quality scalability layers and transmit through LTE system with different modulation schemes. By choosing different modulation and coding schemes for different video layers, thesis aims to show how SVC can provide good video quality to users in good channel conditions while maintaining basic video quality for users in bad channel conditions.

1.3 Thesis Organization

The thesis is organized as follows. Related research about SVC and LTE network with scalability is discussed in Chapter 2. Idea and detailed review of SVC is discussed in Chapter 3. Explanation of LTE network with scalability is discussed in Chapter 4. Simulation results are shown in Chapter 5. In the end, conclusion and discussion on future work is done in Chapter 6.

Chapter 2

LITERATURE REVIEW

In this chapter, related research about SVC and LTE network with scalability are presented.

2.1 Literature Review about H.264/AVC and Scalable Video Coding

Initially scalable video transmission work in a network was done in [3] by the author of [2]. They proposed a method to transmit scalable video over 3G networks by generating scalable files from Joint Scalable Video Model (JSVM) reference software. From the results, it is noticeable that scalability provides flexibility in network integration with respect to originally used H.264/AVC.

In [4], authors conducted various experiments in scaling of H.264/SVC by extracting layers from videos, removing each layer starting from a higher dependency layer or the EL and ending up with the lowest dependency layer or the BL. Later they compared these down sampled videos with the original videos with all the layers intact to gauge the degradation of quality of video. The experiment was carried out for different layers of same video and same layers for different videos as well.

Another altered approach was made in [5]. They tried to find the solution for bandwidth utilization and propose combined scalability technique by applying proposed scalabilities together suggested in [2]. In this paper, they examined the combined scalable layers performance to the non-scalable one, in using bit rate capacity at particular layer. They also studied the effect of Additive White Gaussian Noise (AWGN) and Rayleigh fading channel on Combined Scalable Video Coding (CSVC).

2.2 Literature Review about LTE with Scalability

The research in [6] proposed SVC based video streaming scheme for unicast and multicast transmissions in the downlink direction based on Signal to Noise Ratio (SNR) and channel quality response of User Equipment (UE). The authors explored the idea of cross layer adaptation and scheduling. Cross layer adaption (between Medium Access Control (MAC) and Real Time Transport (RTP)) of signaling was applied to achieve channel dependent adaption for unicast transmission. Simulations were used to measure Signal to Interference plus Noise Ratio (SINR) values of users distributed in Multicast Broadcast Single Frequency Network (MBSFN) area and Modulation and Coding Scheme (MCS) value required for providing coverage in that SINR region. A notable difference in parameters like packet loss ratio, throughput and delay was observed. The authors further suggested that adaptations based on video content are plausible and should be explored. Additionally they also hinted about the possibilities of other cross layer design options in video streaming over LTE advanced networks. At the cell edge where the signal conditions were worst, approximately 13% video quality gain was observed for users using this adaptation scheme. The authors also proposed a scheduling scheme which optimized the radio spectrum allocation by Adaptive Modulation and Coding (AMC) and frequency scheduling based on distribution of users in different channel quality regions. The overall spectrum saving has been improved up to 82%.

The authors in [7] worked on evaluating the video performance using SVC over LTE by creating a LTE network between two UEs. Trace files were generated through JSVM reference software, and later on simulated in LTE network on NS-3. They employed both objective and subjective assessments of the quality of the video and provided a graceful degradation of video quality in a customer served area where signal strength is changeable.

In [8], authors examined SVC in both lossless situation and situation in which packets were lost in LTE network. OPNET simulator was used for LTE network and scalable trace files were created from JSVM reference software. High quality video degradation was matched with degradation alone only one scalability (temporal or spatial or quality). They also observed that spatial scalability leaded to maximum degradation of image quality compared with temporal and quality scalability.

Chapter 3

SCALABLE VIDEO CODING

This chapter presents firstly an overview of SVC then discusses the types of scalability i.e. temporal, spatial and quality.

3.1 Overview of SVC

The SVC design [2], which is an extension of the H.264/AVC [9] video coding standard is a video codec based on layers. These layers make a video scalable in three dimensions which will be further explained in detail in this Chapter. Video scalability is one of the most desirable features of the modern technology which stems from the heterogeneity of communication devices and varying communication channels. It had become compulsory to ensure QoS and transmission of data. SVC provides the solution to this dilemma by separating BL and ELs.

SVC is categorized on the bases of frame rate, resolution and bit rate, more precisely temporal, spatial and quality scalabilities. In this thesis, all three types are briefly discussed later in this Chapter. Indeed our main focus is on quality scalability, related to bit rate.

In [3], the authors discussed two important factors, namely, heterogeneity of UE and quality of the transmission network effect on video delivery services. The former was due to the variation of UE from strictly resource limited cellular smart phones to resource rich multimedia appliances such as internet TV and computers at domestic premises. The latter was due to the varying channel and equipment conditions such as signal fading, dropping battery power, traffic congestion.

H.264/AVC, itself is the state-of-the-art compression standard. Comparison with earlier compression format, H.264/AVC considerably reduces bit rate and represents in certain given video quality. H.264/AVC baseline profile is recommended video codec according to 3rd Generation Partnership Project (3GPP) Multimedia Broadcast Multicast Services (MBMS) video services. Earlier scalability is introduced as addition scalable profiles to H.264/AVC. The delivery of quality and spatial scalability in codec techniques comes along with a significant growing in decoder complexity and a noteworthy reduction in coding efficiency as related non-scalable profiles, i.e., higher level layers bit rate will be increased for restoration. The shortcomings which overcome the attainment of the scalable profiles to the original H.264/AVC settings are solved by the new SVC revision of the H.264/AVC standard.

The Joint Video Team (JVT) and Moving Picture Expert Group (MPEG) developed SVC as an extension to H.264/AVC [2]. Heterogeneous adoptability of SVC provides a solution to existing encountered problems related to video encoding and transmitting high quality video to devices with varying capabilities. SVC provides degradation of video depending on heterogeneous UEs and the robustness counter to variable network conditions. This video coding technology can be applied in all aspects of video sharing. The adaptability of scalable is shown in Figure 3.1.

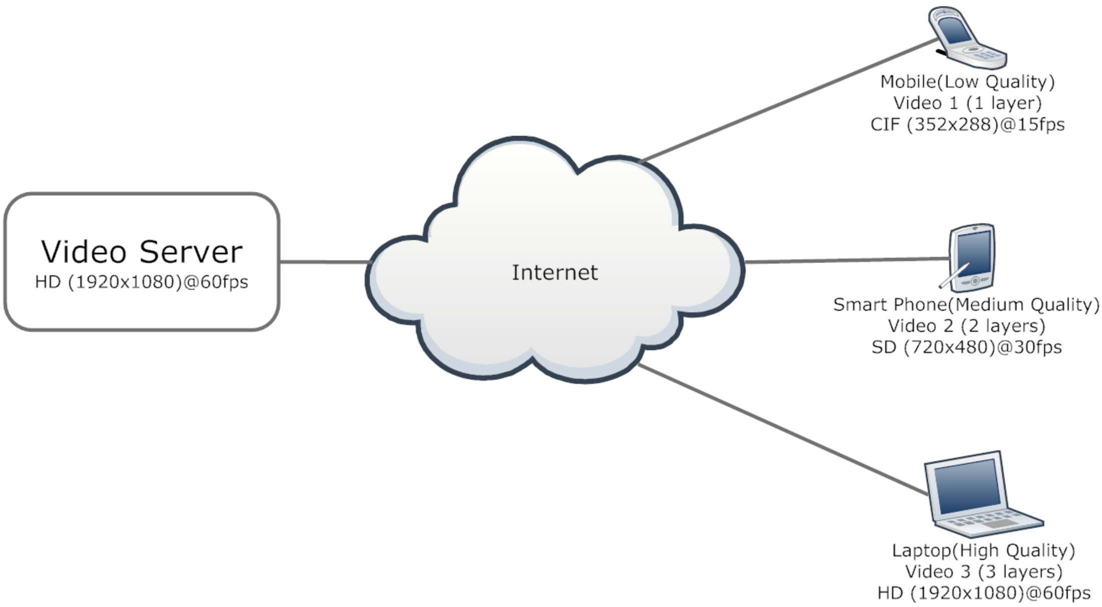


Figure 3.1: Adaptability of SVC.

3.2 Types of Scalability

SVC includes three different types of scalabilities, namely temporal, spatial and quality as presented in Figure 3.2 [10]. SVC encoder converts high quality video bit stream into different layers which allows transmission of different layers depending upon UEs. The most basic layer with minimum detail is called BL which includes lowest quality of temporal, spatial and quality scalability. Other improved quality layers are called ELs. Each EL adds a higher quality to the transmitted video. ELs also include 3-dimensional scalability (temporal, spatial and quality) like BL. A video is said to be scalable if it can divide into sub-stream of different layers. These divided sub-stream layers can be encoded and then decoded to get different quality of video. To attain the scalability, these scalable dimensions can be used independently or together as combined scalability. Considering mobile phones homogenous in terms of resolution and frame rate, our main focus in this thesis will be on Quality Scalability (QS) which is also sometime referred as SNR scalability.

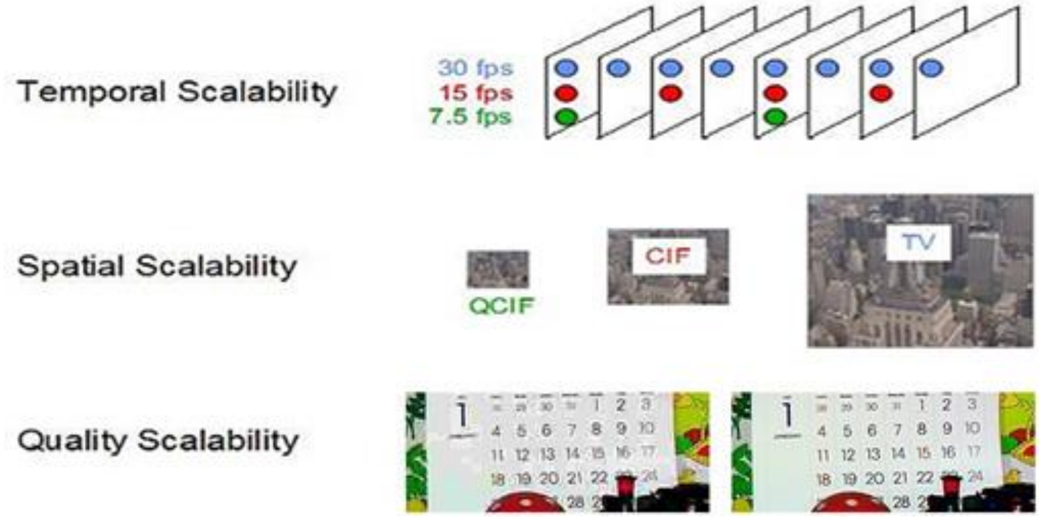


Figure 3.2: The basic types of scalability in video coding.

3.2.1 Temporal Scalability

A bit stream is said to be temporal scalable if it provides temporal BL and one or more temporal EL. Temporally scalable is more precisely referred to as frame per second (fps). Concept behind the temporal prediction is the hierarchical temporal prediction structure. There exist multiple frames in one Group of Picture (GOP) as shown in Figure 3.3 [10]. This set of GOP follows hierarchal order of three different types of frame: I (intra), P (predictive) or B (bi-predictive) [2]. BL is used by building I frames and P or B frames are used to build ELs. Let T_k be defined as the temporal identifier and k = 0 represent BL and increment of 1 in k is for increase in EL as shown in Figure 3.4 [10]. More frames in one GOP give higher quality of video. BL includes minimum number of frames whereas ELs include higher fps. In our case, we keep temporal scalability constant while transmitting through an LTE network.

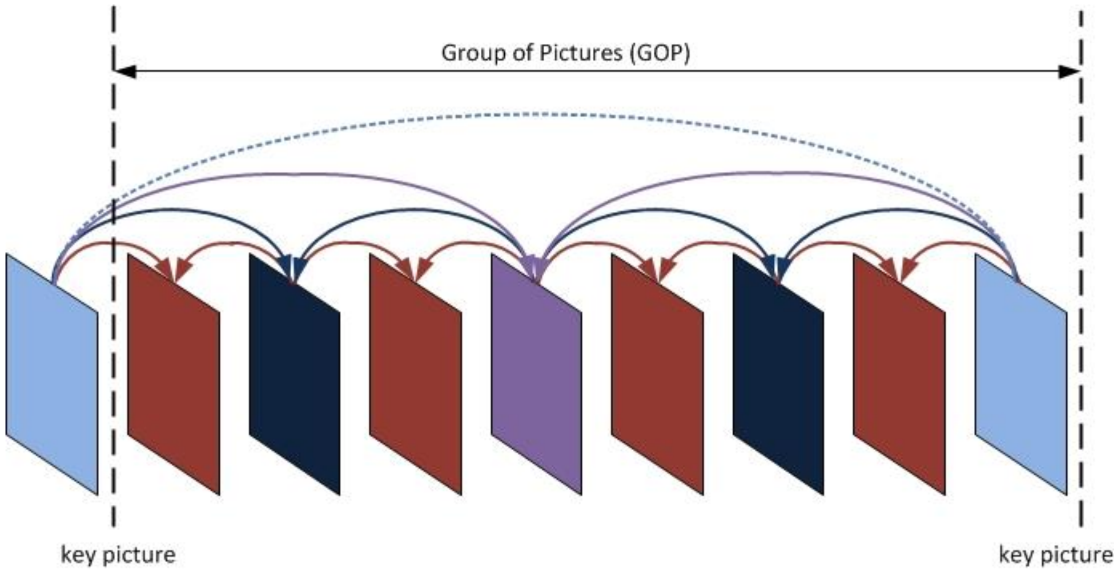


Figure 3.3: GOP and temporal prediction in GOP.

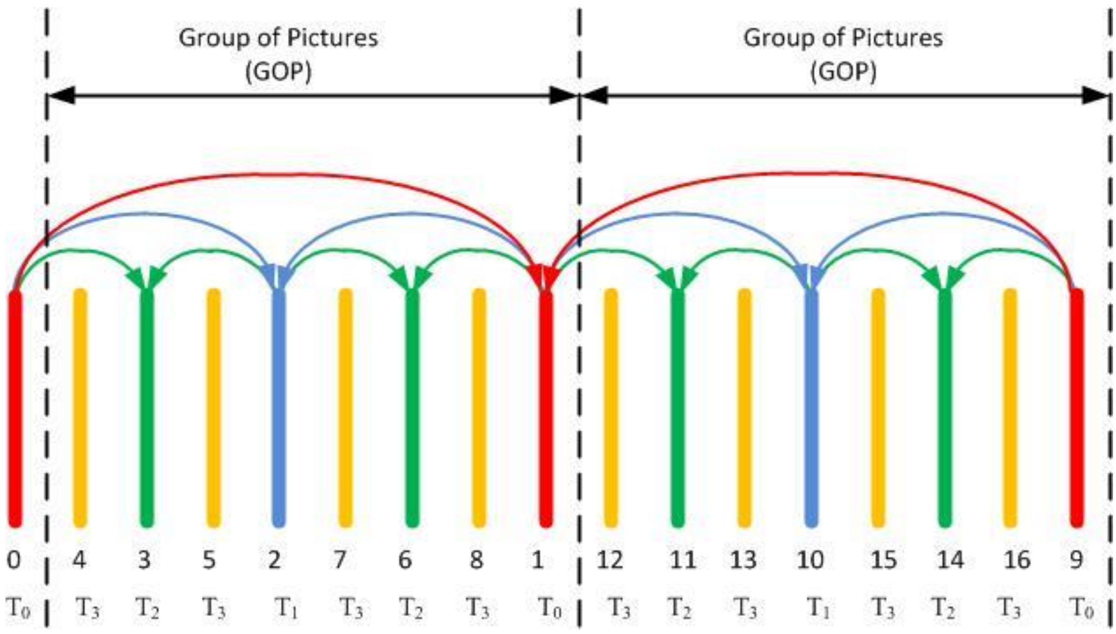


Figure 3.4: Hierarchical prediction structures for enabling temporal scalability.

3.2.2 Spatial Scalability

Spatial scalability refers to the spatial resolution in BL and ELs. It is the scalability which reduces the frame sizes into multiple layers. We use spatial scalability to maintain the heterogeneous client with different resolution from Quarter Video Graphic Array (QVGA) to High Definition (HD). Each layer supports different spatial resolution. Same like temporal scalability, BL also contains basic information with lowest resolution. ELs contain details of higher resolution respectively. Inter layer prediction structure supports EL that exploits the spatial redundancies based on the BL. Inter layer prediction idea is to obtain maximum information from previous reference layer to predict spatial resolution for higher layer. EL frame has the higher spatial detail as compared to BL. This prediction can be obtained either by up-sampling the reference layer for higher layer or by taking the weighted average of the up-sampled signal and the temporally predicted signal [2]. A multi-layer structure with additional inter-layer prediction is shown in Figure 3.5 [10].

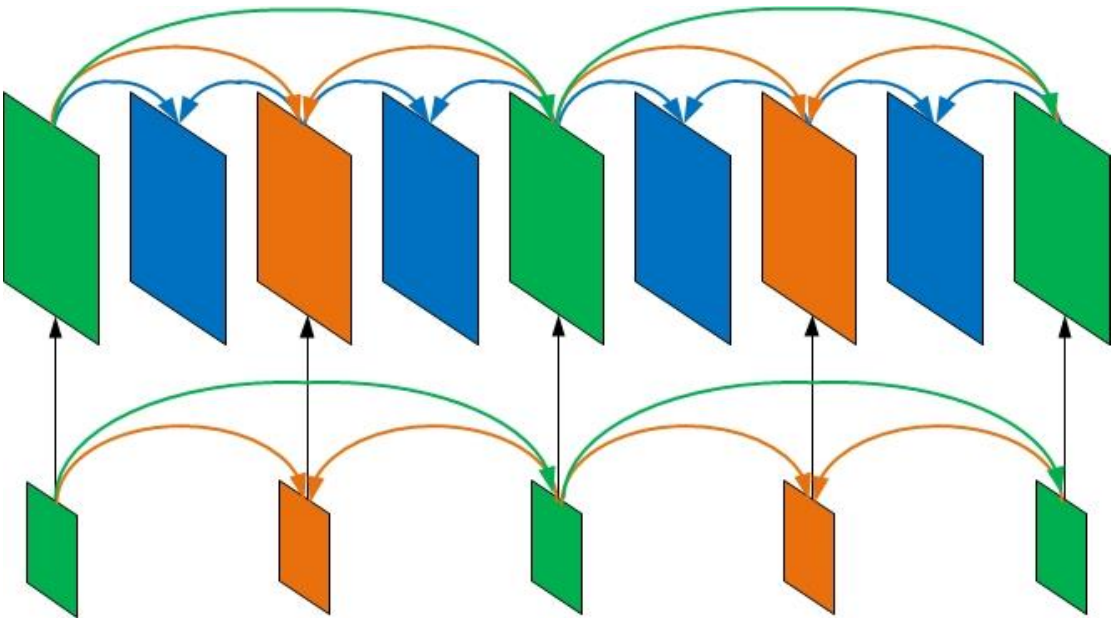


Figure 3.5: Multi-layer structure with additional inter-layer prediction (black arrows).

3.2.3 Quality Scalability

Quality or SNR scalability refers to scaling level of compression to the input video. This is performed in terms of Quantization Parameter (QP). Multilayer approach in QS is defined on these QP levels. Data is transmitted in different layers with different quality levels. An EL is obtained with frame having better quantization than lower reference layer. This is implemented in frequency domain. The QS is considered some special case of spatial scalability with fixed resolution in BL and ELs. There are three different modes to implement SNR scalability i.e. Coarse Gain Scalability (CGS), Medium Gain Scalability (MGS) and Fine Gain Scalability (FGS). FGS has been removed because of its coding complexity and under research consideration [11]. Most commonly CGS and MGS is used as QS.

The same like spatial scalability, inter-layer prediction is used in QS. In CGS, frames in EL are used as prediction references and therefore all the ELs in a GOP typically prepared as a single unit. Prediction method in QS is different from spatial scalability method of prediction. The up-sampling method cannot be applied because of frame size being the same. The remaining signal is again quantized with quantization step size less than previous layer in this mode.

MGS is considered to be more flexible than CGS. While switching between layers, MGS adopts bit stream by enabling high level signaling. Each EL is partitioned into several MGS layers. The value of each layer is different from another. To achieve a better quality in layer, the number of finer quality levels is increased.

Chapter 4

LTE SYSTEM AND SCALABILITY

This chapter firstly gives a brief introduction and explanation of LTE system and then scalability in LTE network.

4.1 Introduction of LTE

Many other systems like iBurst (or High Capacity Spatial Division Multiple Access (HC-SDMA)), Ultra Mobile Broadband (UMB), Flash Orthogonal Frequency Division Multiplexing (OFDM) systems are competed for 3GPP 4G status. But International Telecommunication Union (ITU) selected LTE as standard for 4G. LTE as 4G standard was introduced in 3GPP Release 8 and some addition in Release 9 [12]. Requirement of an average user increased with recently emerged applications like mobile TV, Multimedia Online Gaming (MMOG), video conferencing and video streaming. Keeping these emerging technologies in mind, 3GPP worked on LTE that proved to be most appropriate technology for 4G network. The LTE physical access layer uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). Many other 3GPP technologies are discussed in [10], but according to it, LTE can have 6.5 to 26.3 Mbps in 10/10 MHz as typical downlink speed and 6.0 to 13.0 Mbps in 10/10 MHz as typical uplink speed. Our scalability feature is applied for downlink video streaming in LTE.

LTE offers high data rate, reduced latency, better coverage, upgraded system capacity and less cost as compare to previous technologies. The radio access based concept of LTE enables it to transmit and maintain high speed data and media traffic over heterogeneous devices in multitude. In LTE, Universal Mobile Telecommunications System (UMTS) is improved as Evolved Universal Terrestrial Access Network (E-UTRAN). Moreover, LTE also smoothly supports all previous technologies like Global System for Mobile Communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), Evolved EDGE, UMTS, High Speed Packet Access (HSPA) and High Speed Packet Access Plus (HSPA+). Characteristics of 3GPP technologies are discussed in [10]. LTE proves to be ahead all previous technologies in term of high data rate. Evolution of LTE is shown in Figure 4.1 [13] and characteristic of 3GPP technologies is shown in Table 4.2 [13].

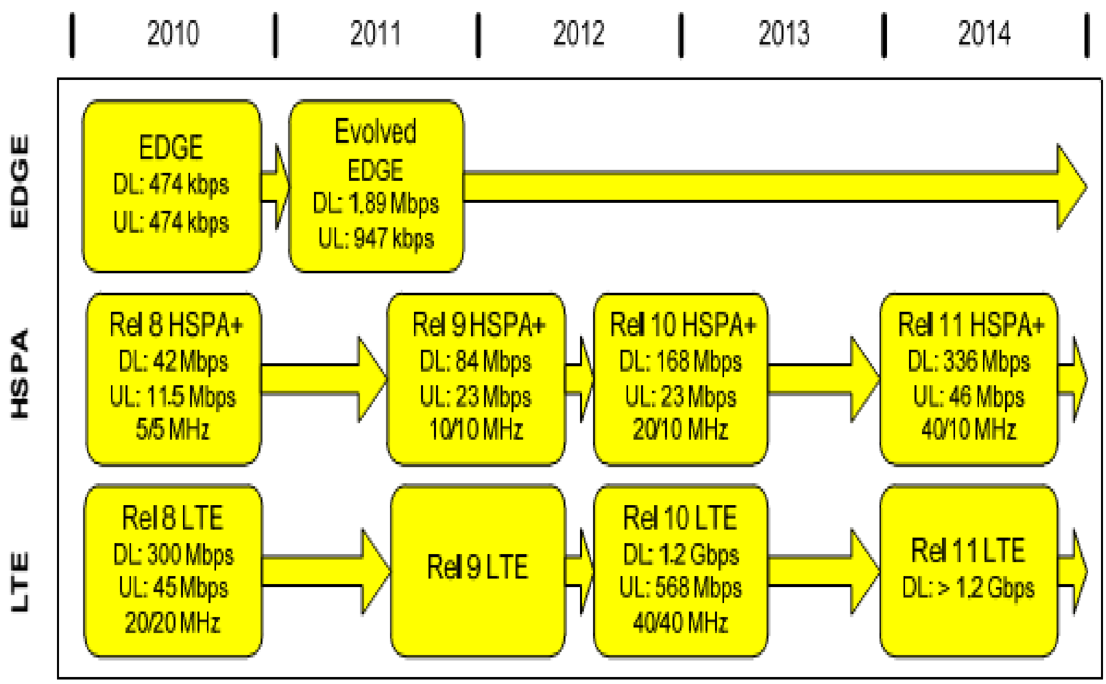


Figure 4.1: Evolution of LTE.

Table 4.1: Characteristics of 3GPP technologies.

Technology Name	Type	Characteristics	Typical Downlink Bandwidth	Typical Uplink Bandwidth
GSM	TDMA	Most widely deployed cellular technology in the world. Provides voice and data service via GPRS/EDGE.		
EDGE	TDMA	Data service for GSM networks. An enhancement to original GSM data service called GPRS.	70 kbps to 135 kbps	70 kbps to 135 kbps
Evolved EDGE	TDMA	Advanced version of EDGE that can double and eventually quadruple throughput rates, halve latency and increase spectral efficiency.	175 kbps to 350 kbps expected (Single Carrier) 350 kbps to 700 kbps expected (Dual Carrier)	150 kbps to 300 kbps expected
UMTS	CDMA	3G technology providing voice and data capabilities. Current deployments implement HSPA for data service.	200 to 300 kbps	200 to 300 kbps
HSPA[30]	CDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 Mbps to 4 Mbps	500 kbps to 2 Mbps
HSPA+	CDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.9 to Mbps to 8.8 Mbps in 5/5 MHz Approximate doubling with dual carrier in 10/5 MHz	1 Mbps to 4 Mbps in 5/5 MHz or in 10/5 MHz
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	6.5 to 26.3 Mbps in 10/10 MHz	6.0 to 13.0 Mbps in 10/10 MHz
LTE-Advanced	OFDMA	Advanced version of LTE designed to meet IMT-Advanced requirements.		

The bandwidths in LTE range from 1.4 MHz to 20 MHz. LTE dynamic modulations are also very diverse where it allows modulation schemes from Quadrature Phase Shift Keying (QPSK) to 64 Quadrature Amplitude Modulation (QAM) modulations. To facilitate the efficient use of radio resources OFDMA in LTE is flexible as in it allows radio resources to be allocated in time and frequency domain. The sub-carriers in LTE are spaced at a constant of 15 kHz and are assigned to users in clusters.

4.2 LTE System Architecture

In LTE system architecture, UE supports DL and UL in air. UE sends information to eNodeB (evolved NodeB). eNodeB is known as LTE Base Station (BS). In this architecture, radio resource management is done by eNodeB. LTE advances the UMTS access network, known as E-UTRAN and the core network as Evolved Packet Core (EPC). The most significant fact about eNodeB is that separate node of Radio Network Controller (RNC) is in eNodeB and it is responsible for reliable delivery of packets. All Radio Resource Management (RRM) functionalities are management by eNodeB. eNodeB sends mobility information to MME (Mobility Management Entity) [14]. The UE packet does not go through MME. Serving Gateway (SGW) works for processing packets and inter eNodeB handover. PDN Gateway (PGW) is responsible for packet filtering and allocating IP addresses to UEs. LTE is radio interphase that can use wide radio channels to transmit high amount of domain which all the communication and traffic is handled in IP domain [6]. The LTE system architecture is shown in Figure 4.2.

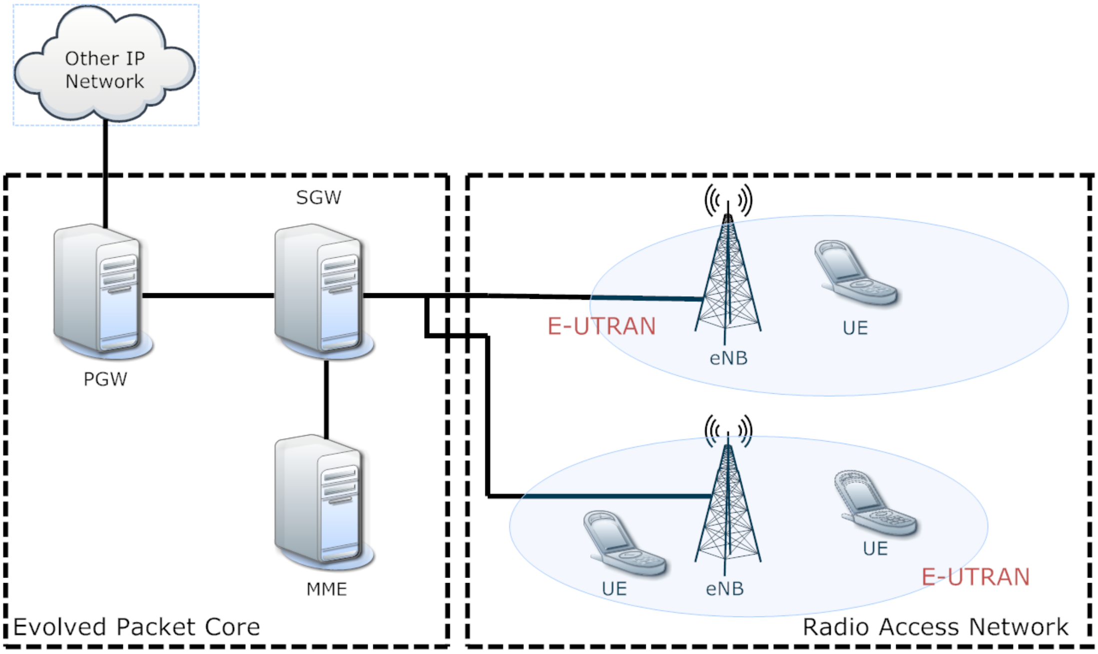


Figure 4.2: LTE system architecture.

4.3 OFDMA and LTE

OFDMA has some vital benefits over other wireless access techniques like Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). The main advantages of OFDMA are low-rate, channel division into many narrowband, frequency-non-selective sub-channels or sub-carriers. In this way many symbols can be transmitted at same time maintaining the high spectral efficiency [15]. This allows transmitting different media like video, voice, messages and other data on same radio link. In OFMD system, different users can experience different Quality of Experience (QoE). Like a user near to BS has a good channel quality, has a high-order modulation scheme, so he will experience high data rate. On the other side, user far from BS or served in highly crowded area, has a poor channel quality, has a low-order modulation scheme, so he will not experience high data rate.

LTE system is offered as a new technology to provide wide media delivery with high speed data rate. LTE systems provide support of Time Division Duplex (TDD) and Frequency Division Duplex (FDD) schemes and frequencies range from 1.4 MHz to 20 MHz. A multi user version of OFDM modulation scheme is OFDMA. The OFDMA spectrum is divided into multiple resource blocks depending on frequency and time domain. OFDMA allows multiple users to access same bandwidth and allocate some frequency-time block to each user. In this way, channel is shared in multiple users. For different QoS, different numbers of sub-carriers can allocate to different user in a spectrum, so that data rate and error probability can be controlled for each user. The OFDMA allows good performance in frequency selective channels. The Resource Block (RB) is a resource that is assigned to a user for the DL. In time domain, 0.5 ms duration is of one time slot and in frequency domain, RB contains 12 sub-carriers as a total of 180 kHz bandwidth. RB size is same for all bandwidths. The Physical Resource Block (PRB) has both frequency and time aspects. It consists of 12 sub-carriers in frequency and 2 consecutive time slots each of which is 0.5 ms long in time. Structure of PRBs in LTE bandwidth and an example allocation pattern of PRBs in OFDMA frame are shown in Figure 4.3 [16].

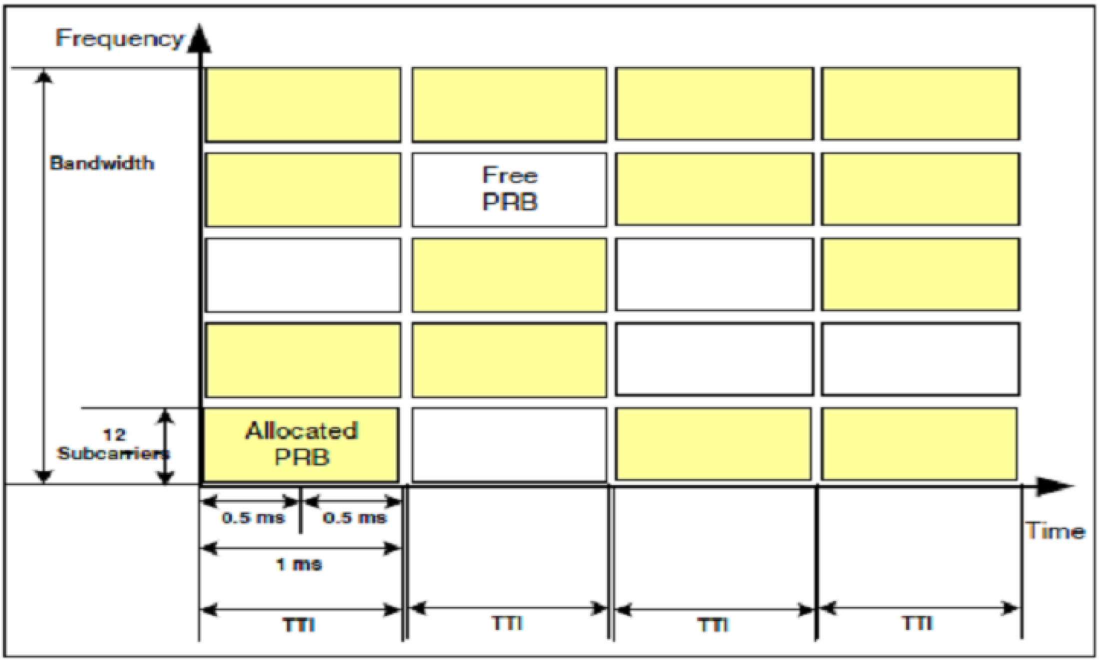


Figure 4.3: Structure and allocation of PRBs in OFDMA.

4.4 Channel Conditions (Quality)

At DL channel, UE send a report to eNodeB about the SNR. That report is known as CQI report. SNR value of UE can be analyzed on the bases of CQI report. LTE system has improved CQI feedback system as compared to 3GPP UMTS. There are two CQI reporting modes used in LTE.

- Aperiodic feedback: UE sends CQI only when it is asked to by BS.
- Periodic feedback: UE sends CQI periodically to the BS; the period between 2 consecutive CQI reports is communicated by the BS to the UE at the start of the CQI reporting process.

The CQI report plays an import part to decide which scalable layer should be transmitted to UE. The three steps to obtain SNR-CQI mapping is explain as following [21].

1. eNodeB inquires CQI one by one in transmission. UE receives the request and measures the SNR-Block Error Ratio (BLER) curve for each CQI. A set of SNR-BLER curve values for each corresponding CQI are preserved in UE.
2. Corresponding to BLER = 10%, an SNR value is selected by UE for each curve which matches to a CQI.
3. UE uses the SNR value from second step and corresponding CQIs for preferred SNR-CQI mapping.

An approximate analysis and mapping is given in [17] and shown in Figure 4.4.

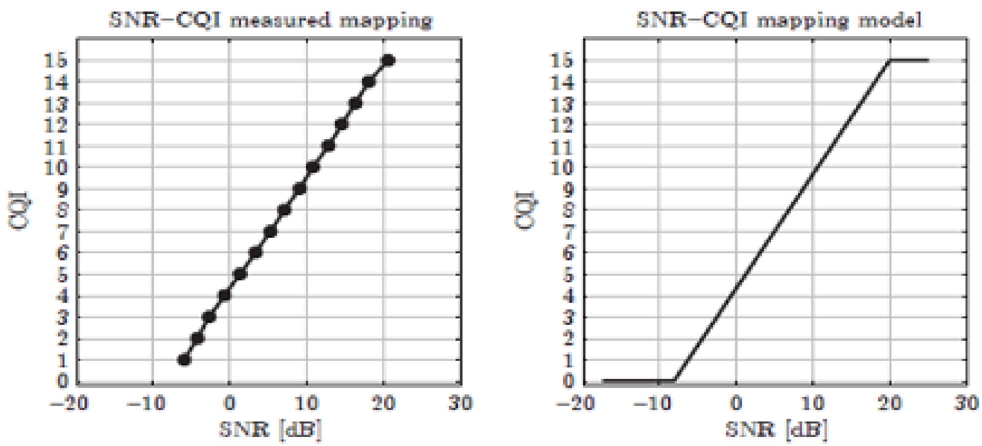


Figure 4.4: SNR vs. CQI report.

Depending on results provided in [18], we concluded a SNR vs. CQI range for video transmission in Table 4.2

Table 4.2: Channel quality vs. SNR range for video layer transmission

CQI Range	SNR Range	SVC Video Layer
1 – 9	-5.6 – 8.4	Base
10 – 15	10.15 – 20	Base + Enhancement

4.5 Video Delivery over LTE

The revenue generation and accomplishment of succeeding mobile networks are dependent of value added services like mobile TV, video conferencing, video streaming and video on demand. The real-time video delivery is shown in Figure 4.5.

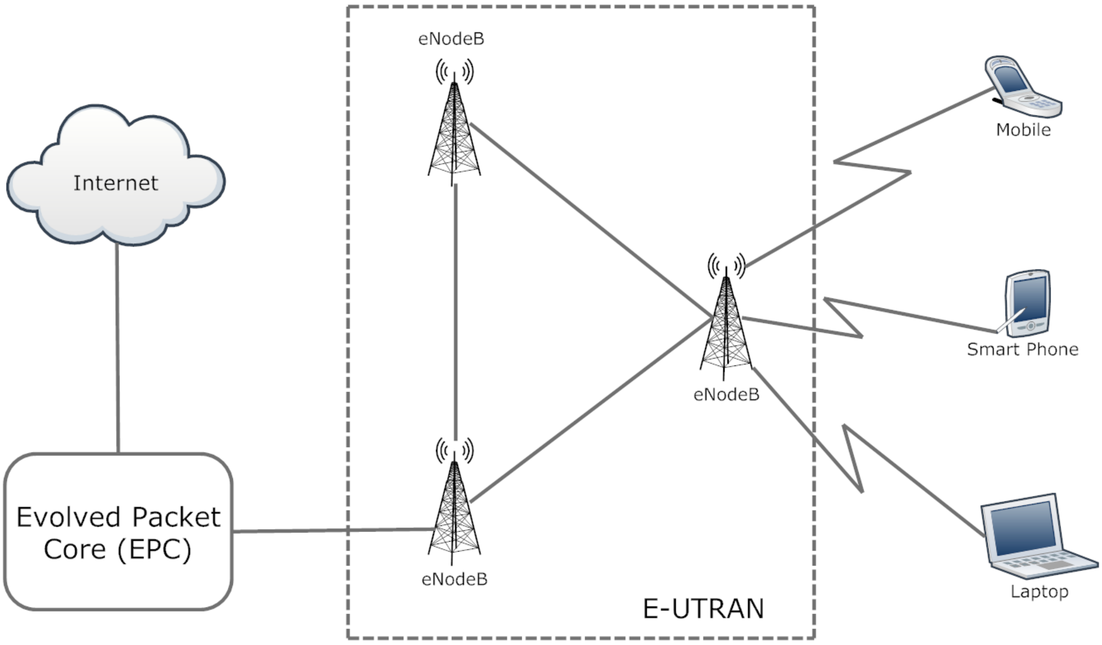


Figure 4.5: Video delivery in LTE network.

Video delivery in a LTE system depends upon many improvable aspects. One of the important aspects is high throughput in a LTE system. The high data depends upon following design characteristics:

Scalable channel bandwidth: LTE supports bandwidth from 1.4 MHz to 20 MHz.

Dynamic Modulation: A widespread range of modulation schemes from QPSK to 64 QAM modulations is possible in LTE network.

Multiple antenna technology: LTE supports up to 4 by 4 Multiple Input Multiple Output (MIMO) antenna configurations.

OFDMA: OFDMA in LTE downlink allows radio resources to be allocated in time and frequency domain. This gives link and channel aware schedulers more flexibility for the efficient use of radio resources.

The details of QS are depicted in Figure 4.6.

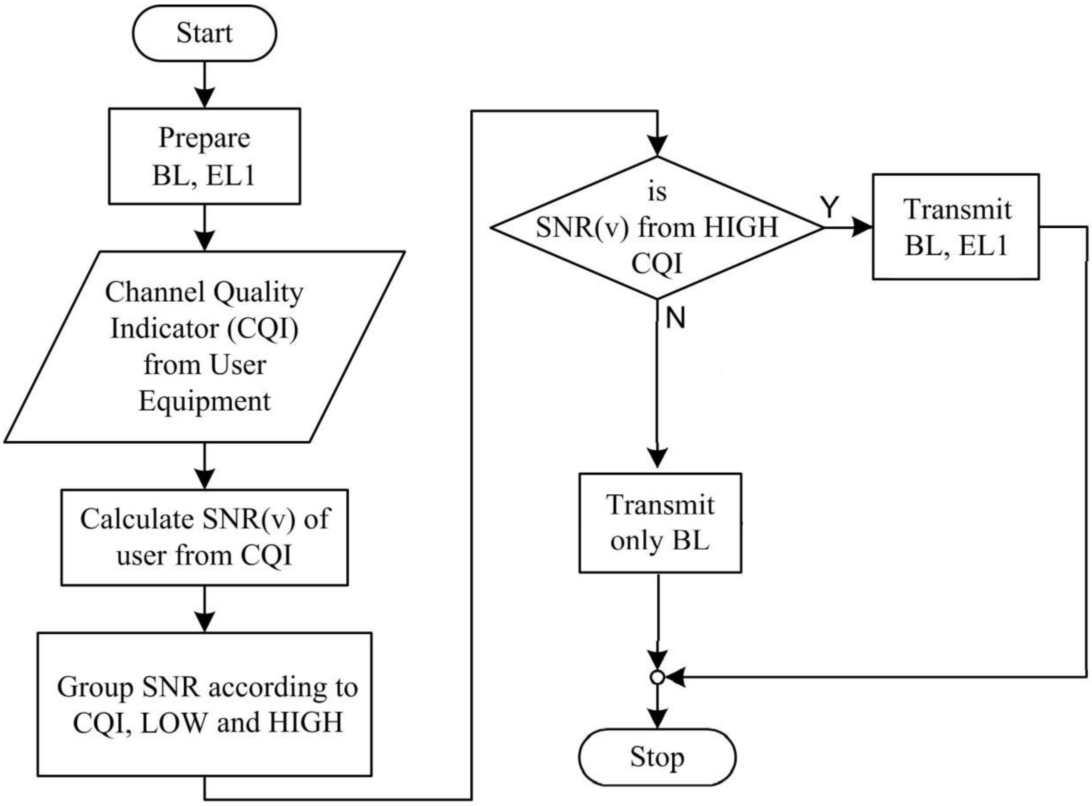


Figure 4.6: Scalability flow diagram.

The proposed method for scalability is shown in flow diagram above. Simulation is conducted according to this approach in Chapter 5.

Chapter 5

SIMULATION RESULTS

This chapter presents simulation of QS in MATLAB and later on transmission of those layers from LTE system in different channel conditions and modulation types.

5.1 Simulation Environment

The aim is to generate QS layers and transmit them through LTE system. There are many simulation tools available to handle these kinds of simulations. In this thesis, the preference was given to use MATLAB. As discussed earlier in literature review, other researchers tried to obtain scalable layers from JSVM software and process them in different network simulation tools depending on their objectives. JSVM is considered to be reference software to obtain scalable layers of trace file. But due to some restriction by our University side, it is not possible to access JSVM server.

MATLAB is considered to be useful as per thesis objectives. As the latest version of MATLAB 2014a includes LTE system toolbox and simulation can be analyzed more easily than many other simulation tools. The plus point of MATLAB is that functions are editable, modifiable and easy to understand. From built-in MATLAB models, LTE Downlink PDSCH with Transmit Diversity (LTETransmitDiversityExample.m) is modified for transmission of QS layers. It uses Physical Downlink Shared Channel (PDSCH), which is the main physical channel used to transmit unicast data with different number of antennas. The function uses single-codeword transmit diversity over two or four antennas. The function is modified to transmit QS layers. It supports channel bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz. Modulation type of QPSK, 16QAM and 64QAM is also supported in it. SNR and number of subframes are adjustable according to user input. Figure 5.1 shows the window of LTETransmitDiveristyExample.m.

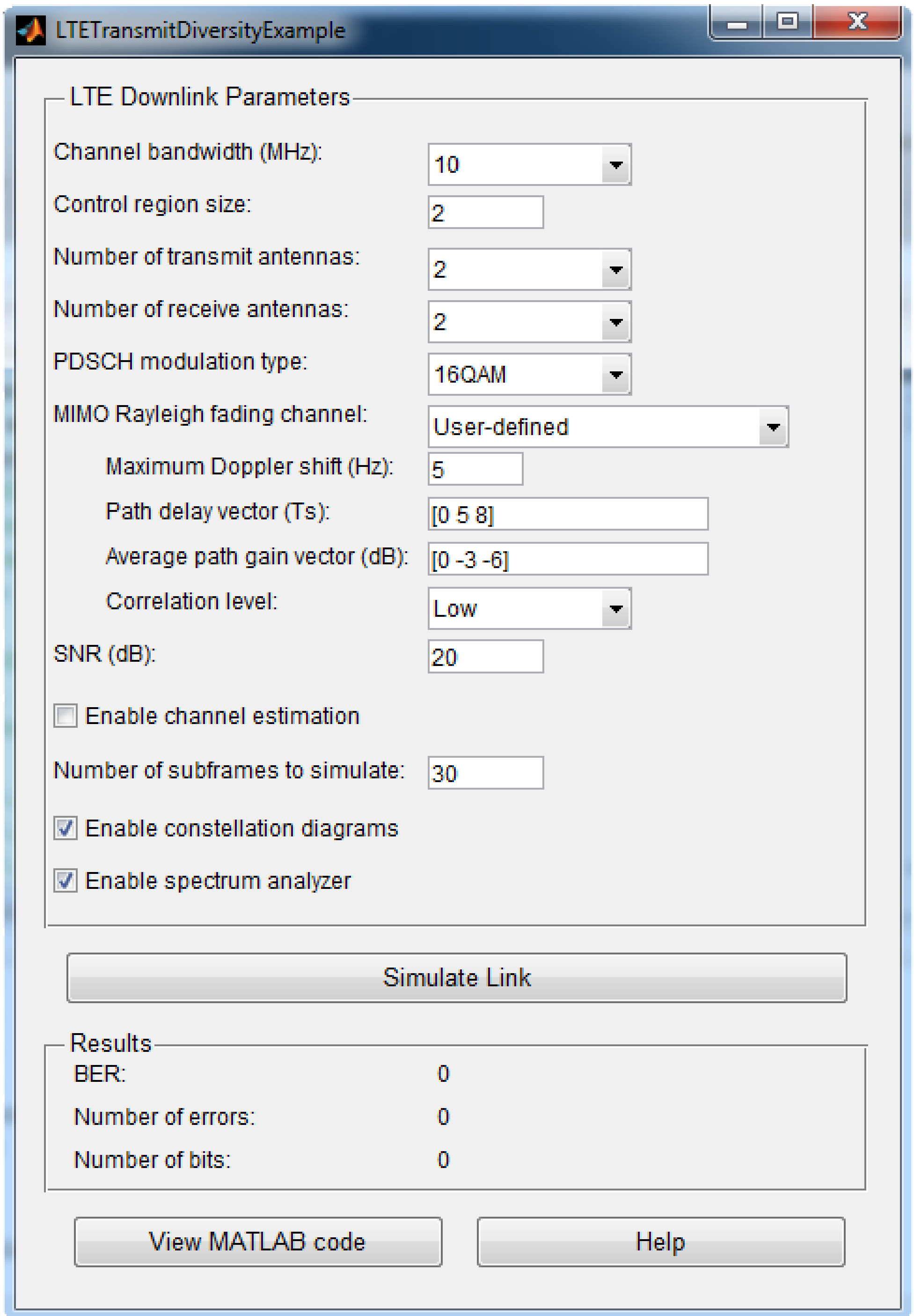


Figure 5.1: LTETransmitDiveristyExample.m from MATLAB.

Other feature of LTETransmitDiveristyExample.m is user-defined MIMO Rayleigh fading channel which includes maximum Doppler shift (Hz), path delay vector (Ts), average path gain vector (dB) and correlation level. However these settings are not changed for simulation and default inputs are used.

5.2 Simulation Results and Analysis

5.2.1 Quality Scalability in MATLAB

As previously discussed by keeping the resolution and fps constant, layers with different SNR value (QS) were transmitted through LTE system. A method proposed in [22] is used to obtain QS layers. H261 video decoder in MATLAB was used to separate YUV (raw video) trace file [19] into Y, U and V frames. In this case, Foreman trace file is used. Each frame is DCT-transformed and then quantized at base level. By inverse quantization, base level DCT coefficients are reconstructed. These base level DCT coefficients are subtracted from original DCT coefficients. Then the residual is quantized on different level to obtain enhancement level, shown in Figure 5.2. Two different frames of Y, U and V are generated at each level. By combining first level, we got base YUV frame and then converting it through ycbcr2rgb to get RBG BL. Same procedure was repeated to obtain EL from second level.

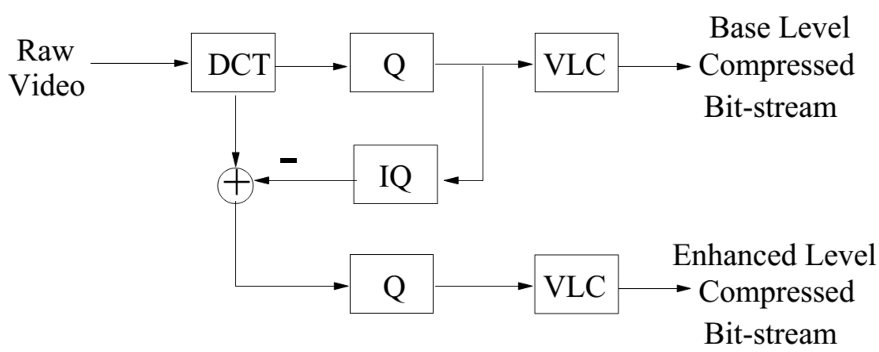
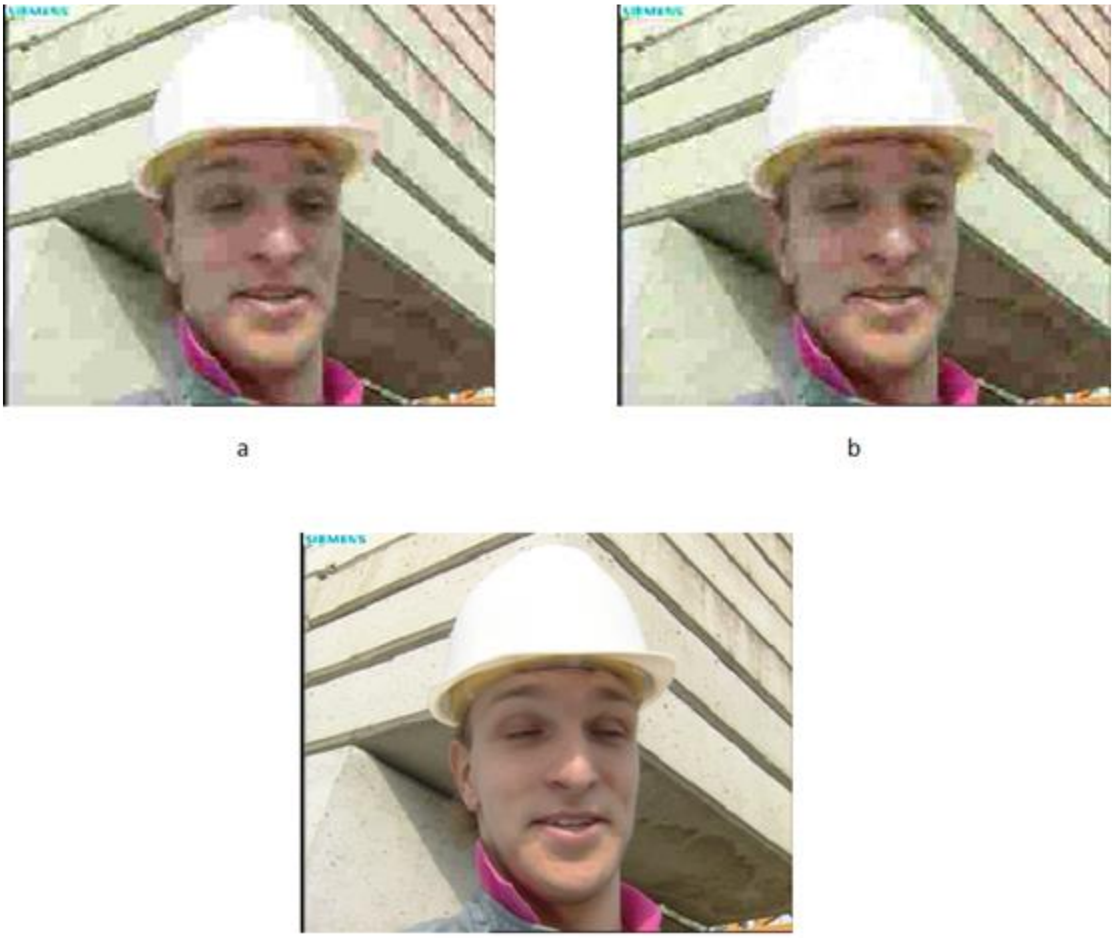


Figure 5.2: A two level quality scalable codec

Both BL and EL with combined one are shown in Figure 5.3.



c

Figure 5.3: Foreman (a) base layer (b) enhancement layer (c) combined layers.

5.2.2 Transmitting through LTE System without Scalability

Initially the frames were transmitted through different modulation schemes to check which modulation is better. Firstly QPSK modulation was used and a total of 186 subframes were transmitted to process this layer. Other parameters were kept as default. Figure 5.4 shows the received Foreman sequence at different SNR values with the Bit Error Rates (BERs).

Figure 5.4: QPSK without scalability (a) original (b) received at SNR=0 dB with BER= 6.9888×10^{-2} (c) received at SNR=13 dB with BER=2.1773×10^{-5} (d) received at SNR=20 dB with BER=6.5729×10^{-6}

From the results shown above, we can conclude that QPSK modulation at medium and high SNR values produces results which are so close to the original one with BERs of 2.1773×10^{-5} and 6.5729×10^{-6} respectively. For QPSK, all over the result is acceptable but process and transmission time is very high.

16QAM which is more effective than QPSK in terms of a higher data rate is used as the modulation scheme to obtain the sequence at low, medium and high SNR values. In this case, number of subframes required to transmit were 93. Results of 16QAM are shown in Figure 5.5.

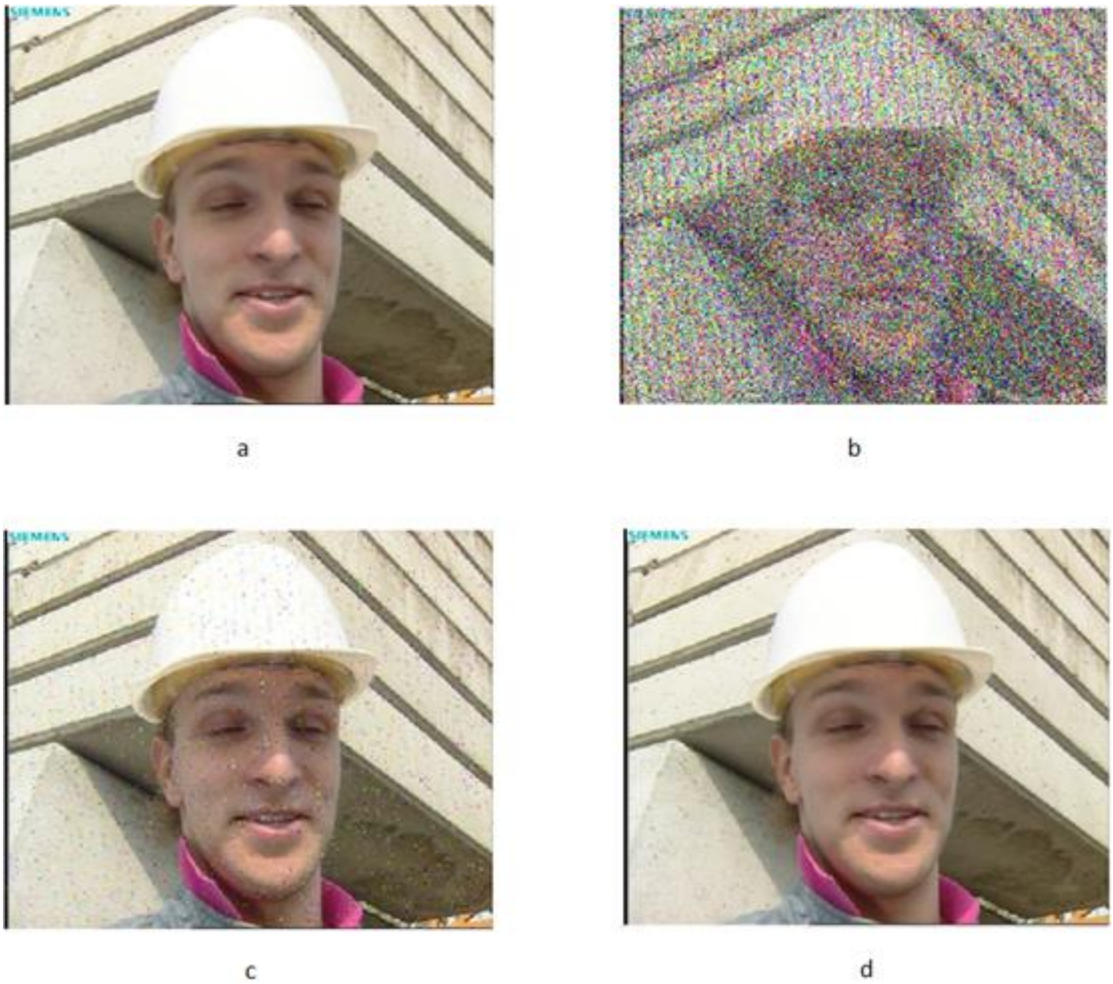


Figure 5.5: 16QAM without scalability (a) original (b) received at SNR=0 dB with BER=2.345×10^{-1} (c) received at SNR=13 dB with BER=8.5327×10^{-3} (d) received at SNR=20 dB with BER=4.6431×10^{-5}

The results presented in Figure 5.5 shows that at low SNR, it is not worthy to use 16QAM because of very high BER. Whereas at medium SNR, the result is quiet better but the image contains severe damages. At high SNR value, transmission is perfect and BER is very low. It would be preferable to use 16QAM only for high SNR because process and transmission time is less than QPSK.

Finally 64QAM is used to transmit at low, medium and high SNR values. 64QAM is considered to be faster modulation scheme than QPSK and 16QAM. However BER is high in this case. There is tradeoff between process and transmission time and error.

In this case, 62 subframes were required to transmit layers. Results of 64QAM presented in Figure 5.6 show more corrupted images with higher BERs for all SNR values.

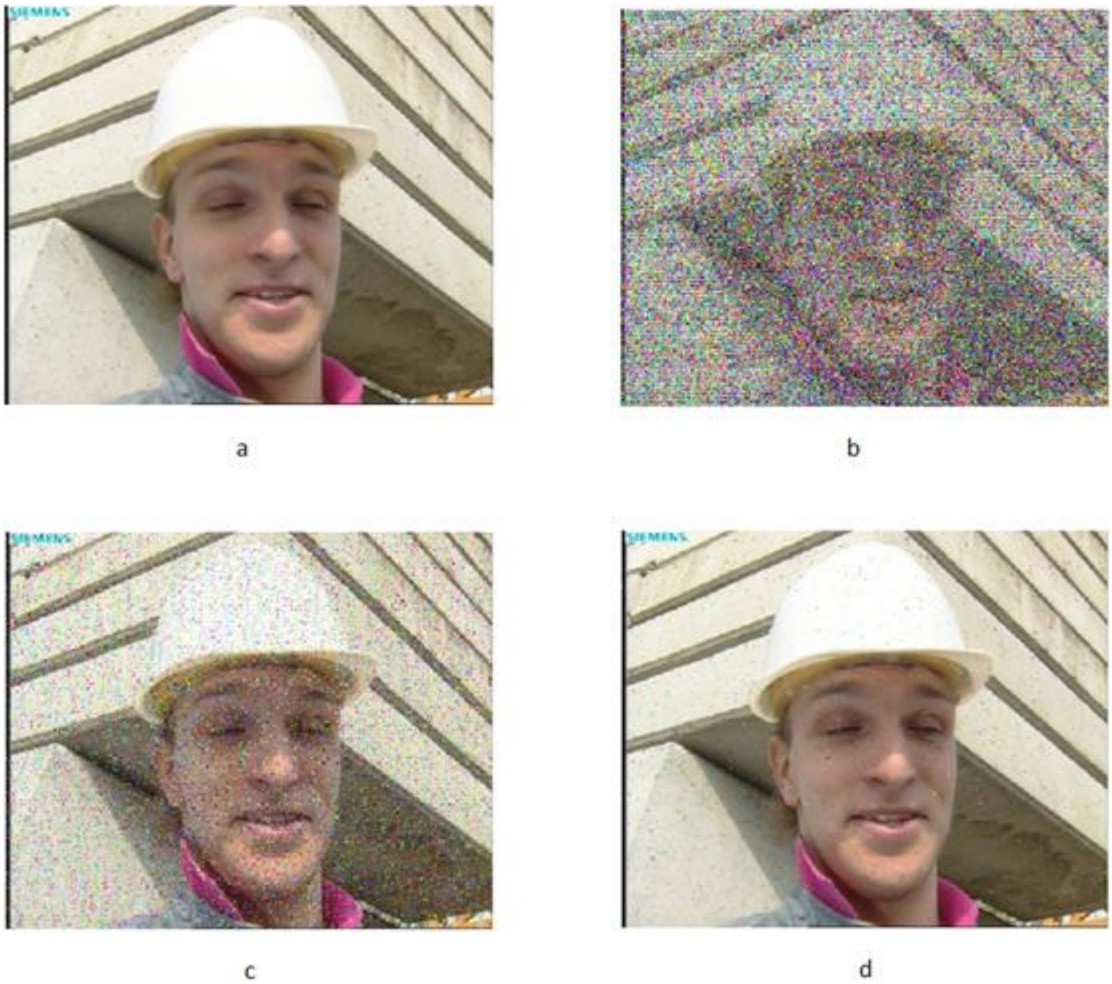


Figure 5.6: 64QAM without scalability (a) original (b) received at SNR=0 dB with BER=3.1271×10^{-1} (c) received at SNR=13 dB with BER=5.8807×10^{-2} (d) received at SNR=20 dB with BER=3.1946×10^{-3}

Average process and transmission time is also calculated for all three modulation scheme and presented in Table 5.1.

Table 5.1: Modulation scheme vs. process and transmission time

Modulation	Process and Transmission Time
QPSK	36
16QAM	19
64QAM	14

As from Table 5.1, it is clear that delay for QPSK is very high as compare to 16QAM and 64QAM. But 16QAM and 64QAM produces so close process and transmission time. So, both can be used interchangeably in tradeoff between process and transmission time and error.

5.2.3 Transmitting through LTE System with Scalability

In this section, we will analyze the transmission with scalability for different modulation scheme. As per our experimental parameters discussed in Table 4.2, only BL will be transmitted for low SNR. For medium and high SNR, BL with EL will be transmitted. This is the same case discussed in section 5.2.2 without scalability. First we will examine transmission of BL through QPSK which is shown in Figure 5.7 and then 16QAM and 64QAM modulation scheme in Figure 5.8 and Figure 5.9, respectively.

a b

Figure 5.7: QPSK with scalability (a) original base layer (b) received base layer at SNR=0 dB with BER= 6.9994×10^{-2}

a b

Figure 5.8: 16QAM with scalability (a) original base layer (b) received base layer at SNR=0 dB with BER=2.3405×10^{-1}

a b

Figure 5.9: 64QAM with scalability (a) original base layer (b) received base layer at SNR=0 dB with BER=3.1263×10^{-1}

As it is seen from Figure 5.7, received BL is acceptable at low SNR. At medium and high SNR, BL and EL are sent together, results will be same as in Figure 5.4 (c) and (d). Received image in Figure 5.8 is very blur and BER is high. 16QAM is not acceptable for low SNR. Figure 5.5 (c) and (d) are the results of 16QAM for medium and high SNR when BL and EL are sent together. As shown in Figure 5.9, BER is quiet high and received image is not acceptable for 64QAM modulation scheme. Figure 5.6 (c) and (d) are the results of 64QAM for medium and high SNR when BL and EL are sent together.

5.2.4 Comparison between QS and non-QS transmission

BER results were generated at different SNR values using all three modulation scheme for scalable and non-scalable case. As the values proposed in Table 4.2, BL and BL with EL are transmitted at different SNR values using different modulation scheme. A comparison graph for non-scalable case is shown in Figure 5.10 and scalable case is shown in Figure 5.11.

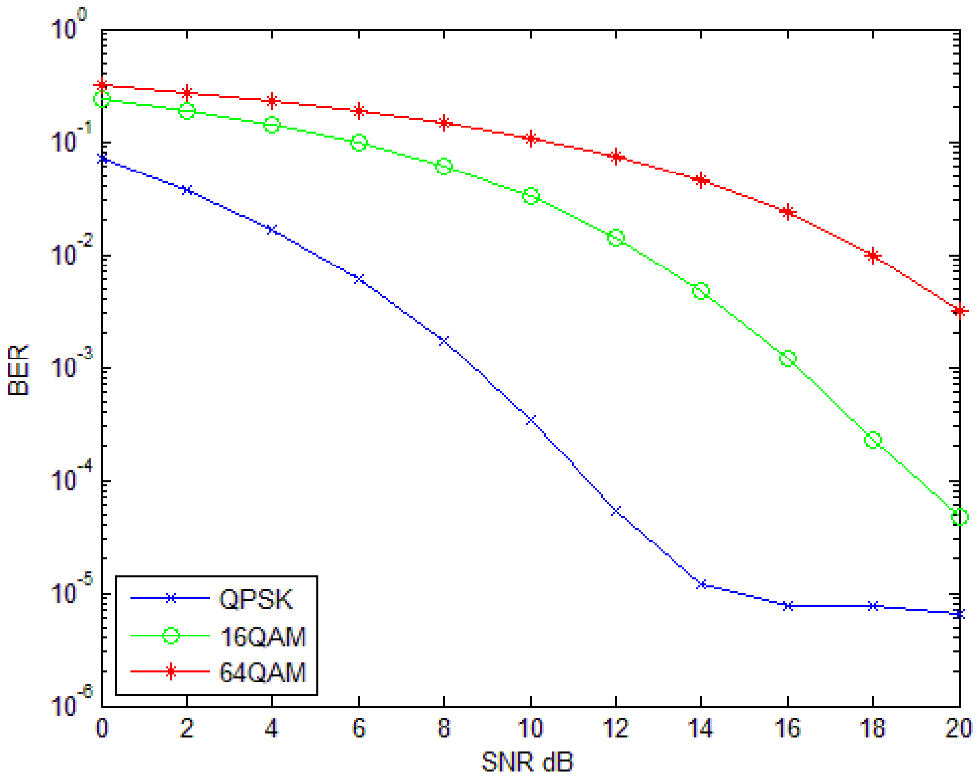


Figure 5.10: BER for non-scalable case.

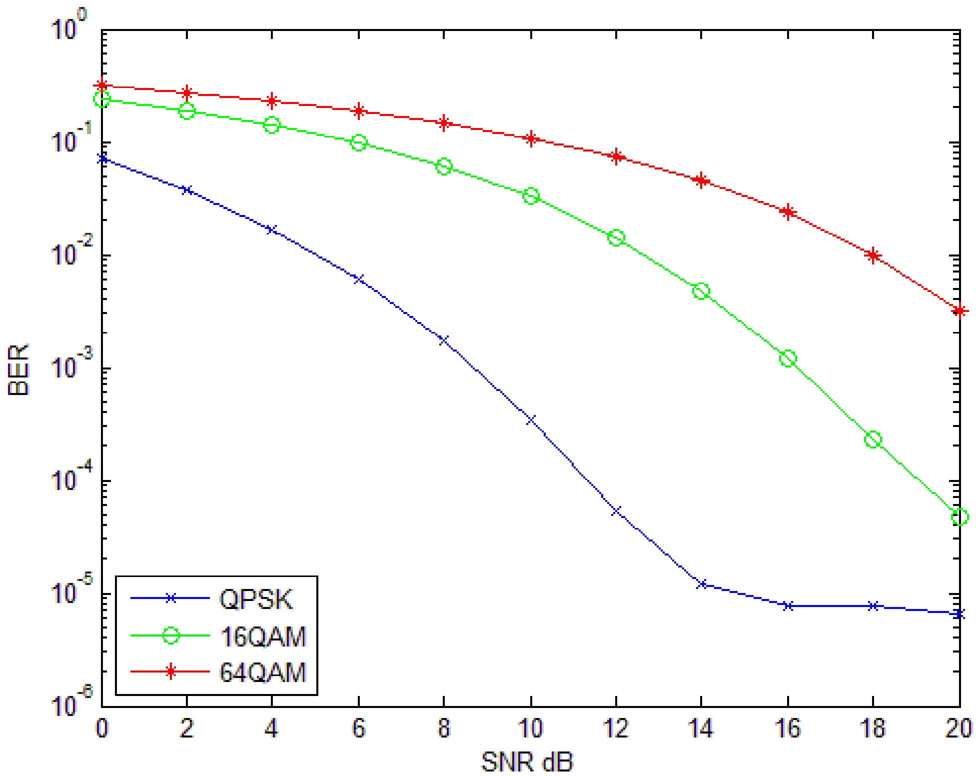


Figure 5.11: BER for scalable case.

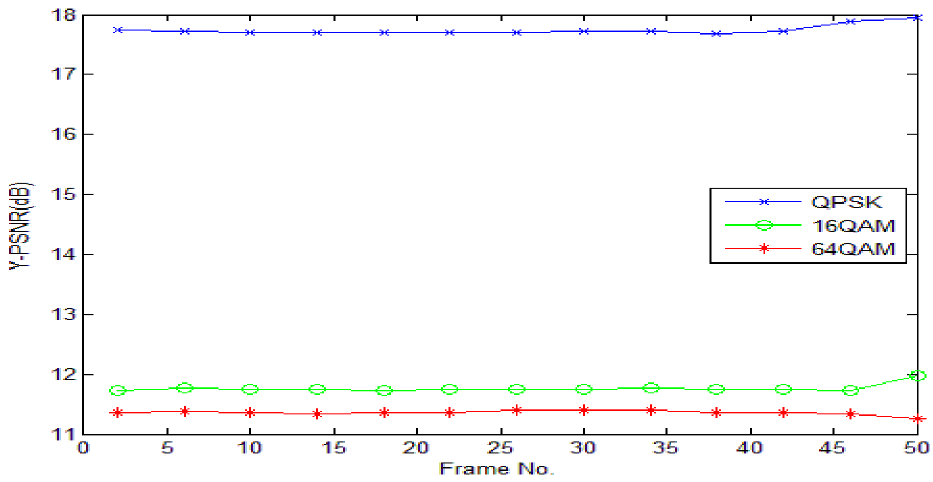
Y-Peak Signal to Noise Ratio (PSNR) in dB is calculated as in (1) for different frames using QPSK, 16QAM and 64QAM at low, medium and high SNR value.

$$\text{Y-PSNR} = 10 \log_{10} \frac{255^2}{MSE_Y} \qquad (1)$$

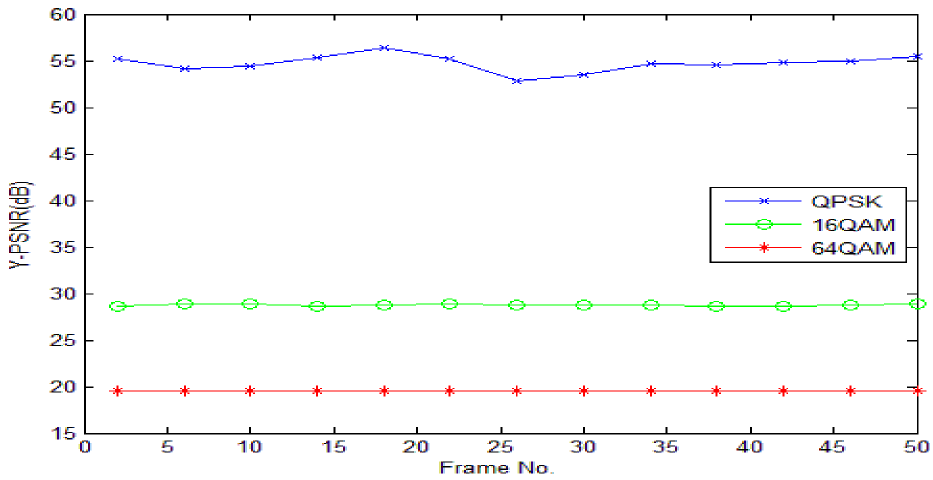
where MSE_Y is Min Square Error that represents the cumulative squared error between the received and the original image.

The Y-PSNR versus frame number graphs are presented for low, medium and high SNR values in Figures 5.12. It is observed in Figure 5.12 (a) that QPSK is reasonably better at low SNR. At medium SNR, Figure 5.12 (b) shows very high Y-PSNR for QPSK, whereas 16 QAM and 64QAM are reasonably better for it. For high SNR, Y-PSNR curve cannot be plotted for QPSK as received image is almost errorless and Y-PSNR is infinite. Because of that for high SNR, comparison between 16QAM and 64QAM is carried out as shown in Figure 5.12 (c). Here, 16QAM shows very high Y-PSNR as compare to 64QAM.

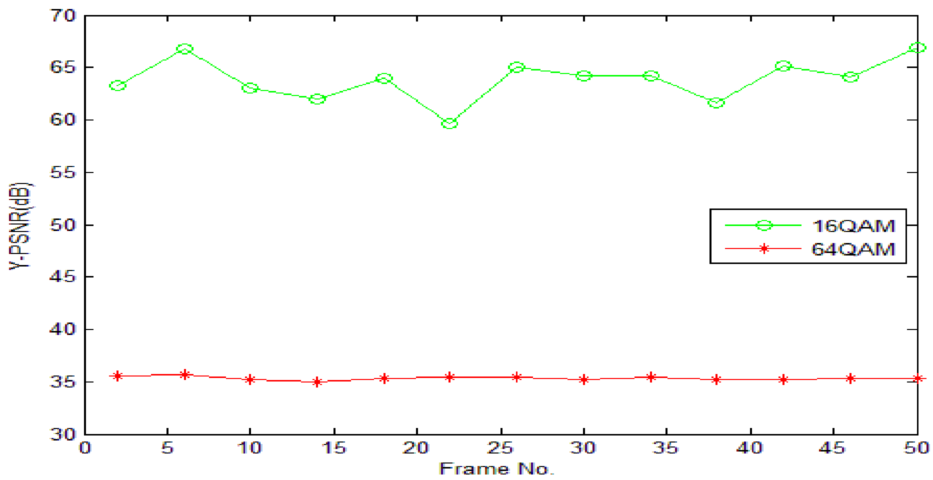
From the results, it is cleared that for both cases BER is slightly different for scalability but Y-PSNR for QPSK at low SNR is better than 16QAM and 64QAM. So we propose to use QPSK and 16QAM with BL because they have less BER at low SNR and 64QAM with BL and EL. Although BER of 64QAM is high, we prefer it because of less transmission and process time.



(a) Base layer with SNR = 0 dB



(b) Base + Enhancement layer at SNR = 13 dB



(c) Base + Enhancement layer at SNR = 20 dB

Figure 5.12: Y-PSNR versus frame number

Comparison between modulation schemes with BER is shown in Table 5.2. From the table, BER is considerably better at proposed scheme. This scenario can improve quality measures and parameters of LTE network for video transmission.

Table 5.2: Modulation scheme vs. BER comparison

CQI	SNR	LAYER	MODULATION	BER
1	-5.6	Base	QPSK	2.0651×10^{-1}
2	-3.85	Base	QPSK	1.6112×10^{-1}
3	-2.1	Base	QPSK	1.1642×10^{-1}
4	-0.35	Base	QPSK	7.6872×10^{-2}
5	1.4	Base	QPSK	4.5483×10^{-2}
6	3.15	Base	QPSK	2.3723×10^{-2}
7	4.9	Base	16QAM	1.208×10^{-1}
8	6.65	Base	16QAM	8.5071×10^{-2}
9	8.4	Base	16QAM	5.4307×10^{-2}
10	10.15	Base + Enhancement	64QAM	1.0458×10^{-1}
11	11.9	Base + Enhancement	64QAM	7.5388×10^{-2}
12	13.65	Base + Enhancement	64QAM	4.9719×10^{-2}
13	15.4	Base + Enhancement	64QAM	2.9116×10^{-2}
14	17.15	Base + Enhancement	64QAM	1.4688×10^{-2}
15	18.9	Base + Enhancement	64QAM	6.1947×10^{-3}

Chapter 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

This thesis proposed a method of adaption scheme for unicast transmission over LTE network using SVC. Scalability is applied at eNodeB using UE's CQI report. CQI report depends upon SNR value of channel. BER analyses for both scalable and non-scalable cases are investigated depending on different network conditions. Each scalable video layer is selected on channel condition based on SNR value. Different modulation schemes are examined at varying network conditions. Y-PSNR versus frame number is also analyzed by varying different channel conditions and modulation scheme. BL is transmitted at low SNR whereas BL with EL are transmitted at medium and high SNR. Simulation results show an adaptive scheme for MCS where layers are transmitted on specific modulation scheme. QPSK and 16QAM is used at low SNR since it has less BER and 64QAM is chosen at medium and high SNR because of less transmission and process time. BER for proposed scheme is analyzed and consider being better for transmission. Re-defining the parameters of LTE system can result in better network optimization in varying channel conditions and crowded area. This will result in better QoE.

6.2 Future Work

Multicast scenario can also be implemented in future for SVC. Saving of radio spectrum can be achieved by examining multicast scenario of video transmission with

SVC. The proposed scheme can also be implement on new video coding standard H.265/HEVC [25]. High Efficiency Video Coding (HEVC) is considered to compatible for SVC applications and reduction of bit-rate up to 50%. Proposed scheme can improve better QoS and network optimization using HEVC.

REFERENCES

[1] European Commission, “The EU Framework Programme for Research and Innovation”, available at http://ec.europa.eu/programmes/horizon2020/, last accessed January 2015.

[2] H. Schwarz, D. Marpe, T. Wiegand, “Overview of the scalable video coding extension of H.264/AVC,” *IEEE Trans. Circuits Syst. Video Technol.,* vol. 17, no. 9, pp. 1103–1120, Sep. 2007.

[3] T. Schierl, T. Stockhammer, T. Wiegand, “Mobile Video Transmission Using Scalable Video Coding”, *IEEE Trans. On Circuits and Systems for Video Technology,* vol. 17, no. 9, pp. 1204-1217, Sep. 2007.

[4] T. Varisetty, P. Edara, “Systematic Overview of Savings versus Quality for H.264/SVC,” Master Thesis, *Blenkinge Tekniska Högskola/COM*, 2012.

[5] K. Rantelobo, Wirawan, G. Hendrantoro, A. Affandi, “Combined Scalable Video Coding Method for Wireless Transmission,” *TELKOMNIKA*, vol. 9, no. 2, August 2011, pp. 295~302.

[6] R. Radhakrishnan, A. Nayak, “Cross Layer Design for Efficient Video Streaming over LTE Using Scalable Video Coding”**,** *IEEE International Conference on Communications (ICC),* Ottowa, 15 June 2012.

[7] J. Surati, K. Goswami, "Evaluate the Performance of Video Transmission Using H.264 (SVC) Over Long Term Evolution (LTE)," *International Journal on Recent and Innovation Trends in Computing and Communication* ISSN: 2321-8169, vol. 2, No. 1 pp 109 – 113.

[8] P. McDonagh, C. Vallati, A. Pande, P. Mohapatra, P. Perry, E. Mingozzi, "Quality-Oriented Scalable Video Delivery using H.264 SVC on an LTE Network," *14th International Symposium on Wireless Personal Multimedia Communications (WPMC'11),* 3-6 October 2011, Brest – France.

[9] T. Wiegand, G. J. Sullivan, G. Bjontegaard, A. Luthra, "Overview of the H.264/AVC video coding standard," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 13, no. 7, pp. 560–576, Jul. 2003.

[10] "The Scalable Video Coding Amendment of the H.264/AVC Standard", available at http://blog.csdn.net/worldpharos/article/details/3369933, last accessed January 2015.

[11] Weiping Li, "Overview of fine granularity scalability in MPEG-4 video standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol.11, no.3, pp.301 -317, Mar 2001.

[12] "Overview of LTE Release 8 and Release 9 radio aspects", available at http://www.mastertelecomfaster.com/lte/overview.php, last accessed January 2015.

[13] "Mobile Broadband Explosion - 3GPP Broadband Evolution to IMT-Advanced (4G)", Rysavy Research/4G Americas, Sep. 2011, available at http://www.rysavy.com/Articles/2011_09_08_Mobile_Broadband_Explosion.pdf, last accessed January 2015.

[14] "Ronit Nossenson — Long-Term Evolution Network Architecture", 2008.

[15] "MIMO-OFDM for LTE, Wi-Fi and WiMAX Coherent versus Non-coherent and Cooperative Turbo-transceivers",

[16] S. Choi, K. Jun, Y. Shin, S. Kang, B. Choi, "MAC Scheduling Scheme for VoIP Traffic Service in 3G LTE," *IEEE Vehicular Technology Conference*, pp. 1441-1445, Oct. 2007.

[17] J. C. Ikuno, M. Wrulich, M. Rupp, "System Level Simulation of LTE Networks," *IEEE Vehicular Technology Conference,* pp. 1 -5, May 2010.

[18] Weiping Li, "Overview of fine granularity scalability in MPEG-4 video standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol.11, no.3, pp.301 -317, Mar 2001.

[19] "YUV Video Sequences", available at http://trace.eas.asu.edu/yuv/, last accessed January 2015.

[20] J. Han, T. Wiegand, “Overview of the High Efficiency Video Coding (HEVC) Standard,” *IEEE Transactions on Circuits and Systems for Video Technolog,* vol. 22, no. 12, December 2012.

[21] Xi Chen, Haike Yi, Hanwen Luo, Hui Yu, Hailong Wang, “A novel CQI calculation scheme in LTE\LTE-A systems,” Wireless Communications and Signal Processing (WCSP), pp. 1-5, Nov. 2011.

[22] Yao Wang, Jörn Ostermann, Ya-Qin Zhang, (2002). Video Processing and Communications. Prentice Hall.