ANALYSISING THE EFFECT OF ENCODING SYSTEMS ON BANDWIDTH UTILISATION INDIGITAL TERRESTRIAL TRANSMISSION SERVICES

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The aim of the study was to analyse the effect of encoding systems on bandwidth utilization in digital terrestrial transmission services using various encodingsystems such as MPEG-2, MPEG- 4 and MPEG-5. The MUX02 BKP of Net processor 9030 encoder was used to analyse (MOTION PICTURE EXPERT GROUP-MPEG);

MPEG-2 and MPEG-4. For MPEG-5o simulation tools such as Matlab R2022a and mathematical formulas were used to estimate the results. The field works were carried out at UBC Kololo Transmission site. The encoding systems were used to analyse the percentage capacity usage for a given available capacity with each encoding system having a different data rate. A data rate of 4Mbps was used for MPEG-2, 2Mbps was used for MPEG-4 and 1Mbps was used for MPEG-5. Factor suchas antenna height, transmitter power and frequency were also analyzed to find their effects on the coverage of the broadcast signal. The study showed that MPEG-5 provides a variety of programs for a given bandwidth as compared to MPEG-4 and MPEG-2, this trades off the quality of the output due to more compression of the original signal which results into poor approximation of the output with input. MPEG-2 provides a high qualityof the output for a given bandwidth as compared to MPEG-4 and MPEG-5, this trades off the quantity of programs that can be transmitted due to less compression of the original signal which results into less number of the output programs. Therefore, if more number of programs are required, then MPEG-5 is recommended and if a higher quality output of the signal is required, then MPEG-2 is recommended. For a larger area of signal coverage, a higher transmitter power, lower transmission frequency and high antenna height are required.

Aim of The Study.
To analyse the effect of encoding systems on the bandwidthin digital terrestrial transmission services

Specific objectives
To analyse the extent to which encoding systems affect bandwidth utilization in (DIGITAL VIDEO BROADCASTING-DVB) DVB-T2.

To analyse the extent to which antenna height affects thesignal coverage area.
To analyse the extent to which transimmiter power affects thesignal coverage area in DVB-T2

INTRODUCTION

ENCODING: is the process of compressing and potentially changing the format of a video/audio content for example changing an analog source to a digital source. In regardsto compression, the goal is to consume less bandwidth [1]. When data is transmitted over a limited bandwidth channel, it becomes important to encode the signal for efficient utilization of the available bandwidth. Bandwidth utilization is mainly affected by factors such as the available signal bit rates which are determined by the type of encoding system used. Encoding started a way back in 1984 when the International Telecommunication Union (ITU) standardized algorithms used for encoding such as H.120 which was followed by
H.261 standard in 1990. The target was to transmit videoover Integrated Service Digital Network (ISDN) lines, with multiples of 64Kbit/s data rates. Therefore, H.262 algorithm was jointly developed by the Internationa Standards Organisation (ISO) and ITU standardization organizations and approved in 1993 [2]. In 1995 the H.263 algorithm was released [2]. The H.263 standard was developed by the ITU and it was a big step forward and is today's dominant video conferencing and cell phone codec. Later in 1995, H.264 algorithm was introduced and has continually been enhanced with new profiles including many novel coding concepts such as interactive graphics, object and shape coding, wavelet- based still image coding, face modeling, scalable coding and 3D graphics. Various encoding systems may be used during processing of data in DVB-T2 and these include; MPEG-1, MPEG-2, MPEG-4 AVC, MPEG-7 [3]. Advancements in the encoding standards was brought about by the need to transmit high quality videos at a lower bitrate and the desire to overcome the challenges faced by the previous encoding systems. For different encoding systems to maintain a similar signal quality, different bit rates are required for different encoding systems. To maintain a similar quality of the signal, MPEG-2 has a minimum bitrate requirement of 4Mbps, MPEG-4 has a minimum bitrate requirement of 2Mbps. Therefore,

new advancements in compression techniques focus on transmitting maximum amount of data at a lowerdata rate.

The DVB Family of Terrestrial Channel Coding

DVB-T [12] was developed in the mid to late 1990s, building on work conducted in a number of European research laboratories in the preceding decade. It uses a multicarrier modulation scheme known as Coded Orthogonal Frequency Division Multiplexing (COFDM). This gives excellent immunity to multipath reception, as well as resistance to interference from analogue television transmission systems. Two variants of the system were defined, using either about 2000 or about 8000 carriers (2K or 8K). The former system gives better performance for mobile reception; the latter allows rejection of very long echoes which occur in a Single Frequency Network (SFN), i.e. a network of multiple transmitters working on the same frequency. DVB-T uses the same error correction scheme as DVB-S [10]. This meant that the first generation receivers were able to use the same silicon as the already developed satellite receivers; an important advantage given that DVB-T equipment was required a very short time after the specification was finalized. Fortuitously, these codes give good performance when combined with the multicarrier modulation system. On each carrier, modulation constellations up to 64QAM are allowed. This means that the system can transmit significantly more data per unit bandwidththan DVB-S, but at the expense of requiring greater signal strength at the receiver. DVB-T2 [13] is the second generation terrestrial broadcasting system. Like DVB-T, it uses COFDM, but with up to 32K carriers. Using more carriers permits a shorter percentage guard interval, and hence a reduced loss of data capacity, for the same length of echoes as with DVB-T. It also has a lower overhead for pilots, closer to the theoretical minimum required to fully exploit a given guard interval. DVB-T2 allows constellations of up to 256QAM per carrier, thus allowing a greater bitrate capacity in each 8MHz UHF channel. DVB-T2 follows DVB-T in inheriting its error correction scheme from the corresponding satellite system, in this case DVB-S2 [11]. The low-density parity-check (LDPC) codes are well-suited to use in applications that approximate to an Additive White Gaussian Noise (AWGN) channel, such as line-of-sight satellite reception. However, they are not as well-suited to terrestrial reception, where COFDM modulationis working in a channel with strong multipath reception. To partially overcome this, DVB-T2 defines rotated constellations.

The transition from DVB-T to DVB-T2

Receiver chip sets for DVB-T2 became available shortly after the finalization of the standard in 2008. Set top boxesfor the reception of DVB-T2 and HDTV are readily available in UK shops, including models priced under £50 at the timeof writing. Some DVB-T only televisions are still being sold, but sets including DVB-T2 tuners are becoming increasingly prevalent. Availability of suitable receiving equipment is therefore not a barrier to the expansion of DVB-T2 services. However, because of the large installed base of DVB-T receivers, it is not yet practical to immediately switch offDVB-T transmissions. The situation in many other countries that have deployed DVB-T transmission is similar to the UK. For example, Italy has recently introduced a single DVB-T2 multiplex carrying both HDTV and SDTV services; most multiplexes are still DVB-T, carrying SDTV services and also a few HDTV services. Sweden is in the process of introducingtwo DVB-T2 multiplexes for (High Definition-HD) HDTV. Some countries that made a late start to Digital Terrestrial Transmission (DTT) are now in the fortunate position of being able to begin with DVB-T2 transmission. Examplesinclude some countries in Eastern Europe (e.g. Ukraine) and several in Africa (e.g. South Africa).

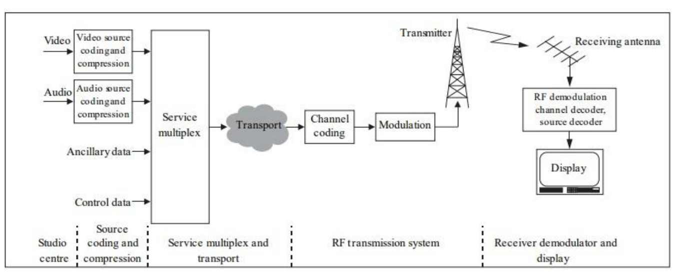

Figure 2.1 The ITU DTTB model / DTV System Model.

LITREATURE REVIEW

Digital Terrestrial Transmission Broadcasting services (DTTB). Digital Terrestrial Television (DTTV or DTT, or DTTB with "broadcasting") is a technology for terrestrial television in which land-based (terrestrial) television stations broadcast television content by radio waves to televisions in consumers' residences in a digital format. The DTTB system is designed to transmit high quality video and audio over a single 6, 7, or 8 MHz terrestrial channel. Modern digital transmission technologies can deliver a maximum of between 17 Mbit/s and 20 Mbit/s to encode video data within a single6, 7, or 8 MHz terrestrial channel. This means that encodingan HDTV video source whose resolution is typically five times that of the conventional television (NTSC, PAL or SECAM) resolution requires a bit-rate reduction by a factorof 50 or higher. To achieve this bit-rate reduction, there is worldwide agreement on the use of MPEG-2 video coding.

In order to meet the requirements of the many applications and services envisioned, the DTTB system must accommodate both progressive and interlaced scanned pictures across a broad range of spatial and temporal resolutions.

The DTTB model is divided into four subsystems as shown in Figure: 2.1 [4].

Source coding and compression
Source coding refers to bit-rate reduction methods also known as data compression and error protection techniques that are appropriate for application to the video, audio and ancillary digital data streams. Ancillary data includes control data, including conditional access control, and data associated with the audio program and video services such as closed captioning. Ancillary data can also refer to independent program and data services.

Service multiplex and transport.
The “service multiplex” and transport refers to the meansof dividing the digital data stream into packets of information, the means of uniquely identifying each packet or packet type, and the appropriate means of multiplexing the video data stream packets, the audio data stream packets and the ancillary data stream packets into a single data stream. Interoperability or harmonization between digital media such as terrestrial broadcasting, cable distribution, satellite distribution, recording media, and computer interfaces must be a prime consideration in developing an appropriate transport mechanism.

The physical layer.
This comprises of; 1 - RF channel coding, modulation and propagation 2 - The receiving installation; demodulator, channel decoder and content decompression.
The “physical layer” refers to the means of using the digitaldata stream information to modulate the transmitted signal and encompasses channel coding, i.e. the forward error-protection to protect the broadcast signal against incorrectly decoded bits.

Planning factors (both transmission and receiver) and implementation strategies.
Planning factors and implementation strategies include discussions of strategies appropriate for the introduction and implementation of digital terrestrial television broadcast service. The plans for any such strategies must recognize the interference characteristics of the over-the-air media and the practical limitations imposed at the receiver.

DTTB in the media environment.
DTTB services are introduced in parallel with other means of delivery such as satellite-TV, cable-TV or IPTV (online TV on managed broadband networks) and streaming services on the open Internet (often called OTT (Over-the-Top) TVor online TV). Satellite and cable TV typically provide more television channels than DTTB owing to the larger channel bandwidth (satellite case) and larger frequency spectrum for TV on cable. In theory, with IPTV or streaming over the open Internet, the number of TV programs available is unlimited. Despite its lower capacity, DTTB is generally seen as most important for the future of TV broadcasting [4].
Terrestrial broadcasting is uniquely important because it is wireless (supports receivers that can move), infinitely scalable (point-to-multipoint and one-to-many architecture), local (capable of delivering geographically local content), timely (provides real time and non-real time delivery of content) and flexible (supports free-to-air and subscription services). The attribute of wireless delivery of media content to a potentially unlimited number of receivers makes terrestrial broadcastinga vital technology all over the world. Broadcasting is, in fact, the most spectrum-efficient wireless delivery means for popular real-time and file-based media content [4].

Channel coding
Channel coding is often used in digital communication systems to protect the digital information from noise and interference and reduce the number of bit errors. Channel coding is mostly accomplished by selectively introducing redundant bits into the transmitted information stream. These additional bits allows the detection and correction of bit errors in the received data stream and provide more reliable information transmission [1]. The cost of using channel coding to protect the information is a reduction in data rateor an expansion in bandwidth. Channel coding enables the receiver to detect and correct errors, if they occur during transmission due to noise, interference and fading. Channel coding modifies the outgoing message, which is known as "Forward Error Correction" (FEC). At the receiving end, the channel coding bits are used to verify the validity of the message and correct most errors. Channel coding improvesthe signal-to-noise ratio (SNR) [1].

METHODOLOGY

Introduction

This chapter presents the steps that were employed during data collection and the research study. It gives details aboutthe research design, procedures taken during the collectionand multiplexing of signal SDI feeds, distribution of the signal stream, determining the coverage area of the signal streams, data collection, presentation and analysis. The analysis involved drafting of graphs that were derived fromthe tables of results from findings.

Research design

The study involved studying the current, assessing alternatives,and discovering new ideas as well as taking on practical tests and simulations. The overall approach followed a four-stage process which was; establishing the basis of the research proposal, field work was done through interviews, simulations and practical tests from UBC transmission site in Kololo, a report about the findings were made, conclusionsand recommendations were drawn based on the findings [17]. The research was carried out to analyse the effect of encoding systems on bandwidth utilization in digital terrestrialtransmission services.

Sample (programs) collection, multiplexing and distribution

Collection of SDI feeds

40 feeds (programs) from various broadcasting houses suchas; NTV, UBC, NBS, SPARK, SANYUKA, TOP, FACE, MAGIC, STAR, BBS were collected at UBC transmission site in Kololo using various transmission media such as microwave used by UBC, MAGIC, STAR and NTV, SPARK TV, i-way fiber link by BBS TV, CGTN TV received by satellite to mention but a few. All the feeds were collected at UBC TV Kololo Transmission site [17].

Encoding the feeds using MPEG-2,3 5

The received feeds at the transmission site were encoded using three different encoding techniques that's to say MPEG-2, MPEG-3, MPEG-5. For MPEG-2 and MPEG-4,
the MUX02 BKP of Net processor 9030 encoder was usedand for MPEG-5, various simulation tools such as Matlab R2022a and mathematical formulas were used to estimate the results. The effect of the encoding system on the bandwidthof the signal feeds from the 40 stations were studied, analyzedand conclusion were made [17]. The feeds that come as IP samples were decoded into SDI signals using the DVB-T2 Gateway1 and 2 for decoding microwave link feeds and for fiber links using a DENSITE 3 of Miranda model equipmentat UBC TV Kololo Transmission site [17].

Multiplexing of SDI signal samples

The converted Serial Digital Interface (SDI) sample feeds were fed into the Platium 1 or a NetVX Harris multiplexer models to get three output streams as configured inside the multiplexers [17]. The three output streams were fed into Fresco-Atom multiviewer to be previewed on the multi-displayscreen connected to the playout server to ensure that all the feeds from the various broadcasting houses have reached the transmission station and that they have been decoded, multiplexed as per the expectation [17].

SDI processing and amplification to produce an RF signal

Using the various encoding techniques, decoding and previewing all the expected feeds and confirming that theyare available, the feeds were then be channeled for further processing that is modulation and amplification [17]. The
40 feeds from the play server were channeled to three transmitters for further processing namely;

1. The Transmitter Control Unit (TCU) Transmitter of Harris model that is composed of the APEX M2XTM Exciter (Modulator) of Maxiva Harris TX A 474MHZ anda non-linear amplifier with a power of 3.6KW: With thistransmitter, 15/45 stations were sent for modulation on a 21 channel so as to obtain an RF signal that were later amplified [17].
2.A TCU Transmitter of Harris model that is composed ofthe APEX M2XTM Exciter (Modulator) of Maxiva Harris TX A 594MHZ and a non-linear amplifier of 3.6KW: With this transmitter, 15/45 stations were sent for modulation ona 32 channel so as to obtain an RF signal that were later amplified [17].
3.A Thomson Transmitter that is composed of an Exciter (Modulator) and a non-linear amplifier with transmitter power ranging from 1.5KW to 2KW: With this transmitter, 10 stations were sent for modulation on a 53 channel so as to obtain an RF signal that was later amplified [17].

Filtering and Distribution of the RF signal

After formation and amplification of the RF signal, bandpass filters were set to allow only the RF signal within the allowable bandwidth assigned to each transmitter by setting the nobs mounted of the filters on each transmitter depending on the channels assigned [17]. The output signals from thetwo TCU Transmitters of Harris model were passed through a MISO combiner to produce a single output. Then the output from combiner one was later combined with the output from the filter at the Thomson to produce a single RF signal that was channeled to the omni-directional antenna for signal distribution [17].

Measurement of the effect of encoding on the available capacity For MPEG-2

A fixed capacity of 30Mbps was used. Each SDI stream received was encoded using a MUX02 BKP of Net processor 9030 encoder configured to encode the streams using MPEG- 2 at a bitrate of 4Mbps. The number of usable channels that can be utilized was calculated from;

$$Number\ of\ channels = \frac{Available\ capacity}{Bitrate\ of\ MPEG-2} \quad (3.1)$$

The streams were fed into available channels with each channel carrying an average of 15 streams multiplexed using Code Orthogonal Frequency Division Multiple Access (COFDM) technique [17]. Considering the average capacityof the composite streams to be 250Kbps and the capacityof the control signals such as sync signals, blunking or zero signals to be 42Kbps leaving a capacity of 208Kbps for the message stream. The total number of composite streams that can be fed into the channels was obtained from;

$$N_{MPEG-2} = 15\,x\ Available\ channels \quad (3.2)$$

The minimum capacity C_{MPEG-2} occupied by the controlsignals for MPEG-2 was obtained from;

$$C_{MPEG-2} = (250K - 208K)\ x\ N_{MPEG-2} \quad (3.3)$$

To get the number of programs $N_{MPEG-2-}$ that are to besubtracted from the total number of composite streams N_{MPEG-2}, the formula below was used;

$$N_{MPEG-2-} = \frac{C_{MPEG-2}}{250K} \quad (3.4)$$

Therefore, the number of message streams $N_{MPEG-2(message)}$ that can occupy the available capacity when MPEG-2 is used was calculated from;

$$N_{MPEG-2(message)} = 15\,x\ Available\ channels - N_{MPEG-2-} \quad (3.5)$$

calculated from;

$$N_{MPEG-4(message)} = 15\,x\ Available\ channels - N_{MPEG-4-} \quad (3.12)$$

The capacity utilized in MHz was obtained from;

$$Capacity\ Utilised = \frac{N_{MPEG-2(message)}\ x\ Average\ capacity\ of\ the\ streams}{1000} \quad (3.6)$$

The capacity utilized in MHz was obtained from;

The percentage capacity utilization was obtained from;

$$Capacity\ Utilised = \frac{N_{MPEG-4(message)}\ x\ Average\ capacity\ of\ the\ streams}{1000} \quad (3.13)$$

The percentage capacity utilization was obtained from;

$$\%\ Capacity\ usage = \frac{Capacity\ utilised}{Available\ capacity} x100\% \quad (3.14)$$

$$\%\ Capacity\ usage = \frac{Capacity\ utilised}{Available\ capacity} x100\% \quad (3.7)$$

The values of the available capacity were altered while maintaining the minimum capacity occupied by the control signals to observe the way how capacity utilization is affected by the use of MPEG-2 encoding system.

For MPEG-4

A fixed capacity of 30Mbps was used. Each SDI stream received were encoded using a MUX02 BKP of Net processor 9030 encoder configured to encode the streams using MPEG- 4 at a bitrate of 2Mbps. The number of usable channels that can be utilized was calculated from;

The values of the available capacity were altered while maintaining the minimum capacity occupied by the control signals to observe the way how capacity utilization is affected by the use of MPEG-4 encoding system.

For MPEG-5

A fixed capacity say 30Mbps were used. Various simulation tools such as Radio Mobile and mathematical formulas were used to estimates the results at a bitrate of 1Mbps [17]. The number of usable channels that can be utilized was calculated from;

$$Number\ of\ channels = \frac{Available\ capacity}{Bitrate\ of\ \ MPEG-5} \quad (3.15)$$

$$Number\ of\ channels = \frac{Available\ capacity}{Bitrate\ of\ \ MPEG-4} \quad (3.8)$$

The streams were fed into available channels with each channel carrying an average of 15 streams multiplexed using Code Orthogonal Frequency Division Multiple Access (COFDM) technique [17]. Considering the average capacityof the composite streams to be 125Kbps and the capacityof the control signals such as sync signals, blunking or zero signals to be 17Kbps leaving a capacity of 108Kbps for the message stream. The total number of composite streams that can be fed into the channels was obtained from;

The streams were fed into the available channels with each channel carrying an average of 15 streams multiplexed using Code Orthogonal Frequency Division Multiple Access (COFDM) technique [17]. Considering the average capacity of the composite streams to be 64Kbps and the capacity ofthe control signals such as sync signals, blunking or zerosignals to be 7Kbps leaving a capacity of 57Kbps for themessage stream. The total number of composite streams that can be fed into the channels was obtained from;

$$N_{MPEG-5} = 15\,x\ Available\ channels \quad (3.16)$$

$$N_{MPEG-4} = 15\,x\ Available\ channels \quad (3.9)$$

The minimum capacity C_{MPEG-4} occupied by the controlsignals for MPEG-4 was obtained from;

The minimum capacity occupied by the control signals forMPEG-5 was obtained from;

$$C_{MPEG-5} = (64K - 57K)\ x\ N_{MPEG-5} \quad (3.17)$$

$$C_{MPEG-4} = (125K - 108K)\ x\ N_{MPEG-4} \quad (3.10)$$

To get the number of programs C_{MPEG-4} that are to besubtracted from the total number of composite streams C_{MPEG-4}, the formula below was used;

$$N_{MPEG-4-} = \frac{C_{MPEG-4}}{125K} \quad (3.11)$$

Therefore, the number of message streams $N_{MPEG-4(message)}$ thatcan occupy the available capacity when MPEG-4 is used was

$N_{MPEG-5-}$

To get the number of programs that are to besubtracted from the total number of composite streams $N_{MPEG-5-}$, the formula below was used;

$$N_{MPEG-5-} = \frac{C_{MPEG-5}}{64K} \quad (3.18)$$

Therefore, the number of message streams $N_{MPEG-5(message)}$ that can occupy the available capacity when MPEG-5 is used was calculated from;

$$N_{MPEG-5(message)} = 15\,x\ Available\ channels - N_{MPEG-5-} \tag{3.19}$$

The capacity utilized was obtained from;

$$Capacity\ Utilised = \frac{N_{MPEG-5(message)}\ x\ Average\ capacity\ of\ the\ streams}{1000} \tag{3.20}$$

utilization of the available capacity for each encoding system that is MPEG-2, MPEG-4 and MPEG-5. The extent to which coverage area is affected by the transmitter power and the antenna height is also presented. The results were obtained from analysis of the available capacity and how it's utilizationis affected by encoding systems using the MUX02 BKP of
The percentage capacity utilization was obtained from;

$$\%\ Capacity\ usage = \frac{Capacity\ utilised}{Available\ capacity} x100\% \tag{3.21}$$

The values of the available capacity were altered whilemaintaining the minimum capacity occupied by the control signals to observe the way how capacity utilization is affected by the use of MPEG-5 encoding system.

Effect of antenna height on the coverage area in DVB-T2.
This was done by the use of directional antennas, the radius of the Fresnel zone of each directional antenna was calculated from [16];

$$r = 0.5x\sqrt{\lambda x d} \tag{3.7}$$

Where r = Radius of the Fresnel zone, lambda = Wavelength Samples: 2 meters for 150 MHz, 0.750 meters for400 MHz, 0.345 meters for 868 MHz and 0.125 meters for
2.4 GHz and $d=\sqrt{a^2+h^2}$ which is the distance between the antennaand the ground level along the main lobe axis (meters) and this height of the tower in meters.
Using equation (2.2), distance from the point of intersectionof the ground and the main lobe axis to the edge of the area covered by the signal was calculated from [16];

$$a = \frac{D}{2} \tag{3.8}$$

Where the maximum distance of the signal coverage on the ground level, is the angle of elevation from the axis antenna to the axis of the main lobe.
The coverage area of the signal from the directional antenna was calculated from [16];

$$A = \Pi ar \tag{3.9}$$

The antenna height was adjusted to obtain different values of and so as to examine the changes in the coverage area of the signal with a fixed transmitter power and a fixed operatingfrequency.

FINDINGS AND RESULTS OF THE STUDY

The results of the study have been presented in this chapter. The results presented are the number of channels, number of programs, capacity utilization and the percentage

Net processor 9030 encoder and various simulation tools suchas Radio Mobile. The results area as follows:

Results for capacity utilization using different encodingsystems
The results presented are the effect of MPEG-2, MPEG-4 and MPEG-5 on utilization of the available channel capacity.

Results for capacity utilization using MPEG-2

Table 4.1: Results for capacity utilization using MPEG-2

Available capacity (Mbps)	No of channels	No of programs	Capacity utilised (Mbps)	Percentage capacity usage
30	8	93	23	77.08
36	9	115	29	79.86
40	10	130	33	81.25
45	11	149	37	82.64
50	13	168	42	83.75
54	14	183	46	84.49
60	15	205	51	85.42
66	17	228	57	86.17

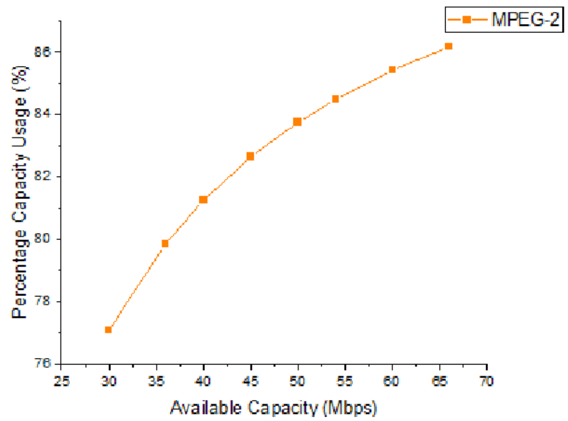

Figure 4.1: A graph of capacity utilisation using MPEG-2 As observed from Table 4.1 and the graph in Figure 4.1, the percentage usage of the available capacity increases exponentially with increase in the size of the available capacity. From table 4.1, the least capacity utilisation is 77.08% for a 30Mbps capacity and the maximum is 86.17% for a 66Mbps capacity.

Results for capacity utilization using MPEG-4

Table 4.2: Results for capacity utilization using MPEG-4

Available Capacity (Mbps)	No of channels	No of programs	Capacity utilised (Mbps)	Percentage capacity usage
30	15	195	24	81.25
36	18	240	30	83.33
40	20	270	34	84.38
45	23	308	38	85.42
50	25	345	43	86.25
54	27	375	47	86.81
60	30	420	53	87.50
66	33	465	58	88.07

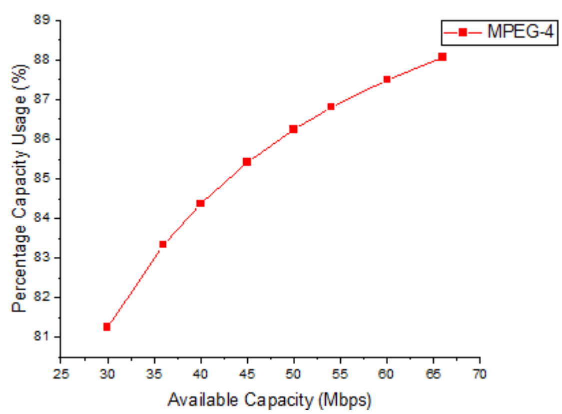

Figure 4.2: A graph of capacity utilisation using MPEG-4 As observed from Table 4.2 and the graph in Figure 4.2, the percentage usage of the available capacity increases exponentially with increase in the size of the available capacity. From table 4.2, the least capacity utilisation is 81.25% for a 30Mbps capacity and the maximum is 88.07% for a 66Mbps capacity.

Results for capacity utilization using MPEG-5

Table 4.3: Results for capacity utilization using MPEG-5

Available Capacity (Mbps)	No of channels	No of programs	Capacity utilised (Mbps)	Percentage capacity usage
30	30	400	26	85.33
36	36	490	31	87.11
40	40	550	35	88.00
45	45	625	40	88.89
50	50	700	45	89.60
54	54	760	49	90.07
60	60	850	54	90.67
66	66	940	60	91.15

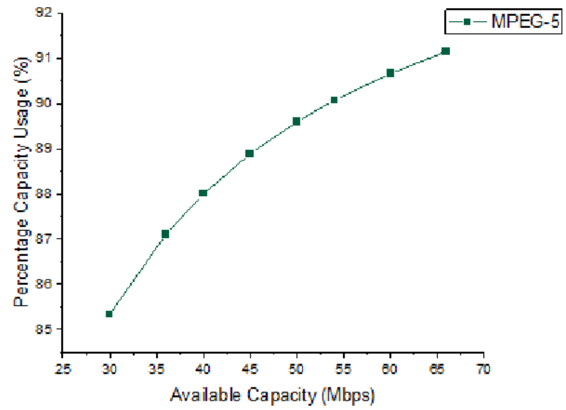

Figure 4.3: A graph of capacity utilisation using MPEG-5 As observed from Table 4.3 and the graph in Figure 4.3, the percentage usage of the available capacity increases exponentially with increase in the size of the available capacity. From table 4.3, the least capacity utilisation is 85.33% for a 30Mbps capacity and the maximum is 91.15% for a 66Mbps capacity.

Results for capacity utilization of MPEG-2, MPEG-4and MPEG-5

Table 4.4: Results for capacity utilization of MPEG-2, MPEG-4 and MPEG-5

Available Capacity (Mbps)	Percentage Channel Utilisation (%)		
	MPEG-2	MPEG-4	MPEG-5
30	77.08	81.25	85.33
36	79.86	83.33	87.11
40	81.25	84.38	88.00
45	82.64	85.42	88.89
50	83.75	86.25	89.60
54	84.49	86.81	90.07
60	85.42	87.50	90.67
66	86.17	88.07	91.15

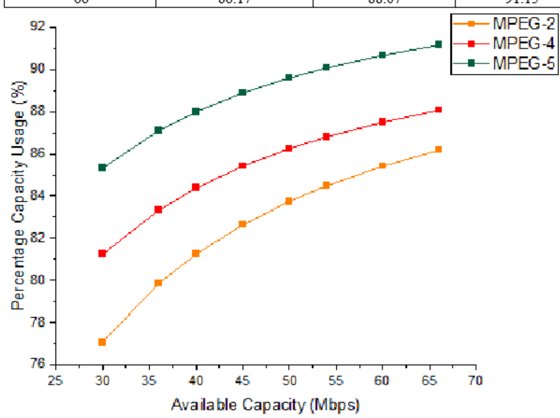

Figure 4.4: A graph of capacity utilization of MPEG-2,MPEG-4 and MPEG-5

As observed from Table 4.4 and the graph in Figure 4.4,the percentage usage of the available capacity increases with increase in the size of the available capacity. Figure 4.4 shows that the percentage usage of the available capacity isthe highest when MPEG-5 is used followed by the usage of MPEG-4 and lastly MPEG2.

Results of the area covered for different antenna heights

Table 4.5: Results of the area covered for different antennaheights

Antenna height (m)	D (m)	a (m)	d (m)	Fresnel Radius, r (m)	Area (sq.m)
100	3310	1655	1658.018396	28.79251982	149762.2353
150	3510	1755	1761.398592	29.67657824	163687.5265
250	3690	1845	1861.860629	30.51115065	176921.0864
500	3840	1920	1984.03629	31.49631955	190057.7911
600	3860	1930	2021.113554	31.78925569	192824.5424
750	3890	1945	2084.592286	32.28461155	197351.2183
800	3890	1945	2103.098904	32.42760324	198225.3061
1000	3910	1955	2195.910973	33.13541137	203593.4347

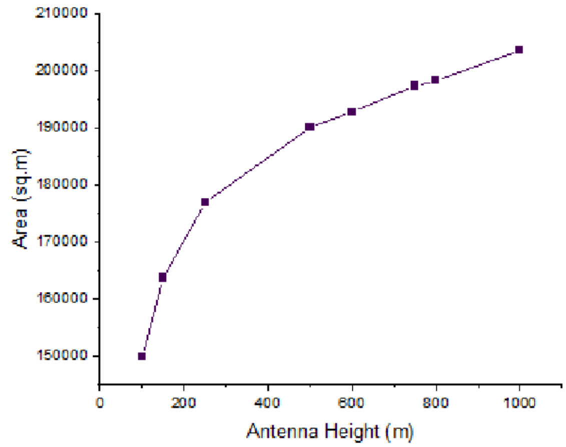

Figure 4.5: A graph of the area covered for different antenna heights

As observed from Table 4.5 and the graph in Figure 4.5,the coverage area increases exponentially with increase in the size of the antenna height. With a fixed transmitter power of 25 dBm, from table 4.5, the least area that can be covered is 149762.2353 sq.m for an antenna height of 100m abovethe sea level and the maximum area that can be covered is 203593.4347 sq.m for an antenna height of 1000m above the sea level.

Results of the area covered given different transmitter power

Table 4.6: Results of the area covered given differenttransmitter power

Transmitter power (dBm)	D (m)	a (m)	d (m)	Fresnel Radius, r (m)	Area (sq.m)
25	3690	1845	1845.169369	30.37407915	176126.2676
30	3720	1860	1860.24192	30.49788451	178281.9192
35	3770	1885	1885.324906	30.70280855	181892.2101
40	3800	1900	1900.421006	30.82548464	184072.1797
50	3820	1910	1910.654338	30.9083673	185538.5134
55	3842	1921	1921.787189	30.99828374	187149.9239
60	3855	1928	1928.433626	31.05184073	188107.6152
65	3876	1938	1939.089735	31.13751543	189654.1583

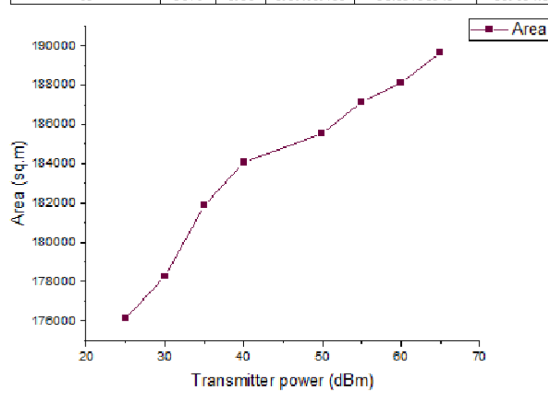

Figure 4.6: A graph of the area covered given differenttransmitter power

As observed from Table 4.6 and the graph in Figure 4.6,the coverage area increases non linearly with increase in the size of the transmitter power. With a fixed antenna height of 250m above the sea level, from table 4.6, the least area that can be covered is 176126.2676 sq.m for a transmitter powerof 25 dBm and the maximum area that can be covered is 189654.1583 sq.m for a transmitter power of 65 dBm.

Results of the area covered given different frequencies

Table 4.7: Results of the area covered given differentfrequencies

Frequency (MHz)	Wavelength (m)	D (m)	a (m)	d (m)	r (m)	Area (sq.m)
100	2.500	3310	1655	1658.018396	32.19101578	167439.2692
150	2.000	3510	1755	1761.398592	29.67657824	163687.5265
250	0.800	3690	1845	1861.860629	19.29694602	111894.7199
500	0.750	3840	1920	1984.03629	19.28747792	116386.1525
600	0.450	3860	1930	2021.113554	15.07896796	91464.7114
750	0.320	3890	1945	2084.592286	12.91384462	78940.48733
800	0.125	3890	1945	2103.098904	8.10690081	49556.32653
850	0.100	3910	1955	2195.910973	7.409303228	45524.87597

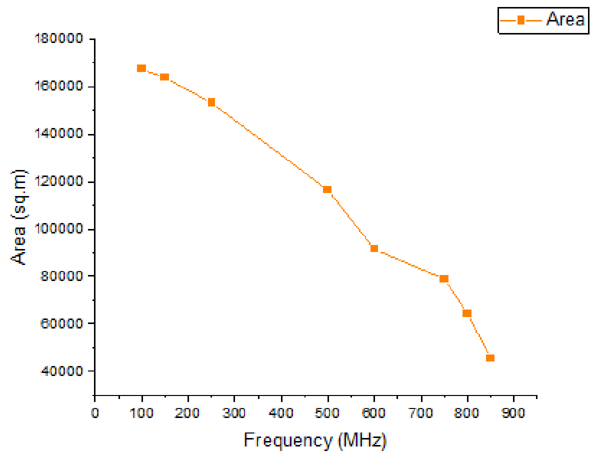

Figure 4.7: A graph of the area covered given differentfrequencies

As observed from Table 4.7 and the graph in Figure 4.7,the coverage area decreases non linearly with increase in the frequency of operation. With a fixed antenna height of 250m above the sea level, from table 4.7, the least area that can be covered is 45524.87597 sq.m for a frequency of 850Mhz and the maximum area that can be covered is 167439.2692 sq.m for a transmitter power of 100Mhz.

DISCUSSION OF RESULTS, CONCLUSION ANDRECOMMENDATIONS

Areas covered during the study

The encoding systems that were used during the study were MPEG-2, MPEG-4 and MPEG-5. The systems were used to analyse how much they affect the bandwidth utilisationin Digital Terrestrial Transmission Broadcasting DTTB. The transmitter power and the antenna height were also adjustedto find how much the area of signal coverage is affected using the Radio Mobile simulation tool.

Encoding systems on bandwidth utilisation

From the results of the study, MPEG-5 outputs more number of programs as compared to MPEG- 4, MPEG-4 outputs more number of programs as compared to MPEG-2. This is because MPEG- 5 has a lower data rate which is 1Mbps as compared to MPEG-4 and MPEG-2 which have a data rate of 2Mbps and 4Mbps respectively. Therefore, the lower the bit rate of an encoding system the more the number of programs that can be carried over the same bandwidth. If more number of programs are required, then MPEG-5 is a recommended encoding system due to its lower data rate.

Encoding systems on the quality of services

From the results of the study, MPEG-2 outputs lower number of programs as compared to MPEG- 4, MPEG-4 outputs more number of programs as compared to MPEG-5. This is because MPEG- 2 has a higher data rate which is 4Mbps as compared to MPEG-4 and MPEG-5 which have a data rateof 2Mbps and 1Mbps respectively. The higher the bit rateof an encoding system the more the quality of the output.
If a program of a higher quality is required, then MPEG-2is a recommended encoding system due to its higher data rate.

Transmitter power on the coverage area of DTTB-T2 The transmitter power and the area of signal coverage are directly proportional to each other, that’s to say a hightransmitter power will result into a longer broadcast distanceof the signal. Therefore, for a large distance to be covered fora given antenna height, a high transmitter power needs to be provided at the broadcasting station.

Antenna height on the coverage area of DTTB-T2

The antenna height and the area of signal coverage are directly proportional to each other, that's to say a higher antenna mounting results into a longer broadcast distance of the signal. Therefore, for a large distance to be covered at a fixed transmitter power, the transmitting antenna needs to be mounted at a higher height during broadcasting.

Frequency on the coverage area of DTTB-T2

The frequency of operation is inversely proportional to the wavelength of the signal, a higher frequency results into a lower wavelength and a lower frequency results into a higher wavelength, therefore lower frequencies result into large values of the Fresnel radius region due to a large wavelength. Therefore, for a large distance to be covered at a fixed transmitter power, a lower frequency of operation is needed during broadcasting.

CONCLUSION

MPEG-5 provides a variety of programs for a given bandwidth as compared to MPEG-4 and MPEG-2, this trades off the quality of the output due to more compression ofthe original signal which results into poor approximation ofthe output with input. MPEG-2 provides a high quality ofthe output for a given bandwidth as compared to MPEG-4 and MPEG-5, this trades off the quantity of programs thatcan be transmitted due to less compression of the original signal which results into less number of the output programs. Therefore, if more number of programs are required, then MPEG-5 is recommended and if a higher quality output ofthe signal is required, then MPEG-2 is recommended. Fora larger area of signal coverage, a higher transmitter power, lower transmission frequency and high antenna height are required.

Recommendations

A detailed study of various advanced encoding systems suchas MPEG-7, MPEG-5 Advanced Video Coding (Advanced Video Coding)AVC etc. should be done in order to examinea wider area of the available encoding systems on how they affect the bandwidth utilization in DTTB. The study can be widened to analyze the effect of encoding systems on bandwidth utilization in all digital transmission services such as digital transmission over IP networks other than limiting it on terrestrial transmission of digital services. High resolution encoders such as Talon-G1 encoders that support the transmission of video and audio over IP networks should be used.

REFERENCES

[1] Anthony Romero, "What is Video Encoding," Codecsand Compression Techniques, 27 March 2018.

[2] Marco Jacobs and Jonah Probell, "A Brief History of Video Coding," pp. 2-7, January 2009.

[3] C.R. NOKES; J.D. MITCHELL; "Potential benefitsof hierarchical modes of the DVB-T specifications," BBCResearch Development, no. 99, 1999.

[4] Christoph Dosch; David Hemingway; Walid Sami;Handbook on Digital Terrestrial Television Broadcasting Networks and Systems Implementation, Geneva: InternationalTelecommunication Union - Radio communication Sector, 2016, pp. 18-19.

[5] Naveen Siddaraju; K.R. Rao; "Multiplexing the Elementary Streams of H.264 Video and MPEG4 HE AAC v2 Audio, De-multiplexing and Achieving Lip Synchronization," American Journal of Signal Processing, pp. 52-59, 2012.

[6] Kuniaki Takahashi; Kazushi Satoh; Teruhiko Suzuki; Youichi Yagasaki; "Motion vector synthesis algorithm for MPEG-2-to-MPEG-4 transcoder," in Visual Communications andImage Processing , 2000.

[7] H. Murugan; Multiplexing H264 video bit-stream withAAC audio bit-stream, demultiplexing and achieving lip sync during playback, Texas: University of Texas , 2020.

[8] B. Haskell; A. Puri; A. Netravali; Digital Video: An Introduction to MPEG-2. Chapman and Hall, 1997.

[9] "STANDARD FOR TV WHITE SPACES ACCESS ANDUSE IN UGANDA," Uganda Communications Commission , Kampala, 2019.

[10] Stefan Meltzer; Gerald Moser; "MPEG-4 HE-AAC v2 — audio coding for today's digital media world , article in the EBU technical review," Coding Technologies, 2006.

[11] V-Nova; "LOW COMPLEXITY ENHANCEMENT VIDEO CODING ACHIEVES ISO FDIS STANDARDSTATUS," MPEG-5 LCEVC standard, Vols. ISO 23094-2, 2020.

[12] Haivision; Makito; Kraken; "Serial Digital Interface (SDI): A standard for the delivery of digital video with coaxial cable," Haivision Media Platform, 2022.

[13] Gerard FARIA, "THE DIGITAL VIDEO BROADCASTING SYSTEM," Coded Orthogonal Frequency Division Multiplex modulation (COFDM)., pp. 3-8, 2000.

[14] SATEL;, "Radio connection distance and RF setup," SATEL, 2019.