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A Review on Performance Evaluation of Dvb-T2 Network and Its Optimization Recommendations a Case of Dar Es Salaam, Tanzania

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Abstract— Digital broadcast systems have increasingly been deployed for various services such as Digital Video Broadcasting (i.e. DVB-S, DVB-T, etc.) and Digital Audio Broadcasting (DAB). Classical digital broadcast systems were designed with fixed modulation techniques, which had to guarantee reliable communication even with very hostile channel environment. In this paper a thoroughly review of different studies was conducted for the performance of Digital Video Broadcasting- Second generation Terrestrial (DVB-T2) signal reception because most of Tanzanian's are complaining about signal coverage and the quality of service in DVB-T2. The performance evaluation of DVB-T2 is done while taking in consideration field data including RSSI values, CNR, MER and BER which was collected through drive test measurement.

Keywords— DVB-T2, Power received (RSSI), SNR, CNR, BER, MER, and Single Frequency Network.

1. Introduction

Digital terrestrial television (DTT), also known as DVB- T/T2 (Digital Video Broadcasting-Terrestrial) television, is nowadays an efficient communication technology for broadcasting television (TV). DVB-T2 is the world's most advanced digital terrestrial television (DTT) system, offering more robustness, flexibility and at least 50% more efficiency than any other DTT system. It supports SD, HD, UHD, mobile TV, or any combination thereof.

DVB-T2 is a 2nd generation terrestrial broadcast transmission system developed by DVB project since 2006. The main purpose was to increase capacity, ruggedness and flexibility to the DVB-T system. The emergence of DVB-T2 is motivated by the higher spectral efficiency going along with DVB-T2 – be it for a transition from analogue TV to DVB-T2, be it for a transition from DVB-T to DVB-T2. Higher spectral efficiency means that with the same amount of spectrum, a larger number of programs can be broadcast or the same
number of programs broadcast with a higher audio/video quality or coverage quality. If in addition improved source coding (MPEG-4) is employed, the gain in broadcast transmission is remarkable.[1]

DVB-T2 is the new DVB standard for DTT. It allows the simultaneous transmission of multiple services, each one with a different configuration, and thus, with different robustness and quality. This permits new type of reception scenarios for these digital terrestrial signals, like mobile and handheld pedestrian reception scenarios, so DVB-T2 can be used for providing both fixed and mobile services within the same channel thanks to the number of configurations supported.[2]

As analogue switch-off (ASO) approaches in a number of countries, and digital television is steadily gaining a large interest from users, the DVB organization decided to design a new physical layer for digital terrestrial television. The main goals of the new standard were to achieve more bandwidth compared to DVB-T, targeting HDTV services, improve single frequency networks (SFN), provide service specific robustness, and target services for fixed and portable receivers. As the result of work carried by the DVB organization, the DVB-T2 specification was released for publication on the DVB website in June 2008. Initial tests shows that the new standard achieves more than 40% capacity improvement compared to DVB-T.[3]

In Tanzania, the process of migration from analogue to digital terrestrial television started in 2005, and in 31st December 2012 the first phase of analogue switch off took place in which five major regions like Dar es salaam, Arusha, Mbeya, Mwanza and Morogoro were forced to migrate to digital broadcasting and effectively from 1st January 2013 they were already in DVB-T2. The second phase of migration in the other regions has started on 1st April 2014. Three multiplex operators were licensed DVB-T/T2 using MPEG4 compression techniques and those were Star Media Limited providing Star times decoders, Agape International providing TING decoders and Basic Transmission Limited providing two decoders which are Continental and Digitek decoders even though Continental are now migrating to DVB-S, these are multiplex operators dedicated to provide only terrestrial television broadcasting. There are other multiplexers who are dealing with satellite broadcasting and these includes Azam decoders, Zuku decoders and DStv.

TCRA and Tanzania Bureau of Standards (TBS) have set standards for Set Top Box (STB) which are intended for DVB-T2 reception and these includes:

- It must allow reception and demodulation of the DVB-T2 signal transmitted in accordance with [4]
- Single frequency Network(SFN)

- Bandwidth 8MHz
- Frequency : 470 – 697MHz
- Transmission mode: 8k COFDM
- Modulation : 64QAM
- Code rate: 2/3
- Guard Interval : 1/8
- MPEG-4; as defined in ISO/IEC 14496
- Video resolution : the decoder of receiver shall decode pictures in resolution 720 x 576 pixels for SDTV services and 1920 x 1080, 1440 x 1080, 1280 x 1080 and 1280 x 720 for HDTV services
- Subtitle information: The STB shall include the capability to receive and output DVB-T2 subtitles in which the user must be able to select or deselect subtitles.

The switching of transmission system was mainly due to increasing number of Televisions and shortage of frequency bands to accommodate increasing number of television stations. The other reason for the migration from analogue to digital television is to release valuable spectrum which can be used for other services. Spectrum is scarce, and hence making more efficient use of the spectrum available is necessary if more telecommunications and broadcasting services are to be made available on a terrestrial basis. [5]

The radio frequency spectrum is a limited natural resource that can be used to increase the efficiency and productivity of a nation's workforce consequently enhance the quality of life. Spectrum is used to provide a wide variety of radio-communication services including; broad casting TV and sound, radio navigation, aeronautical, maritime radio, satellite, radio location and amateur radio. In addition, the spectrum-based services have become important inputs to a range of socio-economic activities such as security, education, health, defence, transportation etc.

The number of Television and Radio broadcasting services are increasing tremendously and this cause some problems in terms of quality of service provided to customers, for example in 2010 there were 10% of Tanzania's population complaining about the quality of service provided by broadcasting network as per figure below.

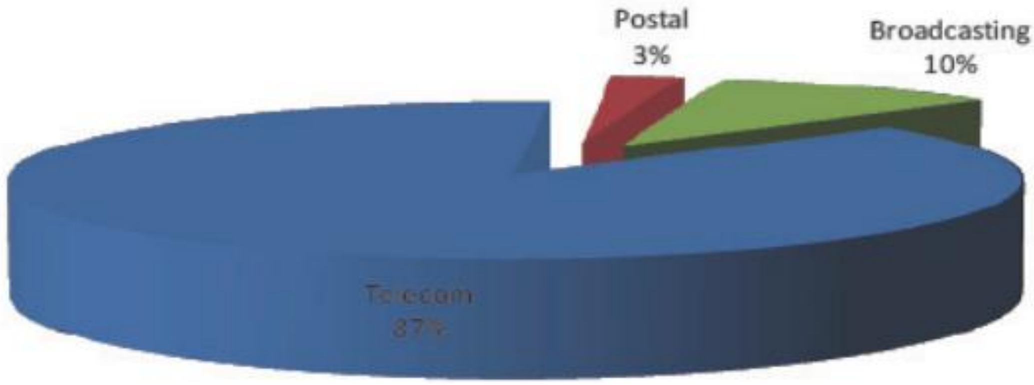

Figure 1: Percentage of customer complaints per service as provided [5]

Performance is a multi-faceted concept and it is conceptualized in many ways. Since networks stand at the heart of businesses, network performance can be perceived in business context in three perspectives: customer perspective, technical perspective and system complexity perspective. It means performance as interpreted by customers and network technicians; and in terms of network components and complexity. Since the official switching from analog video broadcasting to DVB-T2 transmission, there has been an increasing number of complaints from customers (End users) on the bad or scrambled reception of the TV signals or sometimes lack of received signal at all. The source of complaints may be due to settings of the transmission towers of the DVB-T2 multiplex operators, settings of the reception antennas, or geographical layout of the region. Some important services like teletexting, email and subtitling have been missing since the launch of this services. The figure below shows the customer complaints as per TCRA annual report

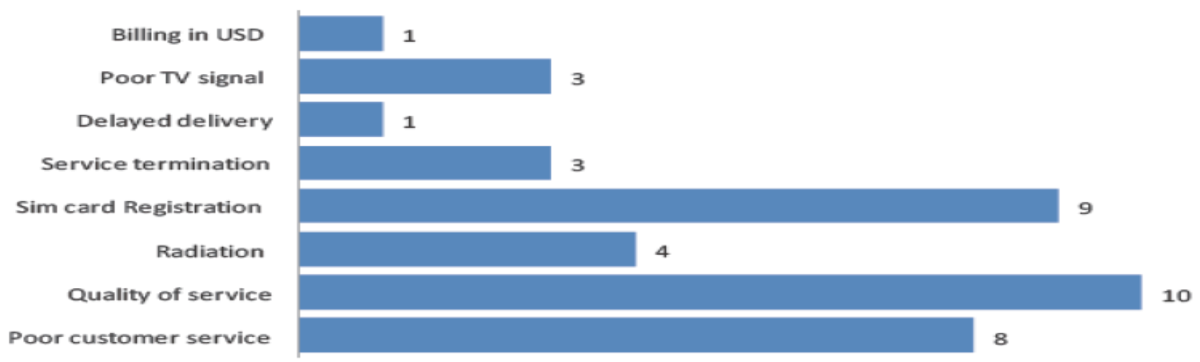

Figure 2: Customer complaints [6]

Due to increasing number of complaints from viewers of television, there was a need to evaluate the performance of this type of broadcasting and then come up with the necessary recommendations on what has to be done so that those constraints which causes undesired signal or video quality to be defined or solved, and the additional services like teletext and email to be provided reliably. So the recommendations on how to optimize can be helpful to the broadcasters and multiplex operators' in order to achieve good quality signals and hence satisfy the users. Also there is a need for broadcasters or network operators to incorporate interactive services like teletexting, emailing and subtitling to the viewers because they all use the same bandwidth.

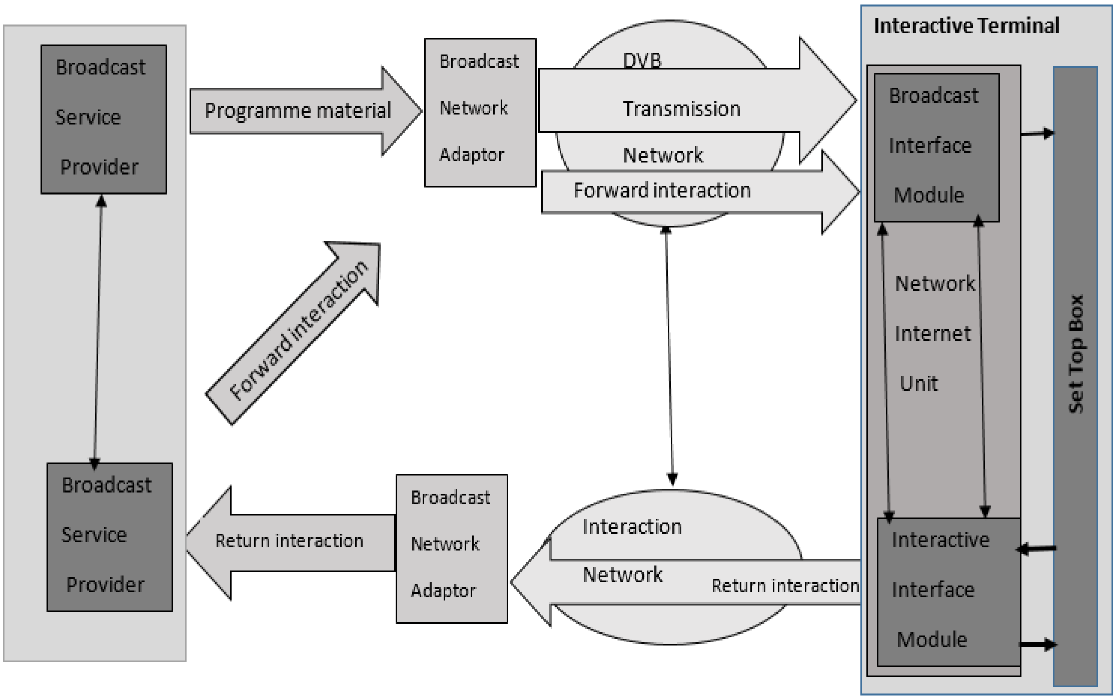

Figure 3: Conceptual block diagram for terrestrial interactive networks [7]

Since the introduction of DVB in Tanzania there is no any multiplex operator whose is capable of providing interactive services in their Set Top Box.

2. BACKGROUND AND LITERATURE SURVEY

Analog video broadcasting technology is being replaced by the digital video broadcasting ones. The common problems found in analog video broadcasting are ghost images due to multipath distortion in the radio channel and noise signals which degrades the quality of the analog video signal and sound which are all efficiently solved by a digital television. The transition of analog to digital by the roll out of the Digital Video Broadcasting-Terrestrial (DVB-T)[4] standards provides advantages in the exploitation of bandwidths, more robustness in front to the noise and another series of advantages that are translated in a clear improvement of the image and the sound, besides adding new applications for users like teletext services, email services in which the user is capable to communicate with service provider from his television through the decoder.

Digital broadcast systems have increasingly been deployed for various services such as terrestrial digital TV, digital radio, satellite TV and radio. Classical digital broadcast systems were designed with fixed modulation techniques, which had to guarantee reliable communication even with very hostile channel environment.[8]

According to [9], BER against SNR is recorded to compare the performance of different configurations. Different types of scattered pilot patterns for DVB-T2 standard are analyzed evaluated and compared in BER through Linear interpolation (Step), Linear interpolation (Line order 0), Linear interpolation (Line order 1) and Spline Least Squares Best Fit estimator methods. As for Rural Area environment there is no performance gain between PP1/PP2 with 8.3% overhead, PP3/PP4 with 4.17% overhead and PP5 with 2.08% overhead. Thus, the optimum pilot pattern can be regarded as PP5 to maximize the data throughput. Simulation results show that for Rural Area environment and PP1, there is a performance gain between 0.5dB to 2 dB by employing SIMO transmission diversity. Simulation results also show that the performance gain for PP7 in SIMO is much greater (between 4 and 17.5 dB) than that of PP1

As per [10], A realistic BER performance have been provided and compared to the suggested ideal values in the standard although the results in the AWGN channel agree, the performance achieved in non-ideal conditions is poorer than expected in multipath environment. It should be noted that the use of channel state information in the inner decoder could lead to a better performance

According to [11], A digital broadcast system utilizes regulated frequency bands with fixed bandwidths. The capacity of a digital broadcast system is limited by transmission power of the system and channel impairments. Since in a broadcast system, the same data is transmitted to all users, there is a tradeoff between transmitted bit rates and intended coverage areas. A digital broadcast system is usually designed with a bit rate that can be reliably received by users in an intended coverage area for a given transmission power.

According to [12] ,The different GI values studied have shown expected behavior. New 1/128 GI duration included in DVB-T2 is clearly worse than others. Its use is recommended to improve data rates in fixed reception but not for low speed mobile reception. The protection offered by the higher values of GI is most evident in this type of reception. The break point is also close to 15 dB value for SNR.

Referring to [13], the performance of the rotated constellation for DVB-T2, with comparison of non-rotated constellation, was explored. It has been shown that for fading channels with very bad conditions, a good performance can be obtained with rotated constellation. On the other hand, only the features of rotated constellation are not allowed for achieving a good signal quality. Unconditionally, the mentioned innovation of FEC coding/decoding, which is used in DVB-T2, has a significant role. Thanks to the number of decoding processes (50 iterations in this simulation), which is used in this paper, the results in the special 0 dB Echo fading channel are much better.

In their paper [14], the performance of two TR-based PAPR reduction methods, gradient and clipping, is evaluated. Also, an iterative method called "One Kernel One Peak" (OKOP) is proposed. It offers the advantage of controlling the mean power increase of the reserved carriers. The performance of these methods is compared in terms of PAPR reduction capability, computational complexity and system interference (BER). Simulation results based on CCDF curves, using the DVB-T2 parameters, show that these methods offer an equivalent performance in term of PAPR gain. They provide a PAPR reduction gain of about 2dB when only of subcarriers is used without BER degradation. Thus, the data throughput is not reduced significantly. The advantage of the proposed TR-OKOP method is that the power of the correction carriers could be controlled more easily than in the case of the TR-Gradient method. Thus, the magnitude of the PRT could be set equal to the data subcarrier magnitude level. Also, the implementation of the TR-Gradient PAPR reduction algorithm in the DVB-T2 modulator was described.

Dependences of the MER on C/N in the DVB-T2 system for all type of channels were obtained according to [15] MER is again descending by decreasing value of C/N in all cases. Generally, higher MER means less fading in the transmission.

The benefits of digital coding and transmission techniques as discussed by [16] allow perfect signal recovery in all the serviced areas avoiding the effects of the wireless channel and noise. Considering the physical level of the communications, the digital data sequences, which contain MPEG video, audio and other information streams, are transmitted using coded orthogonal frequency division multiplexing (COFDM) modulation. The information bits are coded, interleaved, mapped to a quadrature amplitude modulation (QAM) constellation and grouped into blocks. All the symbols in a block are transmitted simultaneously at different frequency subcarriers using an inverse fast Fourier transform (IFFT) operation. The number of IFFT points, which can be either 2048 (2K) or 8192 (8K), determines the transmission mode and the number of the available subcarriers in the transmission bandwidth. Some of these subcarriers are not used to allow for guard frequency bands whereas others are reserved for pilot symbols, which are necessary to acquire the channel information required for signal recovery.

Digital television arises due to the fact that it provides better characteristics than the analog television. The old method has less spectral efficiency, as every single image was transmitted, in order to improve this mechanism, digital television introduces MPEG(Moving Pictures Experts Group) compression which sends the changes of the images and thus, much less information. Due to this fact, the required bandwidth is reduced and then on the same channel several programs can be multiplexed, or they can be transmitted with high definition, multimedia, interactivity can be included. The spectrum efficiency is then much higher on digital systems.

According to the results presented by [17] , when BCH-LDPC coding is used in the presence of bit errors, it is possible to receive the transmitted image without any errors after an SNR value of 3.5 dB in case of AWGN channel; but when LDPC-only is used under the same conditions, a degradation in the performance is observed. This error floor might keep the PSNR of the received image at a fairly constant value, thus limiting the received image quality. Comparing the performance results for ITU- Vehicular A and ITU-Vehicular B channels, we can see that ITU-Vehicular B channel is a more difficult channel than ITUVehicular A. For instance a target BER level of (10^{-3}) can be attained at 5:5 dB and 7:5 dB respectively

Table 1: Showing the transmission frequencies and bandwidth for UHF

1.

Band	Frequency Range	Signal Bandwidth
VHF III	174 – 230 MHz	7 M
UHF IV	470 – 606 MHz	8 M
UHF V	606 – 862 MHz	8 M

In their research concerning performance [18], concluded that, with no power imbalance, the performance of the MISO configuration is better by 0.5dB compared to the SISO configuration, thanks to the diversity gain provided by the Alamouti scheme. With power imbalance, the performance of the SISO configuration remains the same. The performance of the MISO configuration is degraded by 0.9dB because of noise amplification by the Alamouti decoder. The use of MISO for the transmission of a DVB-T2 signal in an SFN environment provides an improvement of the performance of the system. Indeed, it can be assumed that the case when the power imbalance exceeds 6dB would occur in the areas where the receiver is close enough to one of the transmitter to ensure a good reception of the signal, while the case when the power imbalance is moderated corresponds to areas where the receiver is far from each station and will fully.

[18] concluded that, As a first attempt to integrate multi antenna techniques in digital video broadcasting systems, the distributed Alamouti solution essentially improves the signal reception quality in SFN areas.

The differences between the original DVB-T and the new DVB-T2 standards are many and important. The latest coding, interleaving and modulation techniques have been included in this large and flexible specification to provide capacity and robustness in the terrestrial transmission environment to fixed, portable and mobile terminals. Multiple-input multiple output (MIMO) techniques, low-density parity-check codes (LDPC), rotated constellations, new pilot patterns or large interleaving schemes are the most remarkable signal processing algorithms that have been included to overcome the limitations of the much simpler DVB-T broadcasting standard.[16]

For broadcast networks, the Single-Frequency Network (SFN) mode is an alternative to the well-known Multi-Frequency Network (MFN) mode, where instead of transmitters operating at different frequencies, all base stations use the same frequency. Besides the optimal frequency reuse, it is usually expected that the more homogeneous distribution of received signal strength reception in an SFN will improve the quality of service. Nevertheless, it should be noted that not all the locations within the service area will benefit from the SFN configuration. Some areas will show a degraded quality caused by the SFN echoes.[19]

The new technologies, like compression standard Moving Picture Experts Group 4 (MPEG-4) part 10, or H.264/AVC (hereinafter called MPEG-4)[20] and the second generation of digital terrestrial broadcasting standard (DVB-T2)[4], provide increased capacity and ruggedness in the terrestrial transmission environment. As indicated in previous research [21], when considering the whole picture, it is evident that the latest technologies besides technical benefits, increased capacity for new services and higher quality of service, bring also a higher system cost. DVB-T2, second generation of terrestrial digital video broadcasting standard, promises performance gains because of improved coding, modulation and multiple antenna technologies.[22]

3. DVB-T2 SYSTEM OVERVIEW

A. INTRODUCTION

DVB-T2 is a standard for digital terrestrial television broadcasting, offering significant benefits compared to DVB-T. It includes many new techniques not previously used in the DVB family of standards. Some, such as the P1 preamble, are completely novel, having been invented specifically for DVB-T2 and therefore are not yet discussed in the wider literature.

The DVB organization defined a set of commercial requirements which acted as a framework for the DVB-T2 developments. These commercial requirements included[23]:

- ✓ DVB-T2 transmissions should be able use existing domestic receive antenna installations and should be able to re-use existing transmitter infrastructures. (This requirement ruled out the consideration of MIMO techniques which would involve both new receive and transmit antennas.)
- ✓ DVB-T2 should primarily target services to fixed and portable receivers.
- ✓ DVB-T2 should provide a minimum of 30 % capacity increase over DVB-T working within the same planning constraints and conditions as DVB-T.
- ✓ DVB-T2 should provide for improved single-frequency-network (SFN) performance compared with DVB-T.
- ✓ DVB-T2 should have a mechanism for providing service-specific robustness; i.e. it should be possible to give different levels of robustness to some services compared to others. For example, within a single 8 MHz channel, it should be possible to target some services for roof-top reception and target other services for reception on portables.
- ✓ DVB-T2 should provide for bandwidth and frequency flexibility.
- ✓ There should be a mechanism defined, if possible, to reduce the peak-to-average-power ratio of the transmitted signal in order to reduce transmission costs.

DVB-T2 has been designed primarily for fixed receptors, although it must allow for some mobility, with the same spectrum characteristics as DVB-T.

Like its predecessor, DVB-T2 uses OFDM(orthogonal frequency division multiplex) modulation with a large number of sub-carriers delivering a robust signal, and offers a range of different modes, making it a very flexible standard[24]. DVB-T2 uses the same error correction coding as used in DVB-S2 and DVB-C2: LDPC (Low Density Parity Check) coding combined with BCH (Bose-Chaudhuri-Hocquengham) coding, offering a very robust signal. The number of carriers, guard interval sizes and pilot signals can be adjusted, so that the overheads can be optimized for any target transmission channel.[25]

Additional new technologies used in DVB-T2 are Multiple Physical Layer Pipes**(**which allows separate adjustment of the robustness of each delivered service within a channel to meet the required reception conditions (for example in-door or roof-top antenna)and it also allows receivers to save power by decoding only a single service rather than the whole multiplex of services),Alamouti coding**(**which is a transmitter diversity method that improves coverage in small-scale single-frequency networks.), Constellation Rotation**(**which provides additional robustness for low order constellations.), Extended interleaving(which includes bit, cell, time and frequency interleaving.) and Future Extension Frames (FEF)(which allows the standard to be compatibly enhanced in the future.).

- ✓ So from the above explanation: DVB-T2 Capacity = DVB-T Capacity + 50%

The following diagram represents the block diagram of the DVB-T2:

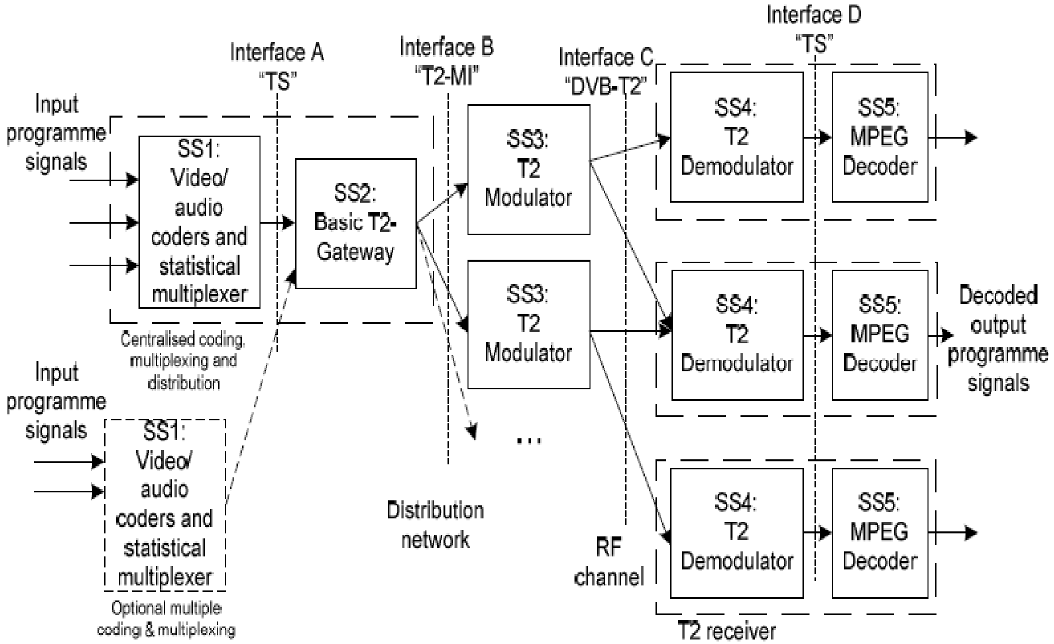

Figure 4: The block diagram of DVB-T2[25]

The DVB-T2 system as it is addressed above, spans from the input Interface A to the output Interface D. The full DVB-T2 system can be divided into three basic sub-systems on the network side (SS1, SS2 and SS3) and two sub-systems on the receiver side (SS4 and SS5). Regarding interfaces, there are two corresponding interfaces on the network side (A and B), and one receiver-internal interface (D). The RF interface (C) is common to network and receiver.

The following serve as the explanation for the figure above:[25]

SS1: Coding and multiplexing sub-system. This includes generation of MPEG-2 Transport Streams and/or Generic Streams, e.g. GSE. For video services this includes video/audio encoding plus associated PSI/SI, or other Layer 2 signaling. Typically the video coding (and possibly audio coding) is performed with variable bit rate with a common control ensuring a total constant bit rate (excluding NULL packets) for all streams taken together. This sub-system is largely the same as for other DVB standards, but there are some T2-specific aspects of the coding and multiplexing

SS2: Basic T2-Gateway sub-system. The input interface to this sub-system applicable both to the basic DVB-T2 physical layer and to the extension. This includes functionality for Mode adaptation and Stream adaptation for DVB-T2, together with scheduling and capacity allocation. The Basic T2-Gateway delivers at its output interface (B) a "T2-MI" stream: a sequence of T2-MI packets, each containing either a Baseband frame, IQ vector data for any auxiliary streams, or signaling information (L1 or SFN). The T2-MI stream contains all the information required to describe both the content and emission timing of T2-frames, and a single T2-MI stream is fed to one or more modulators in a network.

The operations performed by the Basic T2-Gateway include all those parts of the physical-layer that are not completely prescriptive, such as scheduling and allocation. These need to be done centrally in an SFN, to ensure that the same signal is generated by all modulators.

SS3: DVB-T2 Modulator sub-system. The DVB-T2 modulators use the Baseband frames and T2-frame assembly instructions carried in the incoming T2-MI stream to create DVB-T2 frames and emit them at the appropriate time for correct SFN synchronization. The modulators interface to the receivers via the C interface (the transmitted DVB-T2 signal).

SS4: DVB-T2 demodulator sub-system. This sub-system receives an RF signal from one or (in an SFN) more transmitters in the network and (in the transport-stream case) outputs one transport stream. SS4 interfaces to SS5 via the D interface, a syntactically correct transport stream carrying one or more of the services as well as any common signaling data derived from the common PLP. The streams passing the B interface are identical to those passing the D interface.

SS5: Stream decoder sub-system. This sub-system receives the transport stream and outputs decoded video and audio. Since interface D is a syntactically correct transport stream, this sub-system is essentially the same as for other DVB standards, except that some new L2-signalling elements have been defined for DVB-T2

The audio and video can be produced separately but being multiplexed together in the encoder and then transported through gateway after which they will reach the modulator where modulation will take place after which then demodulation must be done followed by the decoding of the program having both the video and the audio codex and finally the decoded program will be taken as output signals after all interfaces from A to D have been passed.

The figure below shows the main stages of a DVB-T2 transmitter, where dashed lines represent optional stages.

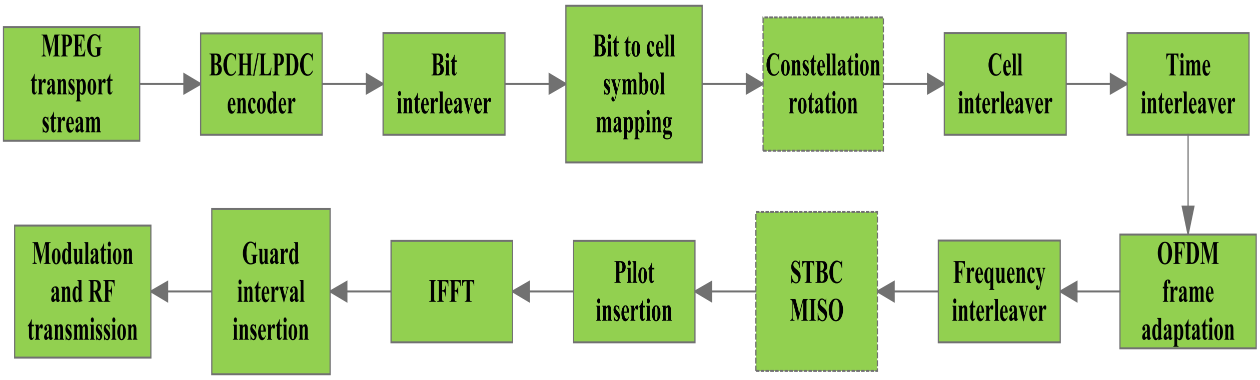

Figure 5: DVB-T2 elementary transmission system[16]

The coding algorithms, based on the combination of LDPC and Bose-Chaudhuri-Hocquenghem (BCH) codes, offer excellent performance resulting in a very robust signal reception. LDPC-based forward error correction (FEC) techniques can offer a significant improvement compared with the convolutional error correcting scheme used in DVB-T.

B. BENEFITS OF DVB-T2 OVER DVB-T

As a result of the technologies introduced in DVB-T2, the potential gain in capacity that could be achieved was expected to be nearly 50 % compared to the pre-switchover mode of DVB-T. In addition to the increased capacity, the DVB-T2 mode was offers greater tolerance of multipath and impulsive interference than the current DVB-T mode**.**

Compared with DVB-T, the DVB-T2 standard offers a bigger choice of the OFDM parameters and modulation schemes. The available bandwidths are increased, too. Combining various modulation schemes with FFT sizes and guard intervals allows construction of MFN and SFN networks designed for different applications: from low bit-rate but robust mobile reception to the high bit-rate fixed reception for domestic and professional use.[1]

The DVB-T2 standard takes into account one of the main drawbacks of OFDM, the peak to average power ratio (PAPR) of the signal and its effects on the transmitter equipments. High power peaks are usually generated by OFDM transmission leading to distortions at the amplifiers, thus minimizing their efficiency.

As with DVB-T, the new standard targets not just roof-top and set-top antennas, but also PCs, laptops, in-car receivers, radios, smart phones, dongles, and a whole range of other innovative receiving devices. In countries where DVB-T services are already on air DVB-T and DVB-T2 services are likely to coexist side-by-side for some time to come, but in green-field countries that have not yet deployed DTT services, there is a unique opportunity to leapfrog directly to DVB-T2 instead of first deploying DVB-T.

DVB-T2 can offer a much higher data rate than DVB-T **OR** a much more robust signal. For comparison, the two bottom rows show the maximum data rate at a fixed C/N ratio and the required C/N ratio at a fixed (useful) data rate.

Table 2: Showing the comparison between DVB-T and DVB-T2 modes [16]

	DVB-T	**DVB-T2**
FEC	Convolutional + Reed-Solomon 1/2, 2/3, 3/4, 5/6, 7/8	LDPC + BCH 1/2, 3/5, 2/3, 3/4, 4/5, 5/6
Modes	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM, 256QAM
Guard intervals	1/4, 1/8, 1/16, 1/32	1/4, 19/256, 1/8, 19/128, 1/16, 1/32, 1/128
FFT size	2K, 8K	1K, 2K, 4K, 8K, 16K, 32K
Scattered pilots	8% of total	1%, 2%, 4% and 8% of total
Continual pilots	2.6% of total	0.35% of total
Bandwidth	6,7,8 MHz	1.7,5,6,7,8, 10MHz
Typical data rate	24Mbit/s	40Mbit/s

Despite the many benefits achieved by the deployment of the DVB-T network, its limitations became clear from the beginning. First, the number and bit rates of the transmitted channels are limited in comparison with new wireless transmission techniques. A new standard was soon required to broadcast more channels and high-definition television (HDTV) using the same frequency spectrum. Second, a new information system was required to allow more interaction with the user. Third, the DVB-T standard, which had been designed for fixed scenarios, had a very bad performance in mobile or portable environments, so it could not be properly implemented in scenarios such as moving vehicles. Last but not least, the deployment of the DVB-T network has been and still is a true nightmare in SFN scenarios, where interferences between repeaters, which transmit the same information on the same frequency bands, may destroy the received signal avoiding its reception in areas with good reception levels.[16]

C. OFDM

The majority of digital terrestrial technologies use multiple carrier orthogonal frequency division multiplexing (OFDM) techniques. Adding forward error correction (FEC) produces coded OFDM (COFDM) to improve the robustness of transmission. OFDM takes a serial data stream to be transmitted and spreads it over a large number of carriers, typically more than a thousand and sometimes many thousands. The data rate conveyed by each carrier is correspondingly reduced and the symbol length is in turn extended. These modulation symbols on each of the carriers are arranged to occur simultaneously. In addition to the data carriers, there are other carriers called pilot carriers or tones which carry information about the radio channel which can be used by a receiver to aid reception.

The carrier spacing is uniform and deliberately chosen so that it is the inverse of each symbol duration. This choice of carrier spacing ensures orthogonality of the carriers which means that the influence of adjacent carriers (in fact all other carriers) on the demodulation of a particular carrier is zero. It ensures there is no crosstalk between carriers, even though there is no explicit filtering and their spectra overlap.

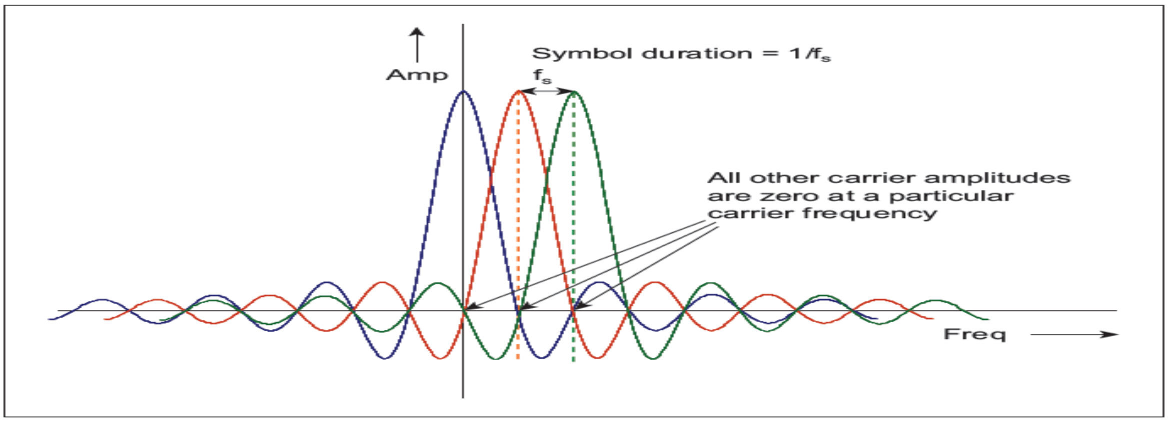

Figure 6: Showing orthogonality

Inside each time-segment, named OFDM symbol, one sub-carrier supply each frequency sub-band.

To avoid inter-carrier interference, the inter-carrier spacing is set to be equal to the inverse of the symbol duration: then sub-carriers are “orthogonal”. The COFDM implements a partitioning of the terrestrial transmission channel both in the time domain and in the frequency domain, to organize the RF channel as a set of narrow frequency sub bands and as a set of small contiguous time segments.

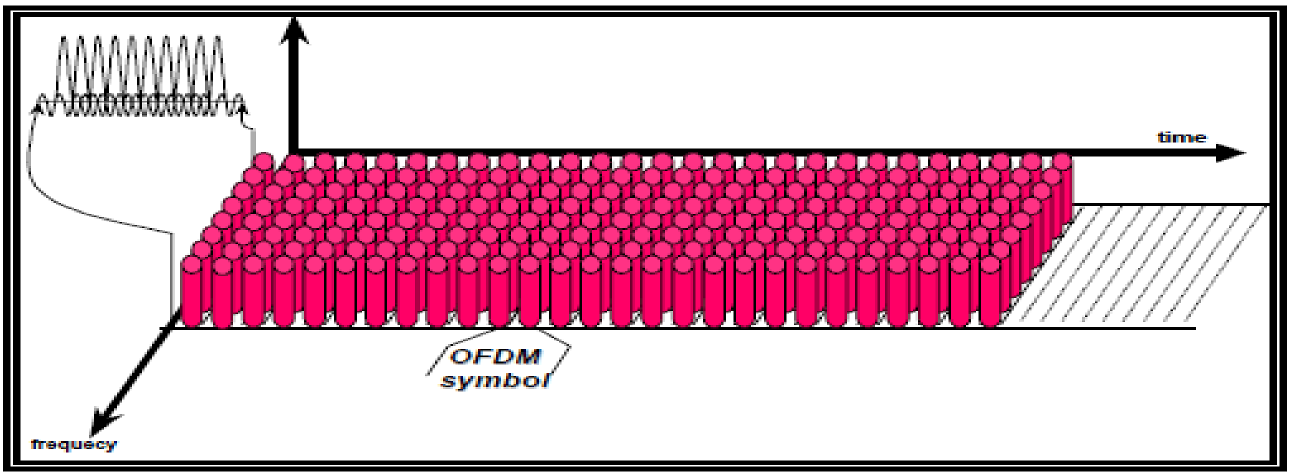

Figure 7: Diagram showing sub-carrier insertion[26]

As « echoes » are constituted with delayed replicas of the original signal, the end of each OFDM symbol can produce an inter-symbol interference with the beginning of the following one. To avoid this effect, a guard interval is inserted between each OFDM symbols. During the guard interval period, corresponding to an inter-symbol interference one, the receivers will ignore the received signal. The COFDM modulation spreads the transmitted data in the time & frequency domains, after protecting data bits by convolutional coding. As the frequency fading occurs on adjacent frequency sub-bands, contiguous data bits are spread over distant sub-carriers inside each OFDM symbol. This feature, known as frequency interleaving, [27]. The figure below illustrate the presence of guard interval.

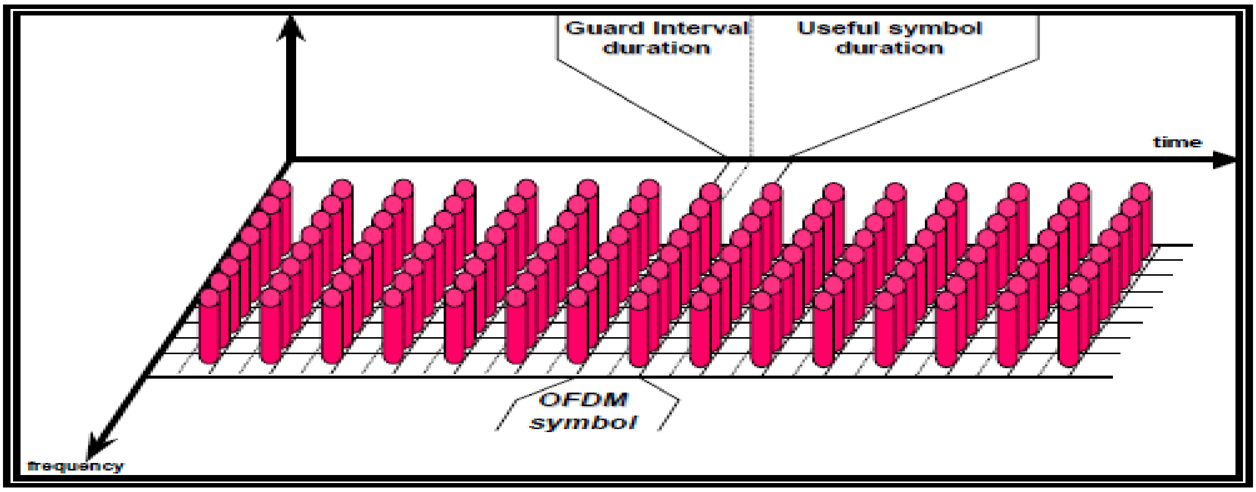

Figure 8: Guard Interval insertion [26]

D. SINGLE FREQUENCY NETWORKS (SFN)

Based on COFDM modulation properties, the Digital Video Broadcasting (DVB consortium) introduced a way to optimize spectrum & bandwidth for DVB-T2 broadcast, namely Single Frequency Network (SFN). SFN topology contrasts with MFN (Multiple Frequency Network) topology, where all the transmitters broadcast over a different frequency. Within a Single Frequency Network, all the transmitters from one SFN cell will broadcast over the same frequency, enabling spectrum & bandwidth optimization. The challenge is thus to provide all the transmitters with necessary information in order to broadcast over the same frequency. Optimizing spectrum and bandwidth is made possible with Single Frequency Network topology: all the transmitters will radiate synchronously based on information provided by Single Frequency Network (SFN) adapter.

One of the strengths of DVB-T is that it can be deployed with a single frequency network scheme (SFN) to get better reception signal quality[28]. This is possible because the physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) and the introduction of a cyclic prefix (CP) between consecutive symbols. SFNs allows a more efficient use of available bandwidth than classical Multiple Frequency Networks (MFNs). They also simplify the radio planning process since frequency allocation strategies are not required.[29]

The main advantage of this deployment strategy is the efficient use of the television spectrum, allowing a higher number of TV programs[30]

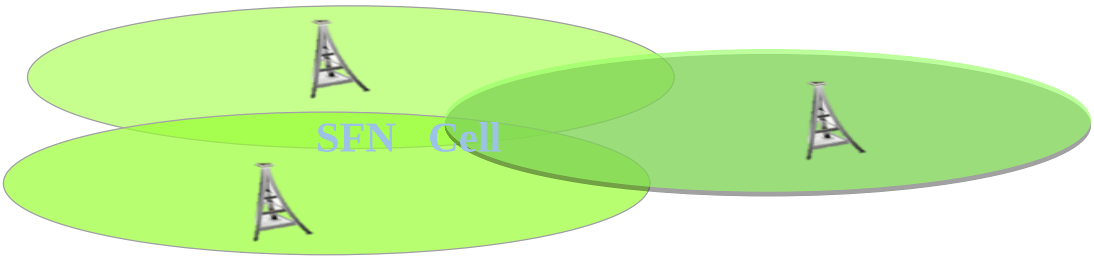

Figure 9: Diagram showing the Single frequency Network cell

The SFN network gain is defined as the positive power contribution due to constructive superposition of all the received signals within the guard interval in comparison to the necessary power in order to cover the same area with a MFN network[31]

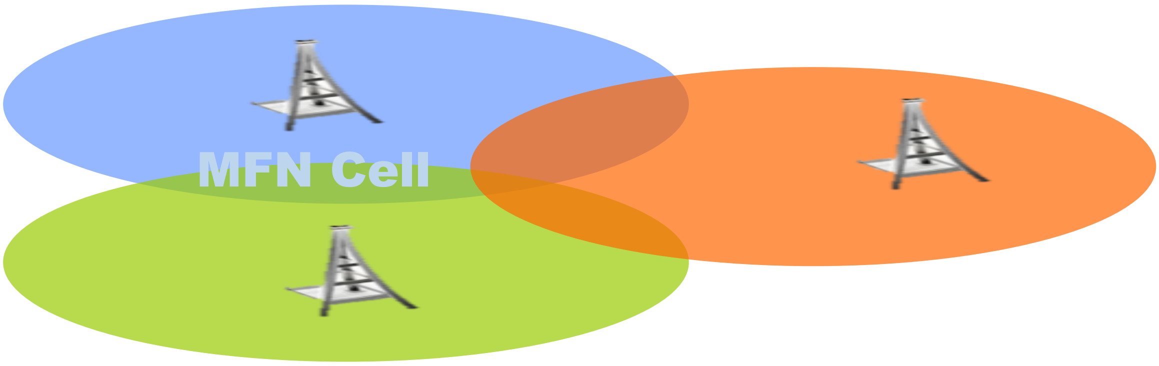

Figure 10: Diagram showing the Multiple Frequency Network (MFN) cell where all transmitters broadcast with different frequencies.

The DVB-T2 technology use SFN in order to serve the spectrum in which all transmitters broadcast with the same frequency and hence serve the spectrum.

According to [1], One approach for selecting a mode for SFN operation would be to select the length of the guard interval according to the physical size of the SFN or the SFN's intra transmitter separation distances, noting of course that it may be possible to have larger transmitter separations than the guard interval depending on practical considerations such as terrain, propagation and system robustness, etc. Additionally, optimization of coverage by modification of antenna diagrams, transmitter powers, antenna heights, transmitter timing, etc. may allow larger transmitter distances in the SFN than the guard interval. However, in such cases, detailed coverage simulations need to be made.

E. PERFORMANCE PARAMETERS AND MODULATION TECHNIQUES

i.) CARRIER TO NOISE RATIO (C/N)

In communications, the carrier-to-noise ratio, often written CNR or C/N, is a measure of the received carrier strength relative to the strength of the received noise or C/N is the ratio of the relative power level to the noise level in the bandwidth of a system. High C/N ratios provide better quality of reception, and generally higher communications accuracy and reliability, than low C/N ratios.

The C/N characterizes the robustness of transmission systems with regard to noise and interference. As such it is used to determine the signal level required to receive a viable signal in noise and interference limited channels. Subsequently, the determination of the C/N is of fundamental importance for network planning as it allows to analyze if a carrier can still be recognized as such, or if it is obliterated by ambient and system noise. C/N Provides a value for the quality of a communication channel.[1]

The carrier-to-noise ratio (CNR) can be calculated through the following link budget formula:

$$\frac{C}{N} = \frac{P_{received}}{P_{noise}} = \frac{P_{received}}{F * k * T_o * B} \qquad (1)$$

Where: $P_{noise} = Received\ noise\ input\ power$

$F = Receiver\ noise\ Figure$ $P_{received} = Minimum\ Receiver\ \ input\ power$

B= Receiver noise bandwidth (MHz)

$k = Boltzman\ constant$

$T_o = Absolute\ temperature\ (290K)$

$\frac{C}{N} = Carrier\ to\ Noise\ ratio$

$$P_{received}(dB) = \frac{C}{N}(dB) + F(dB) + 10log_{10}B(MHz) - 114 \qquad (2)$$

Table 3: Threshold data for CNR in different environment for three bands, for DVB-T2 only band IV and V applies.[32]

Threshold C/N (dB)			
Environment	**Band III**	**Band IV**	**Band V**
Rural	20	20	20
Suburban	22	22	22
Urban	24	24	24

The quality of the system is usually determined through BER plots against C/N.

Increased system robustness will also have a large impact upon SFN performance since a lower required *C/N* will reduce the susceptibility for SFN self-interference. DVB-T2 will give the possibility to provide much higher data rates than current DVB-T networks designed for portable or mobile reception.[1]

ii.) SIGNAL TO NOISE RATIO (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi-channel environment. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels.

$$SNR = 10\log\left(\frac{Signal\ power}{Noise\ power}\right) \quad (3)$$

CNR measurements can be converted to SNR by using the relation[33]:

$SNR = CNR - 10\log_{10}(m)$

Where $m = \log_2 M$ for M-QAM in which for the case of DVB-T2 M= 64 or 256

iii.) BIT ERROR RATE (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage.

$$BER = \frac{Bits\ with\ errors}{Total\ number\ of\ bits\ received} \quad (4)$$

Noise affects the BER performance. Quantization errors also reduce BER performance, through incorrect or ambiguous reconstruction of the digital waveform. The accuracy of the analog modulation process and the effects of the filtering on signal and noise bandwidth also effect quantization errors.

The following expression gives the relationship between BER and the SNR for M-QAM in which for the case of DVB-T2, M=64 or 256 which are square in nature;

The expression for BER is:

$$BER = \left(\frac{\sqrt{M}-1}{M\log_2\sqrt{M}}\right) erfc\left[\sqrt{\frac{2^{\sqrt{N}}-1}{2^{\sqrt{N-1}}}\frac{3\log_2 M}{2(M-1)}SNR}\right] \quad (5)$$

Where *erfc* stands for complementary error function and N stands for carrier mode i.e. in the case of DVB-T2 in Tanzania it is 8k.

iv.) MODULATION ERROR RATIO (MER)

The Modulation Error Ratio (MER) is a measure of the signal-to-noise ratio (SNR) in digital modulation applications. This is used to determine system performance in communications applications. For example, determining if an EDGE system conforms to 3GPP radio transmission standards requires accurate MER, Minimum MER, and 95th percentile for the MER measurements.

For each received symbol, a decision is made as to which symbol was transmitted. The error vector is defined as the distance from the ideal position of the chosen symbol (the center of the decision box) to the actual position of the received symbol.[34]

This distance can be expressed as a vector $(\delta I_j, \delta Q_j)$

The sum of the squares of the magnitudes of the ideal symbol vectors is divided by the sum of the squares of the magnitudes of the symbol error vectors. The result, expressed as a power ratio in dB, is defined as the MER.

MER is a measure of the SNR in a modulated signal calculated in dB and it is given by the following formula:

$$MER = 10\log_{10}\left\{\frac{\sum_{j=1}^{N}\left(I_j^2 + Q_j^2\right)}{\sum_{j=1}^{N}\left(\delta I_j^2 + \delta Q_j^2\right)}\right\} dB \quad (6)$$

Where: I = In-phase measurement and Q = Quadrature phase measurements.

It should be reconsidered that MER is just one way of computing a "figure of merit" for a vector modulated signal. Another "figure of merit" calculation is Error Vector Magnitude (EVM). MER and EVM are closely related and one can generally be computed from the other .Also there is relationship between SNR and the EVM as shown below:

$$EVM = \frac{1}{SNR^{1/2}}$$

In which there is inverse square law relationship existing between the two parameters.

v.) RECEIVER INPUT SIGNAL LEVELS (RSSI)

In telecommunications, **received signal strength indicator** (**RSSI**) is a measurement of the power present in a received radio signal.[35]

RSSI (Received Signal Strength Indicator) is a common name for the signal strength in a wireless network environment. It is a measure of the power level that a RF client device is receiving from an access point. The closer the figure is to zero, the better. For example, RSSI of -65 is better than -85. As a general example, a good signal would be -50, a reasonable would be -75, and a bad one would be -90, while -100 would provide no service at all. [36]
The received signal levels is related to the CNR by the following relations:

$$\frac{C}{N} = \frac{P_{received}}{P_{noise}} = \frac{P_{received}}{F * k * T_o * B}$$

$$P_{received} = \frac{C}{N} \times P_{noise}$$

$P_{noise} = F * k * T_o * B$
In dB, $P_{noise} = F + 10log(k * T_o * B)$
Where $F = \text{Receiver noise figure} = 6\text{dB}$ for DVB-T2 in Tanzania as a case.
$B = \text{Receiver noise bandwidth} = 7.71(\text{MHz})$ For carrier mode of 8k for 8MHz channels.

vi.) MODULATION TECHNIQUES

The DVB-T2 specification allows for time slicing, which is a well-known DVB-H feature. Time slicing reduces the energy consumption of the receiving device. This is achieved by transmitting the services of a multiplex in time blocks which allows the receiver to demodulate the signal only for a certain fraction of time in order to receive a particular service. For the rest of the time the receiver may remain idle, it may use the remaining time for the check of other frequency blocks or channels.[1]
64-QAM and 256-QAM are the modulations used in DVB-T2 technology and in Tanzania only 64-QAM technique is used, delivering a gross data rate of 6 bits per symbol per carrier (i.e. 6 bits per OFDM cell) even though there is a room for 256-QAM which increases this to 8 bits per OFDM cell.

4. OBSERVATIONS AND DISCUSSION FOR THE CASE OF DAR ES SALAAM.

Due to the nature of buildings and poor planning of Dar es salaam city there are places where the signal coverage are poor due to the stated reason as signals from transmitting towers at Kisarawe Hill and Makongo Juu struggle to reach the houses or buildings in some areas causing poor signal quality.

Figure 11: A picture showing some tall buildings in Dar es Salaam as viewed from Posta PPF tower house.
Another observations from survey shows that many outdoor directional antennas (Yagi-Uda antenna) are used and which are placed on the roof approximately 4m from the ground, this may cause poor reception of signals once heavy wind blows as the antenna direction may be twisted. But other buildings near by the transmitting sites uses indoor monopole antennas but there are no any obstruction of signals from those towers. The receiving antenna type used mostly are MISO (Multiple input single output).

Figure 12: Yagi-Uda antenna placed on the roof.

Also the presence of mountainous terrain in some areas like Changanyikeni (University of Dar es salaam), Kimara Bonyokwa and other places causes some poor signal reception to the areas behind those terrain even though taking Star Times as a case have erected their towers 132m high for Kisarawe transmission base and 83m for Makongo Juu transmission base(At first it was constructed as a gap filler or a repeater in technical term but now it is transmission base) but still the signals struggle to reach the receiving antennas in the mentioned areas above.

5. CONCLUSION

A description of DVB-T2 and its performance parameters have been clearly provided along with their strength and how they can be used to evaluate the performance of DVB-T2 broadcasting. The BER against SNR or MER against SNR relationship have been clearly analyzed and concluded that if the BER is too low for large SNR, then the quality of the signal is appreciable and required but if it is opposite, then there must be major optimizations in summary, for good quality of broadcasting signal the BER have been proved to be inversely proportional to SNR. In Tanzania since its official switching to DVB-T2, it has been suffering the Quality of Service (QoS) on the signal broadcast so through above studies and analysis it will be easier to suggest the ways on improving the signal quality and signal field strength to concur the problem of coverage.

FUTURE WORK

In the future, the drive test field measurements will be conducted in order to collect data about Signal power received, CNR or SNR, BER or MER at different places depending on the terrain (mountainous or flat terrain) and tall buildings. Then analysis will be done on the quality of the signal which will involve the BER against SNR (CNR) or MER against SNR (CNR), then comparison with the threshold values have to be done in order to arrive to the conclusion.

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