AN LDPC-BASED TERRESTRIAL MULTIMEDIA BROADCASTING (TMB) SYSTEM: DESIGN, IMPLEMENTATION AND EXPERIMENTAL RESULTS

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ABSTRACT

This paper describes a multicarrier Terrestrial Multimedia Broadcasting (TMB) system that offers system performance and service versatility suitable for future digital broadcasting networks. The new system utilizes variable rate, variable size LDPC codes to allow simultaneous transmission of different programs with diverse requirements. A prototype system is implemented based on the proposed protocol. Results from both lab tests and field trials demonstrate significant performance advantages of the new design over existing systems such as the DVB-T.

1. INTRODUCTION

Existing terrestrial broadcasting systems such as the DVB-T [1] provides primarily one-way television services. To accomodate new applications and services, future terrestrial broadcasting networks must offer the flexibility to simultaneously support HDTV, SDTV, data, and even broadband two-way multimedia services. Such calls for a unified platform that can fulfill the following requirements:

- Multiple data channels with configurable bandwidth and error protection schemes for different services
- Broad coverage and reliable reception in both fixed and mobile environment
- A migration path towards converged broadcasting and telecom networks

The China Academy of Broadcasting Sciences is currently developing the next generation terrestrial TV broadcasting system with enhanced multimedia functionalities to better meet the evolving user demands. Under this initiative, we have designed a multicarrier and LDPC based Terrestrial Multimedia Broadcasting (TMB) system that offers the network capacity, link reliability, and service versatility superior to existing broadcasting solutions. Particular features of the TMB system include:

- A two-layer network architecture that improves the system coverage and enables a progressive and seamless evolution to two-way multimedia services

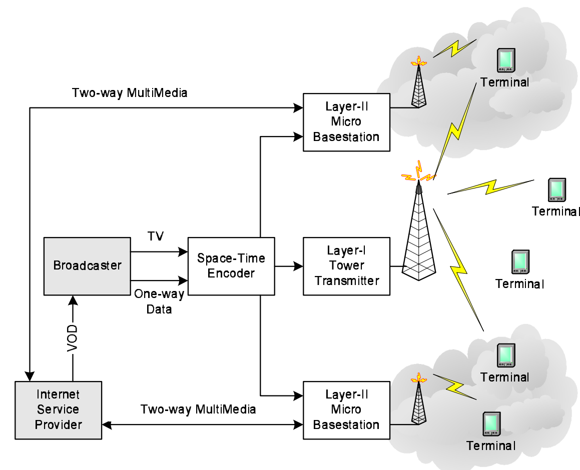

Fig. 1. The TMB network architecture

- Configurable parallel data streams of variable packet-size for TV, streaming, and data services.
- Powerful, low-cost, LDPC-based receivers
- Intelligent frame structure and beacon design for fast synchronization and demodulation

A prototype TMB system has been built on a software defined radio (SDR) platform. Results from lab tests and field trials in Beijing demonstrate significant advantages of the new system over the DVB-T performance benchmark.

2. SYSTEM SPECIFICATIONS

2.1. System Overview

Fig.1 highlights the basic architecture of a TMB network. The system is a two-layer infrastructure comprising of a macro-cell network (a typical TV tower with large coverage) and a micro-cell network (cellular-type) that can be gradually deployed to support future two-way services. In the broadcasting mode, the macro and the micro network transmit collaboratively, using space-time processing (e.g., transmitter diversity as in [2]) to provide better coverage.

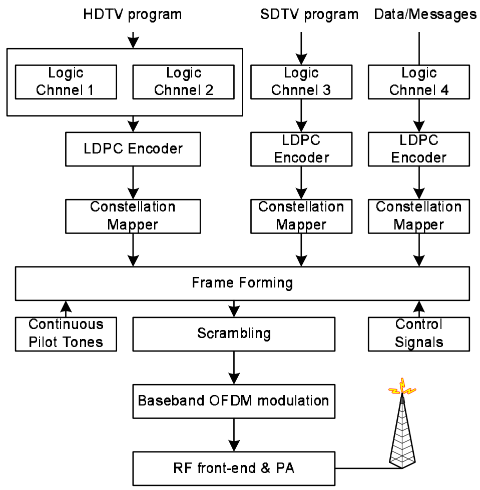

Fig. 2. Functional blocks of a TMB system

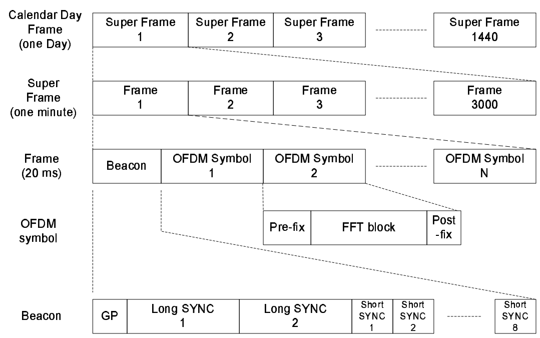

Fig. 3. Frame structure of the TMB system

Up to 4 logic channels are provided for different data streams. Part or all of these 4 channels can be combined into a fatter pipe to support high data rate services. In addition, an independent combination of the modulation scheme, the LDPC block size and code rate is allowed for each logic channel in accordance with the service type and the channel condition. Fig.2 shows an simulcast example of the TMB system with one HDTV, one SDTV and some data services.

Similar to the DVB-T, OFDM is adopted for signal modulation/demodulation in an 8MHz TV broadcasting channel. Referring to the IFFT size, two basic modes, namely, the "1K mode" and the "4K mode", are supported with configurable cyclic prefix (CP) length.

2.2. OFDM Frame Structure

Fig.3 illustrates the TMB frame structure. The top level of the frame structure is termed a *calendar day frame* which is synchronized to the absolute time (e.g., the Greenwich Standard Time) to facilitate the network synchronization.

Unlike the DVB-T system which uses a continuous OFDM stream, a time domain CDMA beacon is inserted in each 20ms frame in TMB to assist synchronization. The inserted beacon contains two identical long CDMA sequences (1023 samples each, denoted as LSYNC) and 8 short modulated CDMA sequences (255 samples each, denoted as SSYNC). The LSNYCs are designed to aid the initial time/frequency acquisition, while the short SYNCs serve the purpose of refined synchronization and compensation of some hardware imperfections (e.g., I/Q imbalance [3]). Furthermore, system configurations critical to the OFDM demodulation, e.g., the 1K/4K mode indicator and the CP length, are modulated on the SSYNCs so that they can be retrieved at the receiver before the FFT computation.

Table 1. LDPC code configuration and performance

Long LDPC			Short LDPC		
Code Rate	Size (bits)	AWGN E_b/N_0	Code Rate	Size (bits)	AWGN E_b/N_0
1/2	9036	1.9dB	1/2	1044	2.3dB
5/8	9472	2.4dB	5/8	1008	2.8dB
7/8	9792	4.3dB	7/8	1458	4.6dB

2.3. LDPC Channel Coding

Low-Density Parity-Check (LDPC) codes not only give Shannon-limit approaching performance, but also are inherently adapted to parallel implementation, which results in simpler and faster decoding [4]. Moreover, the built-in interleaving mechanism in LDPC eliminates the extra interleaver/de-interleaver otherwise needed in communication systems. Such properties make LDPC an ideal candidate for many high speed/broadband applications. For example, the DVB-S2 has recently chosen LDPC over Turbo codes as its channel coding scheme.

A family of highly structured LDPC codes similar to that in [5] is adopted in the TMB system. By exploring the structure, the coding/decoding complexity is greatly reduced and different code rate can potentially be supported by a single decoder core. Furthermore, two types of LDPC codes with different block sizes (referred to as long and short LDPC code respectively) are designed to accomodate both broadcasting and data services. The long LDPC code is designed for broadcasting services for better performance against fading, while the short LDPC code is suitable for data services due to shorter delays. Table 1 lists the LDPC code configurations in TMB and the associated performance in AWGN.

2.4. Signal Types

As illustrated in Fig.4, three types of signals are transmitted over the OFDM time-frequency grid, namely, continuous pilots, control signals and data signals.

The continuous pilot tones are inserted periodically in the frequency domain for the purpose of frequency synchro-

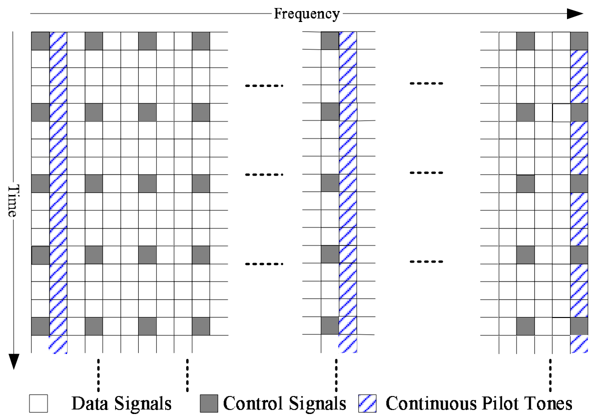

Fig. 4. Different signal types in the time-frequency grid

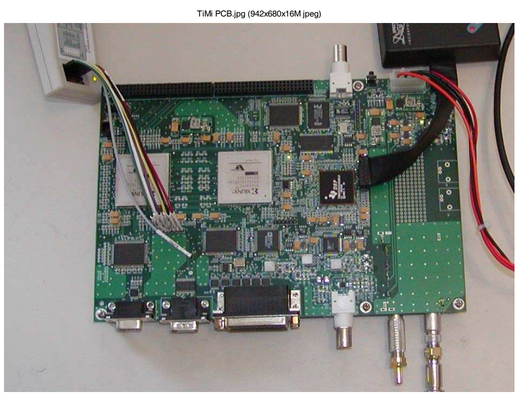

Fig. 5. A picture of the SDR platform

nization and phase tracking. Different from that of DVB-T, the locations of continuous pilots hop between frames to further improve the system robustness against long echoes.

The rectangularly distributed control signals carry important system information such as logic channel configurations and modulation/coding schemes. Once the control signals are demodulated, they can then serve as pilots in channel estimation using decision directed techniques.

The data signals occupy the rest of the time-frequency grid, which are further divided into 4 logic data channels. In particular, every two data signals adjacent in frequency are pairwise grouped to form a basic element of the logic channel to support the space-time collaborative transmission as suggested by [2].

3. EXPERIMENTAL RESULTS

Fig.5 shows a photo of the SDR platform developed for evaluating the proposed system. Two configurations of the TMB system (denoted as low-rate and high-rate respectively) are tested in both lab and field environments. The performance of a commercial DVB-T system with the similar setup is also measured as a benchmark. Table 2 lists the key parameters of both systems.

Table 2. Key parameters of the test setups

Configurations & Parameters	Low-rate		High-rate	
	TMB	DVB-T	TMB	DVB-T
Subcarriers	1k	2k	1k	2k
CP length	1/4	1/4	1/4	1/4
Modulation	QPSK	QPSK	64QAM	64QAM
Code rate	1/2	1/2	5/8	2/3
Data rate(Mbps)	5.12	4.98	19.62	19.91

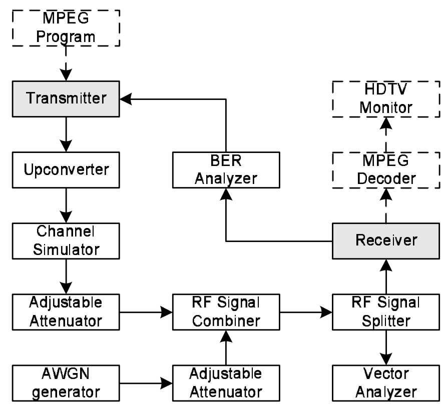

Fig. 6. Laboratory test setup

3.1. Laboratory Performance Results

Fig.6 illustrates the test setup in the laboratory environment. The transmitting signal is subject to channel fading and the additive white Gaussian noise. At the receiver side, by adjusting the additive noise power, the bit error rate (BER) of the demodulated signal is measured and the carrier to noise ratio (C/N) is recorded when the BER exceeds 10^{-6}. A subjective test is also conducted to verify the quality of the decoded picture around the breakdown point.

Static multipath channels are applied to measure the fixed reception performance. Table 3 lists different channel models used in the test. The mobile reception is evaluated by setting the channel simulator to Rayleigh fading with different Doppler shifts. The C/N comparison of TMB and DVB-T under static and Rayleigh fadings are listed in Table 4 and Table 5 respectively. As observed, the detection threshold of the TMB system is 2-3dB better than that of DVB-T in most fixed scenarios, and the gap is even bigger in the mobile reception.

Many other tests have also been performed, e.g., the receiver sensitivity, the resistance to narrow band interference, the maximum tolerance of delay spread, etc. The TMB system consistently provides better performance than the DVB-T. Due to space limitation, not all the details are listed here.

Table 3. Static multipath models: each entry defines the path delay(attenuation) with unit μs(dB)

Path	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
1	-1.8 (20)	-0.2 (19)	-18 (20)	0.07 (5.1)	0 (0)	0 (0)	0.15 (0.1)	0 (0)
2	0 (0)	0 (0)	-1.8 (10)	0.52 (0)	0.15 (13.8)	0.3 (12)	0.63 (3.8)	1 (0)
3	0.15 (14)	0.08 (22)	0 (0)	0.6 (3.9)	2.22 (16.2)	3.5 (4)	2.22 (2.6)	2 (0)
4	1.8 (10)	0.15 (17)	0.15 (20)	0.85 (3.8)	3.05 (14.9)	4.4 (7)	3.05 (1.3)	
5	5.7 (20)	0.3 (22)	1.8 (10)	2.75 (2.5)	5.86 (13.6)	9.5 (15)	5.86 (0)	
6	18 (18)	0.6 (19)	5.7 (14)	3.23 (1.3)	5.93 (16.4)	12.7 (22)	5.93 (2.8)	

Table 4. C/N (dB) in static channels

Channel Model	Low-rate		High-rate	
	TMB	DVB-T	TMB	DVB-T
AWGN	2.21	4.06	15.48	17.44
Model 1	3.34	6.14	18.06	19.23
Model 2	2.51	4.56	15.61	17.94
Model 3	5.76	6.75	19.41	23.14
Model 4	4.29	8.30	17.99	21.05
Model 5	3.11	5.98	16.88	19.37
Model 6	4.53	8.15	18.32	20.73
Model 7	4.09	8.05	17.83	20.79
Model 8	6.93	13.05	23.66	25.71

Table 5. C/N (dB) in Rayleigh fading channels

Doppler Shift	Low-rate		High-rate	
	TMB	DVB-T	TMB	DVB-T
2Hz	13.5	18.2	27.5	31.0
5Hz	14.1	20.3	29.3	32.7
35Hz	14.7	20.0	28.1	Fail
50Hz	14.7	20.0	28.3	Fail
70Hz	14.7	20.0	29.5	Fail
100Hz	14.7	20.3	Fail	Fail
Maximum	120Hz	120Hz	70Hz	8Hz

3.2. Field Trial Results

In addition to the lab test, field trials have been performed in Beijing to verify the system performance under various transmission conditions in a metropolitan city. The trial uses the Central TV Broadcasting Tower that locates at the west third ring in Beijing (coordinates: $116^o17'59''E$ & $39^o55'4''N$). The antenna is about 350 meters above ground, using Channel # 44 (758MHz-766MHz) and transmitting with 300 watts in average power. Three test routes are chosen within the Beijing city, two of which are local streets while the other one is a freeway. Each route is about 10km in length. A test van carries the user terminal and drives along the testing routes, using a dipole antenna mounted on the top of the van. Subjective tests are performed to evaluate the decoded picture quality, while a spectrum analyzer is used to monitor the receiving inband signal strength. It was observed that at the low-rate (QPSK with 1/2 coding), the decoded picture is almost glitchless as long as the receiving signal strength maintains above -80dBm, even when the van drives at a speed exceeding 100km/hour. For the high-rate (64QAM with 5/8 coding), the receiver works very well in fixed reception with signal strength above -70dBm. However, the mobility is not very well supported in most areas.

4. CONCLUSIONS

A new LDPC-based Terrestrial Multimedia Broadcasting (TMB) system suitable for the future TV network is described in this paper. The preliminary lab and field tests based on the prototype system have shown encouraging results on both fixed and mobile reception. In the future, more comprehensive tests of the TMB system in various environments are to be performed. Collaborative transmissions and the network capacity in an SFN (single frequency network) setup will also be of great interest for further study.

5. REFERENCES

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