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A Relaying Scheme for Terrestrial Digital Multimedia Broadcasting (TDMB) Cooperative Network

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Abstract

Terrestrial Digital Multimedia Broadcasting (TDMB) is one popular broadcasting standard that enable digital television transmissions to hand held receivers and cooperative system take advantage of the broadcast nature of wireless channels, uses relay stations as virtual antennas. Relay stations are an attractive solution to penetrate the wireless system with lower transmitting power at the Base station. In this paper, we presented a scheme can switch on/off the power weighting ratio between Base station and Relay station in TDMB cooperative Network. It will control the active relays in different channel propagations effectively.

Keywords: relay stations, TDMB cooperative network, channel propagations

1. Introduction

Future mobile radio systems are expected to provide and serve a wide range of applications, which inherently require high data rates, Orthogonal Frequency Division Multiplexing (OFDM) [1] is a suitable technique for broadband transmission in multipath fading environments and is implemented in digital audio broadcasting (DAB) [2] as wireless local area network (WLAN) standards [3] such as HIPEELAN/2 or IEEE 82.11a and 802.16. Since the Eureka-147 DAB system [2], [4-5] was announces in the middle of the 1990s, many kinds of applications have been introduced in many countries in the world including Europe. Digital multimedia broadcasting (DMB) is one of the applications which have emerged from the Eureka-147 DAB system. Particularly in Korea, DMB focuses on the broadcasting of moving pictures and their reception in harsh conditions such as in places surrounded by high buildings and on highways where vehicles are moving at avery high seed. That is to say, we are using a Eureka-147 DAB system for video streaming services in various mobile and portable There are two kinds of DMB systems, satellite DMB and terrestrial DMB. The terrestrial DMB is called by TDMB in Korea. The terrestrial DMB is called by TDMB in Korea. Although the TDMB system. Without increasing the selectivity of the fading in stationary Rayleigh fading channels, one way to improve the reliability of the radio links. The increased selectivity allows the channel decoder to decode the signals with better performance. Another alternative or complementary approach would be relay stations. Due to the fixed time latency constraints, so far only the analogue type of amplify and forward is under investigation. Relay stations are placed at positions with a line of sight (LOS) link to the transmitter. A relay station will resend the original signal with an increased power level and of course slightly delayed [6]. The additional delay increases or creates selective fading of the channel responses or creates selective fading of the channel response at the receiver, just as is it intended in transmit delay or phase diversity schemes. In Section 2 the switch on/off scheme in TDMB cooperative system is introduced. Followed by Section 3 the Channel model is presented. Finally numerical results show the performaces in Section 4.

2. System Description

Four different TDMB signal broadcasting modes have standardized depending on the kind of service that is planned to be provided. We consider Mode III. In TDMB, rate compatible

punctured convolution (RCPC) code with G=[133,171,145,133] and k=7 [2] is employed. The outer convolutional interleaver acts on the bytes at the output of the Reed-Solomon encoder while the inner interleaver scrambles the bits at the output of the RCPC encoder. It also has separate frequency and time inner interleaving: the frequency inner interleaver permutes data within the same OFDM symbol, whereas the time inner interleaver is more complicated and spans along time interval of 320ms (i.e., 2160 OFDM symbols) [2]. The signal is transmitted through a single antenna from the BS to the relay station (RS) and directly to the MS as well in Figure 1. The retransmitted signal from the relay station experiences for simplicity the same delay spread as the directly transmitted signal from BS, but an additional delay is applied. The overall power is normalized between the base station (BS) and the relay station (RS) and the additional delay is as low to ensure the total received signal is received within the guard interval. This means the total signal from the BS and the RS can be represented by:

$$
\begin{aligned}
s_i(k) &= \frac{1}{\sqrt{N_T}} \cdot s\left(k - \delta_{RS} \bmod N_{FFT}\right) \\
&= \frac{1}{\sqrt{N_T \cdot N_{FFT}}} \sum_{l=0}^{N_{FFT}-1} e^{-\frac{j2\pi \cdot \delta_{RS} \cdot l}{N_{FFT}}} \cdot S(l) \cdot e^{-\frac{j2\pi \cdot k \cdot l}{N_{FFT}}}
\end{aligned}
\tag{1}
$$

For the time interval $k = -N_G, \ldots, N_{FFT}-1$, we get the OFDM symbol together with the cyclic prefix. $S(l)$ are the complex valued frequency domain symbols, carrying data. N_T is 1 for the single BS or only the RS being representative for the transmission of the signal. $N_T > 1$ in case the BS and the RS are jointly active.
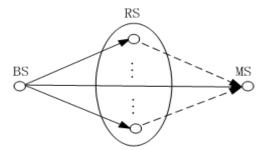

Figure 1. TDMB cooperative Network

First, the guard interval is removed from the received time domain baseband signal in the receiver.

$$
r(k) = \sum_{i=0}^{N_T-1} \sum_{m=0}^{N_{\max}} h_i(m) \cdot s_i(k-m) + n(k)
\tag{2}
$$

$n(k)$ denotes complex valued additive white Gaussian noise (AWGN) with variance σ^2 and $N_{\max}$ is the maximum channel delay spread. The remaining OFDM time domain symbol is transformed into the frequency domain by an FFT, which yields.

$$
\begin{aligned}
R(l) &= \frac{1}{\sqrt{N_{FFT}}} \sum_{k=0}^{N_{FFT}-1} r(k) \cdot e^{\frac{j2\pi \cdot k \cdot l}{N_{FFT}}} \\
&= S(l) \cdot \frac{1}{\sqrt{N_T}} \sum_{i=0}^{N_T-1} H_i(l) \cdot e^{-\frac{j2\pi \cdot \delta_{RS} \cdot l}{N_{FFT}}} + N(l)
\end{aligned}
\tag{3}
$$

With $H_i(l) = \sum_{k=0}^{N_{FFT}-1} h_i(k) \cdot e^{\frac{j2\pi \cdot k \cdot l}{N_{FFT}}}$ and the AWGN term $N(l)$ again with variance σ^2. Equation (3) shows that the relayed signal experiences a channel that can be described as an equivalent channel transfer function. Therefore, a receiver cannot distinguish whether a propagation path results from a RS or the BS directly.

LOS propagation is normally a significant advantage as any fast or slow fading is avoided. These additional propagation paths could be LOS or NLOS. The received signal from the relay will be slightly delayed due to the additional path and due to the latency of the relay station itself. In (3), An AWGN with a channel transfer function (CT) of $H_i(l) = 1$ transforms into a channel with an absolute square CT $\left|\bar{H}(l)\right|^2 = 1 + \cos\left(2\pi \cdot \delta_{RS} \cdot l/N_{FFT}\right)$. This is depicted for $\delta_{RS} = 10$ samples in Figure 2 with graph $\Delta P = 0dB$, where frequency $f = \Delta f \cdot l$ and be calculated from subcarrier index l and the subcarrier spacing $\Delta f = 8000Hz$ of the considered TDMB mode III. We can clearly observe deep fades, which degrade the system performance compared to the single direct LOS case. The reason for these deep fades is the equal power distribution among the BS antenna and the RS antenna.
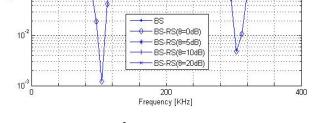

Figure 2. CT $\left|H(f)\right|^2$ for AWGN with $\delta_{RS} = 10$ Samples

A solution to overcome this problem is to weight the signals at the transmitter and the relay by different factors α_i in our switch on/off scheme with $\alpha_0 = \alpha_{BS}$, $\sum_{i=1}^{\infty} \alpha_i = \alpha_{RS}$ and $\alpha_1 = \ldots = \alpha_\infty$. To keep the transmitted power independent of the number of relays yields to the normalization.

$$\sum_{i=0}^{N_T} E\left\{\left|\alpha_i\right|^2\right\} = 1 \tag{4}$$

First of all, the implementation allows a flexible allocation of power to the different transmitters with several degrees of freedom. In order to describe the power distribution by one parameter, we define:

$$\theta = 10 \cdot \log \frac{\left|\alpha_{BS}\right|^2}{1 - \left|\alpha_{BS}\right|^2}\left[dB\right] \tag{5}$$

As the TX power ratio between the BS antenna and the BS antenna. The parameter θ allows switching the relay station on/off. Note that $\theta = +\infty$ completely switches off the relay station. Subsequently a single antenna at the BS and a single at the RS with different power levels simulation is investigated. For that, definition (6) provides a unique description of the power distribution. For AWGN (LOS) the equivalent CT is:

$$\left| H\left(l\right)\right|^2 = 1 + \frac{2 \cdot \sqrt{\vec{\theta}}}{1 + \vec{\theta}} \cdot \cos\left(\frac{2\pi \cdot \delta_{BS} \cdot l}{N_{FFT}}\right) \tag{6}$$

Which is shown in Figure 2 for $\delta_{RS} = 10$ samples and different TX antenna power ratios.

$\vec{\theta} = \dfrac{\left|\alpha_{BS}\right|^2}{1 - \left|\alpha_{BS}\right|^2}$ is the linear representation of θ.

3. Channel Model

For receivers in motion, complexity comes not only from the multiplicity of received echoes delayed in the time domain, but also from the frequency-shift affecting such echoes.

As described by the Austrian mathematician Christian Andreas Doppler (1803-1853) and depicted in the following formula, signals received in motion are affected by the receiver speed and the relative angle between the motion direction and the signal incoming direction:

$$\Delta f_D = V * \frac{f_{rf}}{C} * \cos(\phi) \tag{7}$$

Where:

V receiver velocity

f_{rf} carrier frequency of transmitted signal

C speed of light (299,792,485 m/s in vacuum)

ϕ angle between motion direction and signal incoming direction

Table 1. TU6 Channel Model

Tap number	Delay (us)	Power (Lin)	Power (dB)	Dopper Spectrum
1	0.0	0.5	-3	Rayleigh
2	0.2	1	0	Rayleigh
3	0.5	0.63	-2	Rayleigh
4	1.6	0.25	-6	Rayleigh
5	2.3	0.16	-8	Rayleigh
6	5.0	0.1	-10	Rayleigh

We consider a time-varying multipath channel obtained by discrete-time sampling a continuous-time channel. Since time variation implies time-selective fading, while multipath implies frequency-selective fading, we are actually considering discrete-time doubly-selective fading channels. The time evolution of the lth channel path is expressed by:

$$h_l\left[k\right] = h_c\left(kT_s, lT_s\right), \quad l = 0, \ldots, L-1 \tag{8}$$

Where the continuous-time channel $h_c\left(t, \tau\right)$ is wide-sense stational with uncorrelated scattering (WSSUS) [7], $L = \left[\tau_{\max} / T_s\right] + 1$ is the number of discrete channel paths, $\tau_{\max}$ is the sampling period, $\left\{\sigma_l^2 = E\left\{h_l\left[k\right]^2\right\}, l = 0, \ldots, L-1\right\}$ represents the power delay profile (PDP) and k denotes the discrete-time temporal index. The delay spread of the multipaths depends on the nature of the geographical area where the signal propagation is taking

place. Like typical urban (TU) channels, the tall buildings of urban area generate high relative delays. The Typical Urban 6-paths model (TU6) depicted in Table 1 [8], proven to be representative for the typical mobile reception with Doppler frequency above 10Hz.
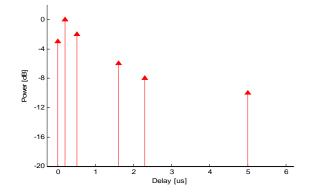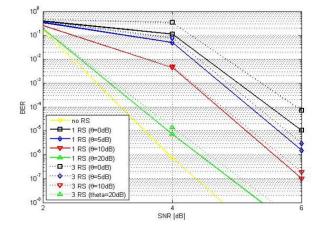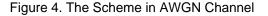

Figure 3. Power-delay Profile of TU 6 Channel

4. Results and Analysis

A link level simulation was performed to give an insight into the switch on/off relaying scheme. The system parameters we focused on, are summarized in Table 2. We use the TDMB mode III with spacing of $\Delta f = 8000 Hz$. The data is modulated by a $\pi/4 - DQPSK$ and encoded by a convolutional code with R=1/2. We consider direct link only and direct plus the relayed link with $\delta_{RS} = 10$ samples. The Doppler spectrum of Rayleigh components is uniform with a bandwidth of $f_{D_{max}} = 8 Hz$, which is of the subcarrier spacing and thus negligible in terms of intercarrier interference.

Table 2. Simulation Parameters (Mode III)

Bandwidth(MHz)	1.536
Useful sub-carriers	192
FFT size	256
Channel separation (MHz)	1.75
Subcarrier spacing (kHz)	8.0
Sampling frequency (MHz)	2.048
Block duration (us)	125
CP duration (us)	31
Bit rate (Mbps)	1.1342
Spectral efficiency (bps/Hz)	0.7384

Figure 4 and Figure 5 show the bit error probability (BER) curves for the switch on/off relaying scheme in AWGN channel and Rayleigh fading channel, respectively. The BER performances of different RS situation get gain with power weighting ratio θ increased in AWGN channel however the situation in AWGN channel however the situation in Rayleigh fading channel is opposite. The BER performances loss with decreased RS in Rayleigh fading channel is different with that in the AWGN channel. For Rayleigh fading channel in Figure 4, we get an SNR loss of 3 dB at BER = 10^{-4} for 1 RS ($\theta = 0 dB$) compared to no RS. For the AWGN channel in the Fig.5, however, an SNR gain of 7dB for 1 RS ($\theta = 0 dB$) compared to no RS. Power weighting θ between the station (BS and RS) allows finding a compromise between SNR gains and losses in different channel environment. In Rayleigh fading channels a relay station provides additional propagation paths, which increases the available diversity. In AWGN channel, however, these additional propagation paths are static, and thus, transform the AWGN channel into a static frequency selective one, which degrades the system performance.
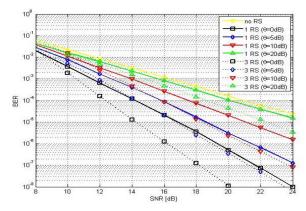
Figure 4. The Scheme in AWGN Channel

Figure 5. The Scheme in Rayleigh Channel

4. Conclusion

In this paper, we have presented a switch on/off relaying scheme in TDMB cooperative Network. It can be able to adjust the power weighting ratio between the BS and RS for the different channel environment. By the simulation results in Section 3, it shows the different performances of our scheme with the same adjustment parameters in the two kinds of propagation, AWGN channel (LOS) and Rayleigh fading channel (NLOS). Therefore our switch on/off scheme will be better to adjust performance in channel propagations.

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