Abstract—In mobile radio communications there is an ever-increasing demand for high speed and high quality data transmission. Error correction and multi-channel reception are two promising techniques incorporated in the present-day cellular system to attain high-quality and high-speed communication in a multipath fading environment where the rapid variations of the channel gain degrades the transmission quality and limits the speed. Turbo code is a new coding scheme that has gained a lot of attention recently. Rake reception, antenna diversity reception and retransmission are some of the technologies that exploit the multipath fading nature of the channel. As yet, the combined effect of turbo coding and multi-channel reception has not been analyzed. In this paper, we derive the turbo decoding principle in the case of multi-channel reception.

Keywords- Turbo code, multi-channel, combination

I. INTRODUCTION

The migration from 3rd generation mobile communication networks to 4th generation (4G), which are purely IP-based networks, leads to new challenges, but also great risks for the traditional mobile network operators, as competition increases dramatically. While this competition potentially improves the cost-value ratio for mobile users, they might well find their freedom of seamless session mobility abruptly end at the administrative borders of Wireless Internet Service Providers [1].

In mobile radio communications, the received signal experiences multipath fading, which is produced by interference of many waves having different Doppler shifts created by reflections and refractions by nearby buildings surrounding a mobile station. Since the propagation channel consists of numerous paths, the transmitted signal suffers from so-called frequency-selective multipath fading. Where high bit-rate transmissions are involved, the effects of frequency-selective fading cannot be ignored and the inter-symbol interference is produced. Hence, some error control techniques are necessary[2].

Turbo code is a new and powerful error correction code which outperforms all previous known coding schemes. It was introduced in 1993 by Berrou, Glavieux, and Thitimajshima [3], who reported extremely impressive results for a code with long frame length. They claimed that the performance of Turbo-codes in terms of bit error rate (BER) is close to the Shannon limit. Since then turbo coding has evolved at an unprecedented rate and has also been included in the standardization of the third generation (3G) of mobile radio systems. Rake reception[4], antenna diversity reception[5] and retransmission[6] are some of the technologies that exploit the multipath fading nature of the channel. As yet, the combined effect of turbo coding and multi-channel reception has not been analyzed. In this paper, we derive the turbo decoding principle in the case of multi-channel reception.

II. MULTI-CHANNEL TURBO DECODING PRINCIPLE

An L branch multi-channel reception is considered. Let the $l$th channel received signal sequence be expressed as follows.

$$\mathbf{y}_0 = (y_{01}, \ldots, y_{0K}, \ldots, y_{0l}, \ldots, y_{0K})$$

$$\mathbf{y}_{0l} = (y_{0l}^u, y_{0l}^{(p1)}_1, y_{0l}^{(p2)}_2)$$

![Fig. 1 Iterative turbo decoder](image)

where $l = 0, 1 \sim L-1$. Turbo decoding[7] (Fig.1) based on MAP algorithm consists of calculating $\gamma_1(S_{k-1}, S_k)$ is shown below.

$$\gamma_k(S_{k-1}, S_k) = p(y_k | x_k)P(u_k)$$

$$= p(y_k^u | u_k) p(y_k^{(p1)} | p_k^{(1)}) P(u_k)$$

(1)

When the signal is received from $L$ channels, $\gamma_1(S_{k-1}, S_k)$ changes to
\[ y_k(S_{t-1}, S_k) = \prod_{j=0}^{L-1} p(y_{ij} | S_k) P(u_k) \]
\[ = \prod_{j=0}^{L-1} p(y_{ij} | S_k) P(u_k) \]
\[ = \prod_{j=0}^{L-1} p(y_{ij} | u_k) p(y_{ij} | p_k) P(u_k) \]
\[ = \left( \frac{1}{2\pi\sigma^2} \right)^{\frac{L}{2}} \exp\left\{ -\frac{1}{2\sigma^2} \sum_{j=0}^{L-1} \left[ y_{ij} - \sqrt{2S \xi_{ij} u_k} \right]^2 \right\} \exp\left\{ -\frac{1}{2\sigma^2} \sum_{j=0}^{L-1} \left[ y_{ij} - \sqrt{2S \xi_{ij} p_k} \right]^2 \right\} \right\} P(u_k) \]

(2)

Taking into account the fact that the state transition and the received channel sequence for this transition depends on the signal sequence received from all the channels. If the signal sequence received from all the channels experiences uncorrelated fading, then Eq. (2) can be written as

\[ y_k(S_{t-1}, S_k) = \prod_{j=0}^{L-1} p(y_{ij} | u_k) p(y_{ij} | p_k) P(u_k) \]

From the above result it is found that the turbo decoding algorithm used for the single channel reception need not be modified for the multi-channel reception, only the input to the turbo decoder should be replaced by the value obtained after MRC.

III. MULTIPLE TRANSMIT ANTENNA

If the systematic bits \( \{u_k\} \) and parity bits \( \{p_k\} \) are transmitted from different antennas using different spreading codes, the systematic bits and the parity bits will arrive at the receiver from different paths and will have no mutual correlation. Space interleaving is used in addition to time interleaving to improve the interleaving effect. Three different types of such jumbling scheme were considered.

Scheme 1: The systematic bits are transmitted by one antenna and the parity bits from the other antenna using different spreading codes.

Scheme 2: In this scheme each antenna transmits an alternate systematic/parity bit pair. This is pictorially shown in Fig.2. The idea behind this was to ensure that the neighboring systematic/parity bit pair experience independent fading.

Scheme 3: This scheme distributes the encoded bits more severely. The 0th systematic bit is transmitted by antenna 1 and the 0th parity bit from antenna 2. The following systematic bit is transmitted by antenna 2 and the parity bit from antenna 1. This ensures that the neighboring systematic bits and neighboring parity bits are transmitted from different antennas and at the same time the systematic/parity bit pair is also no longer transmitted by the same antenna.
In transmit diversity the power of the two antennas may be varied as desired. Figure 5 plots the BER characteristics obtained by varying the transmit power for the transmit diversity scheme 1. (In scheme 1, the systematic bits are transmitted from one antenna and the parity bits from the other.)

The X-Y in the legend represents the percentage of total power for the systematic bits and the parity bits, respectively. It can be seen that the BER is the lowest when the transmit power from the two antennas is equal. As the power changes, the BER performance worsens. However, the waterfall nature in the BER curve is observed in all cases. The "60-40" power distribution is better than the "40-60" case; it shows that it is advantageous to transmit the systematic bits with higher power. This is as expected because the same received systematic bits are used by both the component decoders in the turbo decoder. This is verified by the "70-30" and "30-70" results where the degradation is even worse.

RAKE receiver consists of correlators, each receiving a multipath signal. After despreading by correlators, the signals are combined. After spreading and modulation, the signal is transmitted and it passes through a multipath channel, which can be modeled by a tapped delay line (i.e., the reflected signals are delayed and attenuated in the channel).

The RAKE receiver has a receiver finger for each multipath component. In each finger, the received signal is correlated by a spreading code, which is time-aligned with the delay of the multipath signal. The PN-code forms a high autocorrelation peak in response to differences in time delays. This effect is utilized to synchronize the local PN-generator with the incoming signal. After despreading, the signals are weighted and combined. Since the received multipath signals are faded independently, diversity order and thus performance is improved.

The combined signal is used as the channel value in the turbo decoder. If there exists L paths, the independent signals received from each path can be written as

\[ y(l) = (y(l)_1, \ldots, y(l)_K) \]

for \( l = 0, 1, \ldots, L-1 \). If the signals are weighted by the path gain factor (complex conjugate of the path gain \( \xi(l) \)) and added as in the maximum ratio combining, then the signal can be fed directly to the turbo decoder and as said earlier no modifications are necessary in the decoder structure.
The wireless channel hardly has a uniform power delay profile. Large values of $\alpha$ correspond to the concentration of power in one path. The change in the BER with the change in $\alpha$ is plotted in Fig. 7 for $L=4$. It can be observed that the BER is the lowest for a uniform power delay profile, i.e., $\alpha = 0$.

V. CONCLUSION

In this paper, the combined effect of turbo coding and multi-channel reception is investigated. The theoretical expression for the turbo code in the presence of multiple channels was derived which showed that even in the case of multi-channel reception the turbo decoder structure need not be changed and decoding can be realized with the same algorithm as used for the single channel reception just by replacing the input to the decoder by the maximum ratio combined signal. Large improvement in the BER characteristic was obtained.

REFERENCES


