3GPP RAN1 meeting #44-bis **R1-060908**
Athens, Greece, 27th–31th March, 2006

Agenda Item: **10.2.3**

Source: **Nortel Networks**

Title: **On the performances of LTE RACH**

Document for: **Discussion**

1 Introduction

While several issues on RACH have been raised in the previous meetings, one of them is how to send RACH message. The RACH message can be scheduled on the shared channel or transmitted on RACH along with the preamble. The main purpose of this contribution is to discuss the performances on LTE RACH.

In the first scheme, we considered the preamble performances since scheduled message is out of scope in RACH. Additionally, the supported simultaneous preambles are simulated if an interference cancellation scheme is applied. In the second scheme, we investigated the RACH message performance sent along with the preamble. Since we didn't consider pilot symbols, the RACH preamble is used for the estimation.

In section 2, we configured RACH structure for each case and the performance results can be shown in section 3.

2 Considered RACH configurations

2.1 Case 1 : Sending only preambles

Figure1 shows the transmission structure for LTE RACH preamble. Zadoff-Chu CAZAC is used for the code signatures of RACH preamble. They are mapped to the sub-carriers in localized manner before N point FFT is accomplished. We should note that Zadoff-Chu CAZAC has the following features.

- Low PAPR than random-code signatures
- Zero autocorrelation for the delay over one-symbol duration
- Applicable to SC-FDMA transmission block

The transmitted RACH symbol can be identically repeated in order to make the receiver simple and accumulate the symbol energy over the time domain. Through identical symbols, the detector can be designed simply. As shown in figure 2 and figure 3, the UE transmits preamble symbols over RACH and then the Node B detects a preamble sequence from RACH preamble detection window. The detected symbols are compensated by all the possible codes. The receiver can recognize the preamble sequence with threshold detector i.e. if the received energy of a code is more than the threshold, the receiver presumes that the code is detected.

In this section, we consider only preambles since the message can be scheduled on UL SCH if the preamble is detected. However, this scheme can be extended to support SC-FDMA as well as OFDMA.

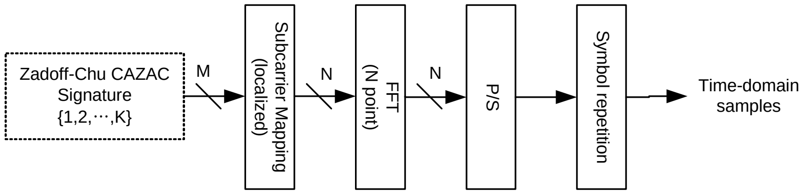

Figure 1. Tx structure for RACH preamble.

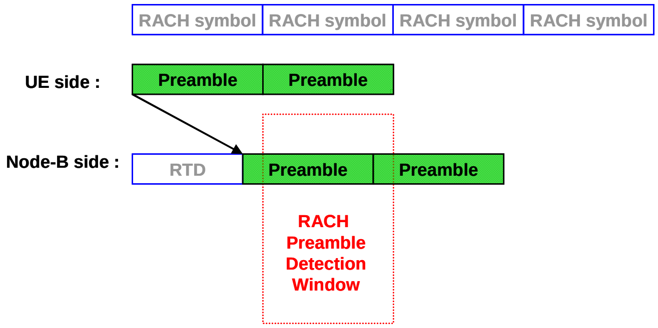

Figure 2. The RACH preamble signal format

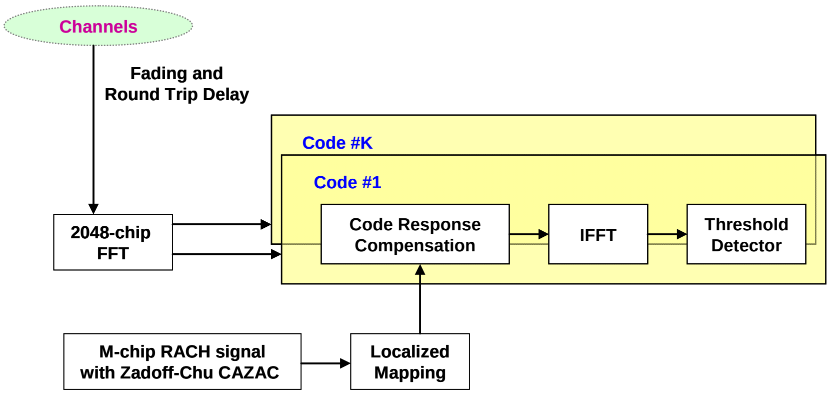

Figure 3. An example of RACH detector

2.2 Case 2 : Sending messages along with preambles

We had investigated RACH message transmitted along with the preamble. In that scheme, the RACH message signals are transmitted after RACH preambles and identically repeated similar to the preamble symbols. It is shown in the figure 4. Zadoff-Chu CAZAC is used for preamble signatures and for channel estimator. In order to send RACH message FEC, symbol repetition, interleaver and BPSK modulation are assumed. Note that for convenience, tail biting convolution coding with K=7 and R = 1/2 is used. In order to coherent RACH message demodulation, the channel estimation is extracted from the preamble since the pilot symbols are not devised in the structure.

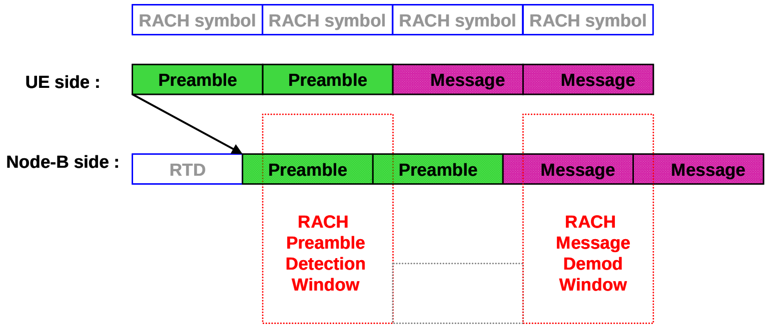

Figure 4. The preamble and message signal format

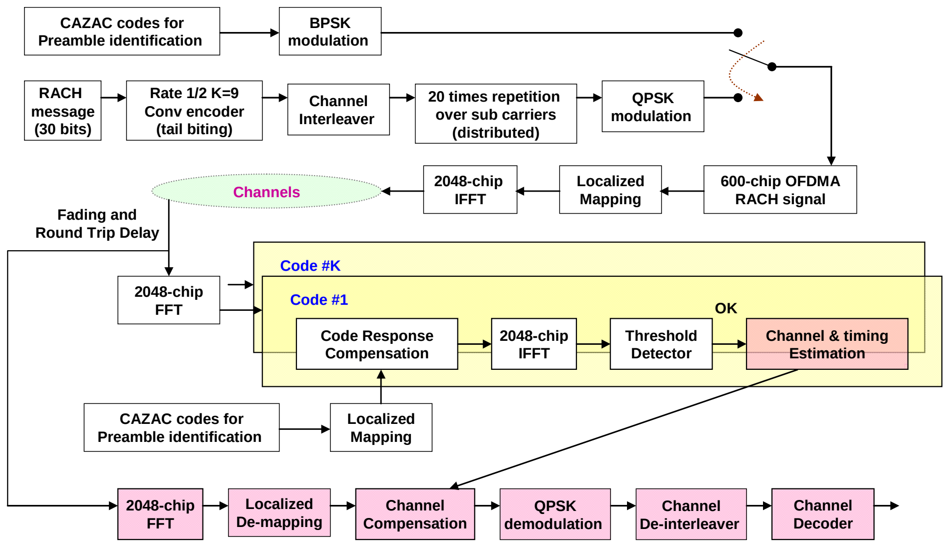

Figure 5. The modem structures for RACH preamble and message (An example)

3 Simulation results

Based on [1], we designed a random access channel. The symbol parameters are same with that of UL SCH LB. Table 1 shows the assumptions and the parameters for simulation. The used subcarrier, Nu is 600 since RACH BW is 10MHz, while the used subcarrier for RACH preamble, M is 599 which is the maximum prime number less than 600. The channel estimator for RACH message can be either perfect or real. Two symbols for RACH message are transmitted after RACH preamble so that the message demodulation is simpler. To get sufficient performance for the message, 10 times repetition is used and distributed over frequency domain.

Table 1. The parameters and assumptions for RACH simulation

RACH symbol duration	66.67 μsec
Number of Rx antennas	2
N (FFT Size / Samples in a symbol)	2048 samples (20MHz)
Nu (used subcarriers in a system BW)	1200 subcarriers (10MHz)
Number of subcarriers for RACH BW	600 subcarriers (10MHz)
M (used subcarriers for RACH preamble)	599 subcarriers
K (number of signature in a cell)	16
Fading Channel	TU1, 3Km/h
Txed RACH symbols	2 (but effectively, 1 symbol for detector)
Round trip delay	Less than 1 symbol duration
RACH preamble Detector	Threshold detection
RACH preamble codes	Zadoff-Chu CAZAC
False-alarm probability	0.001
Channel estimation	Perfect or Real
RACH message information	30 bits (RRC request) 5 bits (CQI)
RACH message channel codes	1/2 K=7 tail-biting convolutional codes (30 bits) Modified Reed Muller (5 bits : HSDPA)
RACH message channel interleaver	Block interleaver
RACH message repetition	10 (30 bits, distribution scheme over subcarriers) 30 (5 bits, distribution scheme over subcarriers)

While keeping 0.1% false-alarm probability, the missing probabilities were simulated as shown in figure 6. The 0.01 missing probability at 10MHz BW can be obtained at -9.5dB CINR, which means about 18dB Ep/No is required for RACH preamble. If 2.5MHz BW for RACH preamble is used, 7.5 dB is needed additionally. In figure

7, the detector performance with IC technique is compared with that of a conventional detector. With the conventional detector, 3 signatures are decoded while with IC detector, 7 signatures are simultaneously detected at -2.5 dB CINR.

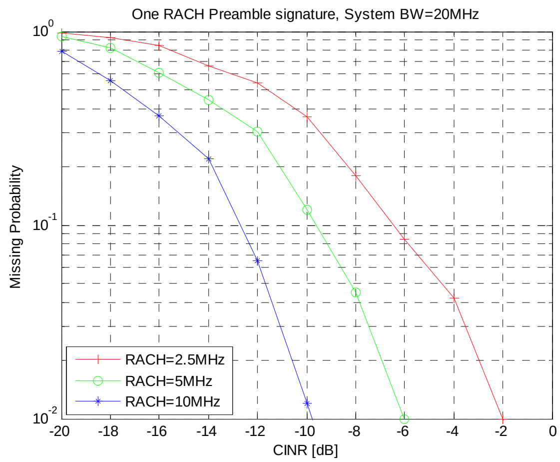

Figure 6. The missing probability of RACH preamble over TU1 channels (2 Rx antennas)

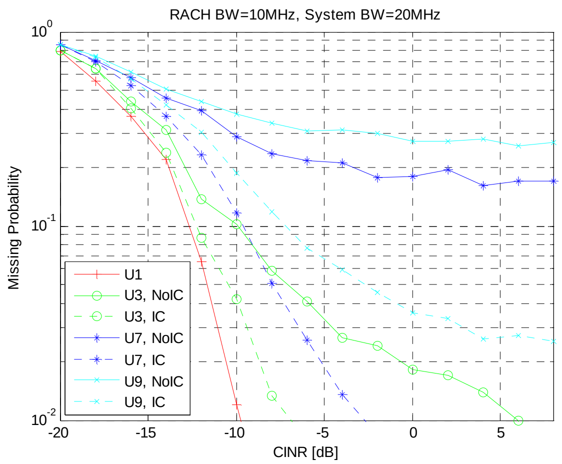

Figure 7. The performance comparison between a conventional detector and a detector with IC technique

Figure 8 shows the BER/BLER performances of RACH message with perfect estimator and real estimator. To get the results, we assumed Node-B know the transmitted preamble sequences, and channel estimator operates with the received preamble signals. For perfect estimation, the required CINR is achieved at -10dB to get 1% BLER. However the performance with real estimation needs -6dB that is about 4dB greater than the performance of RACH preamble at 10MHz BW. The performance gap is caused from channel estimation error. As shown in figure 9, the MSE of channel estimation is about 0.63 at -10dB CINR. This is so poor that the channel estimator can not be operated properly.

In Figure10, RACH information bits are replaced by 5-bit CQI information as HSDPA cases. CQI is encoded to 20 bits as the same way with HSDPA. The number of symbol repetition for a coded bit is 30. The required CINR to get 5% BLER is about -13dB CINR. The performance difference between ideal estimator and real estimator is about 7dB. Compared with the operating point of RACH preamble, CQI operating point is lower than about 4 dB. However the information is not CQI, the performance requirement becomes tighter and the performance gap may decrease.

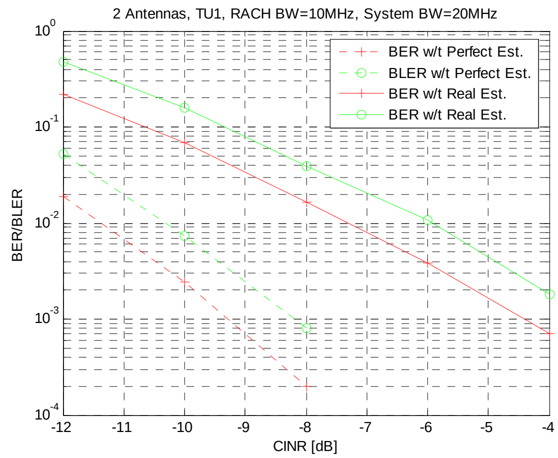

Figure 8. The BLER of RACH message (TU1, 2 Rx antennas)

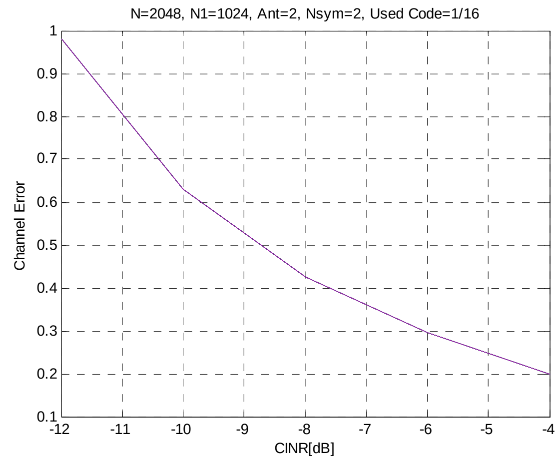

Figure 9. The MSE of channel estimation (TU1, per Rx antenna)

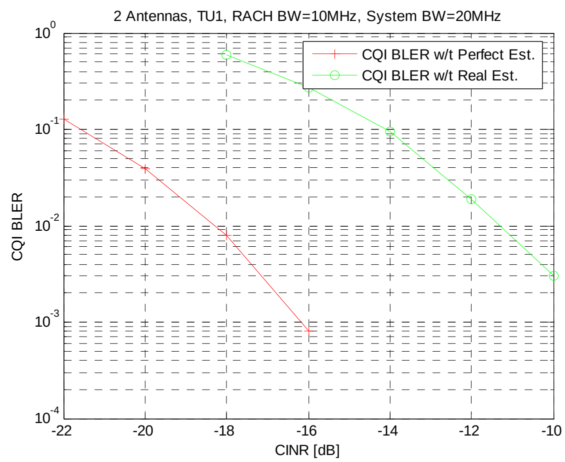

Figure 10. The CQI BLER (TU1, 2 Rx antennas)

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