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Athens, Greece, 27 – 31 March, 2006

Source:	**NTT DoCoMo, NEC**
Title:	**Investigations on Random Access Channel Structure for E-UTRA Uplink**
Agenda Item:	**10.2.3**
Document for:	**Discussion and Decision**

1. Introduction

The basic principle of a random access channel (RACH) with a non-synchronized [1]-[13] and synchronized [7]-[13] mode was agreed upon through E-mail discussion after RAN1#44. Moreover, the RACH structure such as the transmission bandwidth and the lengths of the preamble part and message part were investigated considering the link budget in [1]-[8] for the E-UTRA uplink. This paper investigates the RACH structure such as the transmission bandwidth, length of the preamble part, and the allowable number of control bits in the uplink. Investigations on the preamble parameters follow the approaches described in [4] and [6]. Furthermore, the allowable number of control bits is obtained from the evaluation results on the preamble and message parts.

2. Evaluation on Preamble Detection

2.1. Transmission Bandwidth

First, the optimum transmission bandwidth of the RACH is evaluated from the viewpoint of the preamble detection probability. Figure 1 shows the structure of the preamble sequence assumed in the simulation. The preamble sequence is generated by repeating the 133-μsec-length CAZAC (Constant Amplitude Zero Auto-Correlation) sequence N_{rep} times, where N_{rep} is parameterized in the simulations [6],[7]. Table 1 lists the number of symbols in the preamble part for the respective transmission bandwidths.

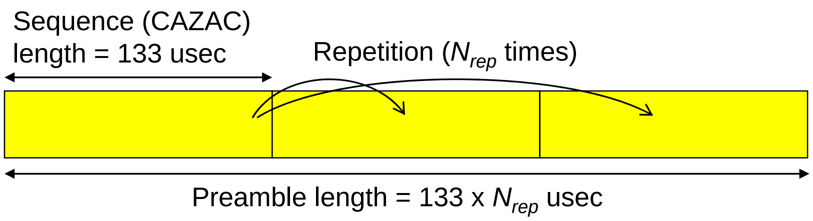


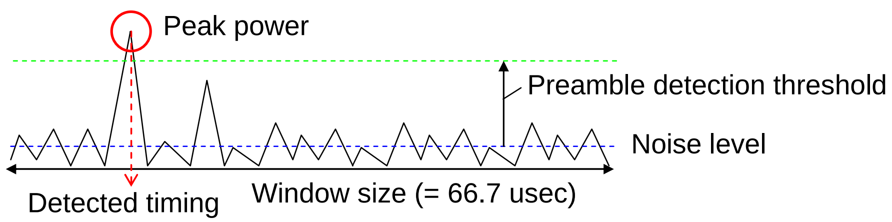
Figure 1 – Preamble sequence assumed in simulation evaluation

Table 1 – Number of symbols of preamble part for each transmission bandwidth

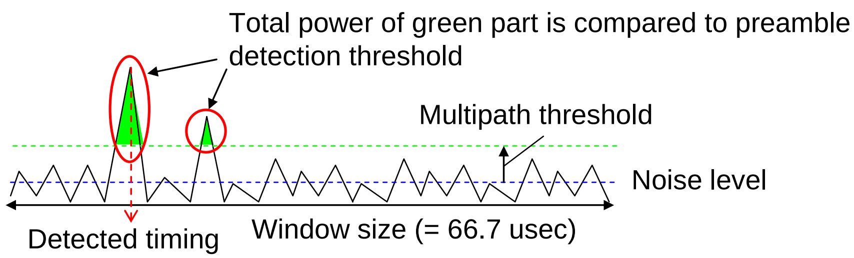
Transmission bandwidth (symbol rate)	Number of symbols in preamble part
0.35 MHz	47
1.12 MHz	149
2.20 MHz	293
4.49 MHz	599
8.95 MHz	1193

*Pulse shaping filtering is not assumed in the evaluation

Figure 2 illustrates the detection method of the preamble. We measured the power delay profile assuming a total 16 candidates for the CAZAC sequence using an aperiodic cross-correlation [3]. The search window duration is set to 66.7 µsec. We employ two-branch antenna diversity reception. Thus, the measured power delay profiles received at two antennas are combined in squared form, i.e., power summation. Using the measured power delay profile after combining between antennas, the detection threshold is calculated from the averaged correlation values at sampled points except for the samples around the peak value. We investigate the detection probability of the preamble part for two detection methods, i.e., with and without multipath combining in the following evaluation. As shown in Fig. 2(a), the maximum peak power is compared to the preamble detection threshold without multipath combining. Meanwhile, with multipath combining, effective paths are selected from the pre-determined power threshold value. The total received power after combining the effective paths is compared to the preamble detection threshold.



(a) Without multipath combining



(b) With multipath combining

Figure 2 – Preamble detection scheme

Figure 3 shows the miss detection probability of the preamble part without multipath combining, as a function of the received signal-to-noise power ratio (SNR) with various transmission bandwidths as a parameter. Here, the received SNR is defined as the SNR after despreading the CAZAC sequence over the preamble duration. We assume that the preamble length is 0.4 msec, which corresponds to $N_{rep} = 3$. The preamble detection threshold for each transmission bandwidth is independently optimized based on the simulation to achieve the false alarm probability of 10^{-3}. The false alarm probability is defined as the probability of a particular code being detected when nothing, or different code was transmitted. The fading maximum Doppler frequency is set to $f_D = 5.55$ Hz, which corresponds to the moving speed of 3 km/h at a 2-GHz carrier frequency. A six-ray Typical Urban channel model is assumed [14]. Interference from the RACH attempt of other UEs and other cell interference are approximated as Gaussian noise. Figure 3 shows that the miss detection probability is minimized when the transmission bandwidth of the preamble part is approximately 2.5 to 5 MHz due to frequency diversity. These results agree well with the results in [4]. It is also seen when the transmission bandwidth becomes wider beyond the above near optimum bandwidth to, for example, 10 MHz, the miss detection probability is degraded due to the increasing number of paths.

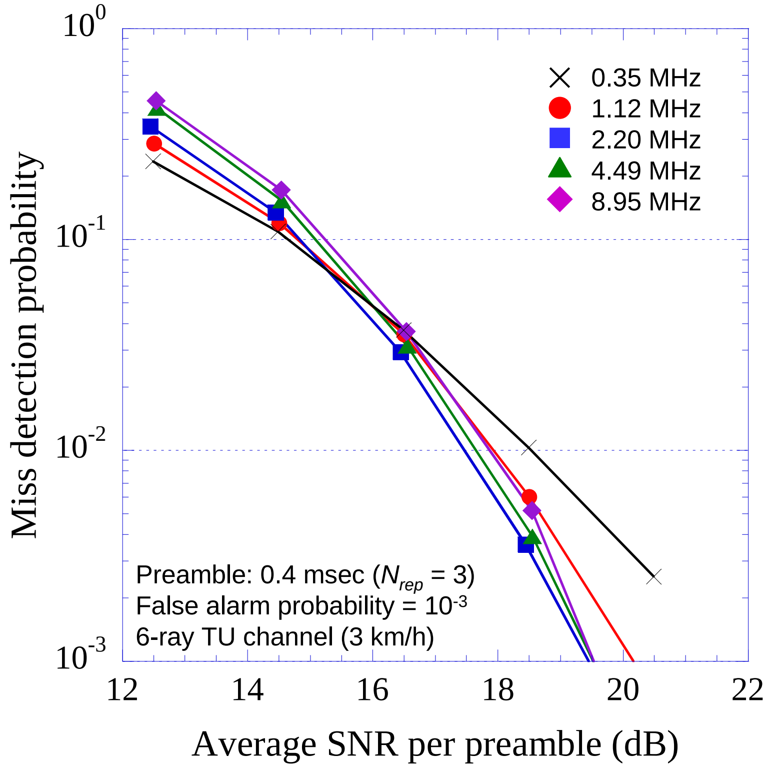


Figure 3 – Miss detection probability performance for each bandwidth (without multipath combining)

Next, Fig. 4 shows the miss detection probability of the preamble with multipath combining as a function of the received SNR after despreading with various transmission bandwidths as a parameter. Other simulation conditions are the same as those in Fig. 3. Compared to the case without multipath combining, Fig. 4 shows that by using multipath combining, the miss detection performance of a wide transmission bandwidth is improved since the increased number of resolved paths is effectively Rake-combined. However, we find that the miss detection probability with the 10-MHz transmission bandwidth is slightly inferior to the case of the 5-MHz bandwidth. This is because since the received signal power per path becomes very low due to excessive resolution of the multipath, and detection error of the correct path frequently occurs due to the influence of noise. From the figure, we can see that the optimum transmission bandwidth of the RACH is approximately 2.5 to 5 MHz from the viewpoint of the preamble detection performance.

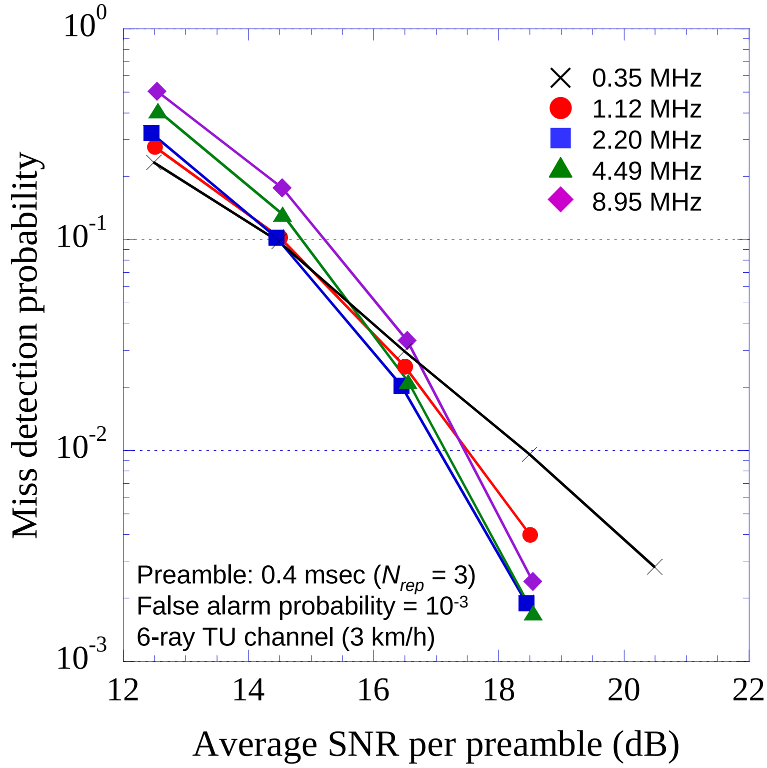


Figure 4 – Miss detection probability performance for each bandwidth (with multipath combining)

2.2. Required Sequence Length for Coverage

Figure 5 shows the required average signal energy per symbol-to-noise power spectrum density ratio (E_s/N_0) per antenna for achieving the miss detection probability of 10^{-1} and 10^{-2} as a function of the preamble length. We assumed a 5-MHz transmission bandwidth. The maximum Doppler frequency is set to f_D = 5.55 Hz and 222 Hz corresponding to the moving speed of 3 km/h and 120 km/h at the frequency of 2 GHz. Preamble detection without multipath combining is used in this figure. From [1], when inter-site distance (ISD) is 500 and 1732 m, the 5% value for the cumulative distribution function (CDF) of the required average received E_s/N_0 becomes approximately -13 and -18 dB, respectively, assuming a 20-dB penetration loss and one-cell reuse with a full traffic load. Therefore, considering the results in Fig. 5, we can see that the preamble length of approximately 0.3 and 0.8 msec is required for ISD = 500 and 1732 m, respectively, to achieve the average miss detection probability of 10^{-2}. Therefore, at least the duration of two sub-frames (= 1 msec) is necessary for the RACH including the preamble and guard time to support typical environments. These results yield almost the same length as that of the preamble part in W-CDMA (= 1 msec). It is also observed that the required preamble length can be reduced according to the reduction in the path loss, i.e., distance of the UE from the cell site. Moreover, we see that the same preamble length can be used to support high mobility up to 120 km/h. The conclusion regarding the required length of the preamble part for ISD of 500 and 1732 m also agrees well with the conclusion presented in [6].

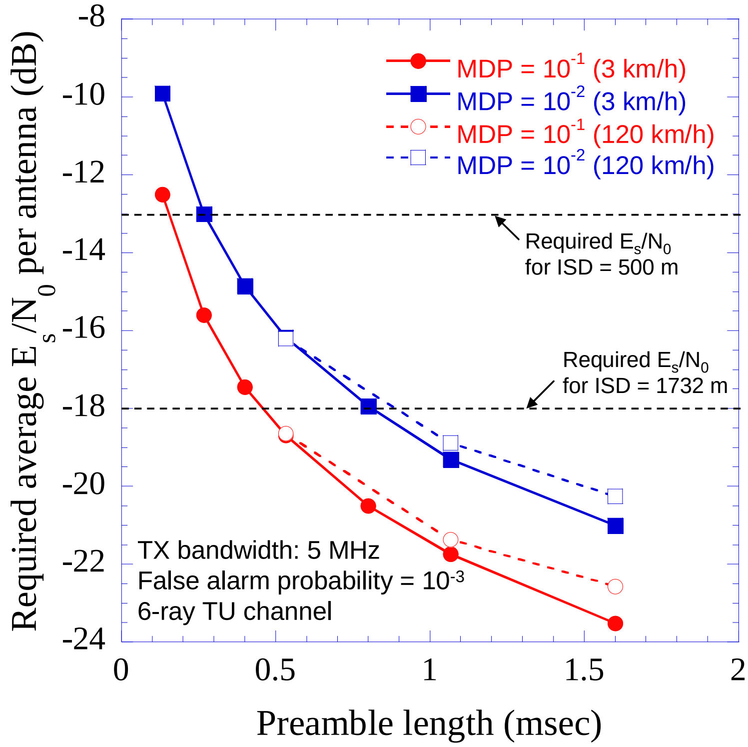


Figure 5 – Preamble length to achieve required E_s/N_0 for miss detection probability of 10^{-1} and 10^{-2}

3. RACH Length and Number of Control Bits

In this section, based on the evaluation results of the number of control bits of the RACH in the previous paper [1] and that of the required preamble length, we present a recommendation for the RACH frame structure assuming the 5-MHz transmission bandwidth for RACH. Tables 2(a) and 2(b) give the number of information bits assuming the spreading factor of 64 and 16, respectively (extracted from [1]). From [1], the spreading factor of 64 is required when the required minimum E_s/N_0 = -18 dB (corresponds to the case with ISD of 1732 m). For the required minimum E_s/N_0 value, the required preamble length becomes approximately 0.8 msec assuming the required miss detection probability is 10^{-2}. Therefore, the appropriate RACH structure may have a 1-msec format with a 3-bit control message or a 2-msec format with a 46-bit control message, using a 800-µsec preamble part in both cases. Similarly, the spreading factor of 16 is required when the required minimum E_s/N_0 = -13 dB (corresponds to the case with ISD of 500 m). In this case, a 1-msec format using a 266-µsec preamble can convey a 25-bit control message. Further investigation on the RACH structure is necessary considering the required number of bits for control information and the number of control bits that can be conveyed by the preamble part as presented in Section 2.

Table 2 – Number of information bits for RACH (5-MHz bandwidth)

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