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Source: **Panasonic**
Title: **Random access design for E-UTRA uplink**
Agenda Item: **11.1.2**
Document for: **Discussion and Decision**

1. Introduction

In this document, we discuss the random access structure as follows. This document only discusses non-synchronized random access structure.

- The preamble sequence
- The minimum preamble length
- The minimum bandwidth
- The sequence composition in preamble
- The control information over the preamble part
- The necessity of message part

2. Random access structure design

2.1. Preamble sequence

Random access is a contention based transmission. Therefore, multiple random access bursts from multiple UEs could be transmitted simultaneously. It is also good, if multiple random accesses are detected simultaneously at E-NodeB. To reduce the collisions among the random access, a common approach is UE randomly chooses one out of plural different preambles/signatures. To distinguish random accesses from different UEs at NodeB, a sequence with good auto-correlation and good cross-correlation property is required. For these reasons, we compare the miss detection probability vs. the average Ep/No among the different type of sequences (i.e. W-CDMA preamble sequences, different CAZAC sequences and cyclic-shifted CAZAC sequences).

Performance of different preamble sequences

The simulation parameters are shown in Table 1. Preamble performance evaluation criteria used are false alarm and miss detection probability to the average Ep/No. The definition is as follows:

- **False alarm** (**Pfa**): the probability of a particular code being detected when nothing, or different code is transmitted
- **Miss detection** (**Pmd**): the probability of a particular code not being detected when the code is transmitted

Table 1 Simulation parameters

Parameter	Value
Transmission Bandwidth	1.25MHz (Allocated bandwidth: 1.024MHz)
Preamble length	Approximately 400 usec
Guard time	Approximately 100 usec
Signature Pattern	- W-CDMA (truncated) - CAZAC sequence (Zadoff-Chu CAZAC[20])
Length of CAZAC sequence (N)	- W-CDMA (400 symbols: 16 signature * 25 repetition) - CAZAC (401 symbols) - Cyclic-shifted CAZAC (401symbols, shift duration: 50usec)
Number of multiplexed preambles	1, 2, 4, 8, 12, 16
Antenna configuration	1 Tx antenna, 2 Rx antennas (power profiles are combined)
Detector	Matched filtering in time domain. See Appendix.
Number of detector	16
Channel model	6-path Typical Urban 120km/h

Figure 1 shows the miss detection probability (Pmd) against the average Ep/No of each preamble sequence to achieve the false alarm Pfa = 10^{-3} under TU 120km/h. The miss detection probability against the Ep/No is always satisfied in Pfa = 10^{-3}. The result reflects that the false alarm probability is fluctuated due to mutual interference between preambles when plural preambles are transmitted.

From the evaluation, both CAZAC sequence and cyclic-shifted CAZAC sequence show better detection performance compared with the truncated WCDMA preamble sequence. Eight cyclic-shifted CAZAC sequences mixed have similar performance with only one CAZAC sequence. Moreover, the performance in 8 cyclic-shifted a CAZAC sequences and 4 cyclic-shifted other CAZAC sequences mixed have similar to 4 different CAZAC sequences mixed. Therefore, cyclic-shifted CAZAC sequence has superior performance among compared sequences. This aspect is also discussed in [14] .

As the results, we propose to choose cyclic-shifted Zadoff-Chu CAZAC as preamble sequence mainly. In addition, to have more signatures, we also propose to use different Zadoff-Chu CAZAC sequence.

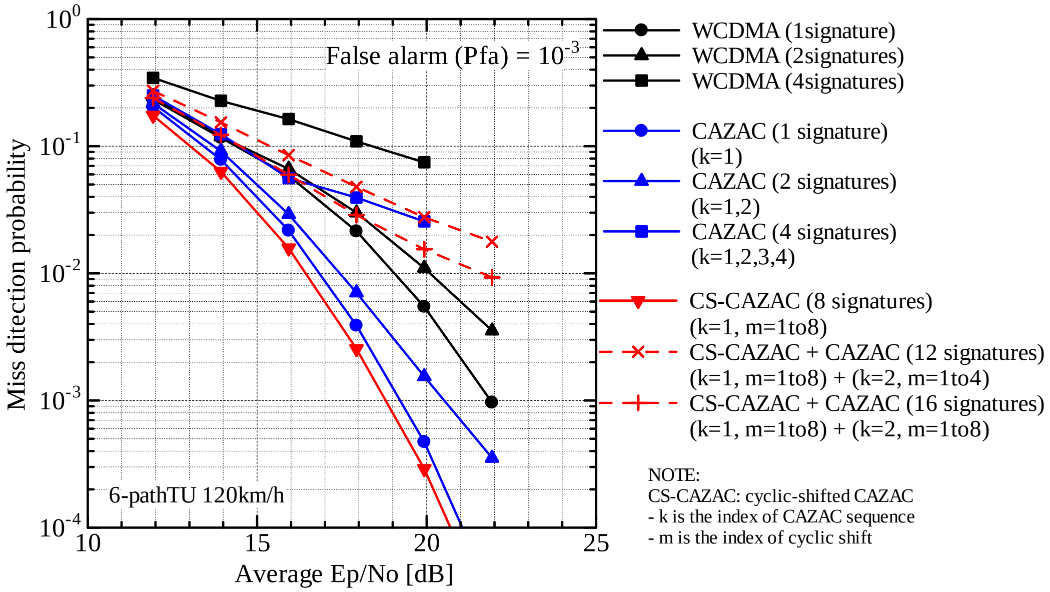

Figure 1 Miss detection probability (Pmd) to the average Ep/No (TU 120km/h)

2.2. Preamble length

Approximately 300 usec preamble length is required for ISD=500m and approximately 900 usec is required for ISD=1732m to achieve Pmd = 10^{-3} on CDF = 5% under TU 120km/h from the preamble detection performance in [13] . In the document, power control scheme assumed is relatively simple one. If more sophisticated one is assumed, the averaged received SINR at CDF = 5% would be further improved. In addition, more sophisticated preamble detectors in [15] [16] improves the preamble detection performance. These two aspects would allow reducing the required preamble length. Therefore, we propose to have two preamble lengths, around 400 usec and around 800 usec.

2.3. Minimum bandwidth

We propose the minimum bandwidth (BW) of random access burst is 1.25MHz. More than 1MHz BW would be required in order to obtain 1 usec time resolution for the uplink time alignment [19] . If only rough resolution is obtained in random access procedure, timing alignment control after random access procedure would get complicated.

In addition, sufficient number of symbols of the CAZAC sequence is required to eliminate mutual interference among preamble signatures. Therefore, we propose 1.25MHz as the minimum bandwidth.

2.4. Sequence composition in preamble

In the previous sections, we discussed the preamble sequence, the preamble length and the minimum bandwidth. Next topic is how to fulfill the possible preamble field using preamble sequence. Two approaches have been proposed. One is composed of multiple short CAZAC sequences [15] [16] . The other is one long CAZAC sequence [19] . For the decision among two, following aspects should be considered.

- Mutual interference among preambles
- Reuse factor of CAZAC sequence
- The possibility to transmit control information
- Decoder complexity

Mutual interference among preambles

Multiple short CAZAC sequence approach suffers more mutual interference among preambles. In addition, as we saw the evaluation in section 2.1, cyclic-shifted CAZAC sequence has superior performance. But cyclic-shifted CAZAC sequence requires relatively long sequence. Therefore, long CAZAC sequence is better than multiple short CAZAC sequence on this aspect.

Reuse factor of CAZAC sequence

The longer CAZAC sequence has a benefit to have bigger reuse factor of sequence management with less inter-cell interference when cell planning aspect is considered [19] . Therefore, long CAZAC sequence is better than multiple short CAZAC sequence on this aspect.

The possibility to transmit control information

To have a few number of control information bits on random access burst allows of an more efficient uplink and downlink resource utilization after random access attempt. In the case control information is mapped on the preamble part, control information including random ID is mapped to different signatures one by one. This means the more control bits are contained, if the larger number of signatures is used in one cell. Therefore, the required length of CAZAC sequence increases when more number of control bits is used. In addition, the length of CAZAC sequence further increases when bigger reuse factor are used. The number of different CAZAC sequences used by one cell is shown in Table 2. The number in ( ) shows the case four cyclic-shifted sequence are generated for each CAZAC sequence.

Table 2 the number of CAZAC sequences used in one cell

Number of control information bits (including random ID)	3 cell reuse	4 cell reuse	7 cell reuse
5 bits	96 (24)	128 (32)	224 (56)
6 bits	192 (48)	256 (64)	448 (112)
7 bits	384 (96)	512 (128)	896 (224)
8 bits	768 (192)	1024 (256)	1792 (448)
9 bits	1536 (284)	2048 (512)	3584 (896)

Discussion

From above discussion, long CAZAC sequence is preferred option. From the previous sections, we proposed 400 usec as the minimum preamble length and 1.125MHz (90% of 1.25MHz) as the minimum preamble bandwidth. Therefore, the maximum number of symbols contained in the preamble part is around 450 symbols.

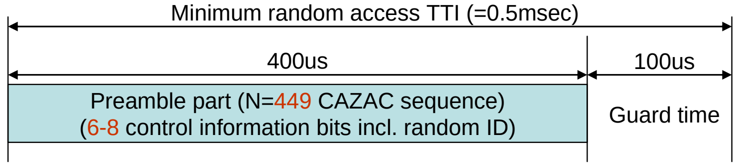

Figure 2 proposed the non-synchronized random access structure

We propose the N=449 (prime number) cyclic-shifted CAZAC sequences with also use different CAZAC sequences for the preambles. For supporting larger cell size, repeating this sequence twice (i.e. 800 usec) can be used.

According to this design, up to 8 control information bits including random ID can be transmitted on the preamble part with 7 cell reuse. A fewer usage of code sequence alleviate the decoder complexity. With also taking into account complexity aspect, we propose the number of control information bits contained in the preamble is around 6 bits.

2.5. Control information over the preamble part

We propose the followings control information is transmitted in non-synchronized random access preamble part.

- Random ID: To avoid collisions and to distinguish random access attempt from different UEs.
- Access type and buffer status: To allocate appropriate first uplink resource corresponding to the access reasons. One example is to distinguish among initial access/TA-update, handover, recovery of the synchronization in LTE_ACTIVE with bigger buffer size and recovery of the synchronization in LTE_ACTIVE with smaller buffer size
- UE Tx power head room or Downlink CQI: To perform link adaptation and/or power control for allocated uplink/downlink resource.

Example of possible mapping usage of 6 bits is shown in table 3. Similar way of mapping is also proposed in [15] .

Table 3 Example of propose control information mapping to signatures

Tx power head room	Cause/Access type	Signature ID (=Random ID) (case of 64 signatures)
Large Tx power head room	Initial access/TA-update	1-3
	Handover	no allocation
	LTE_ACTIVE(small buffer size)	4-6
	LTE_ACTIVE(large buffer size)	7-9
Middle Tx power head room	Initial access/TA-update	10-13
	Handover	no allocation
	LTE_ACTIVE(small buffer size)	14-17
	LTE_ACTIVE(large buffer size)	18-21
Small Tx power head room	Initial access/TA-update	22-26
	Handover	no allocation
	LTE_ACTIVE(small buffer size)	27-31
	LTE_ACTIVE(large buffer size)	32-36
No Tx power head room	Initial access/TA-update	37-45
	Handover	46-54
	LTE_ACTIVE(small buffer size)	44-64
	LTE_ACTIVE(large buffer size)	no allocation

2.6. Necessity of message part

If more than 6-8 control bits are required to be transmitted on random access burst, the message part has to be associated with the preamble part. However, in that case, the preamble part and message part should support the following properties.

- Channel estimation for coherent detection by the preamble part
- Message part should have similar BLER with miss detection probability of the preamble part.
- Message part should have similar collision avoidance performance with that of preamble part.

In order to achieve the above requirements, the longer associated message part might be required [17] . This consumes more uplink radio resources. Therefore, the trade-off between the merit of associating message part and the demerit of radio resource expense should be carefully considered.

3. Conclusion

We propose the following random access burst.

- Zadoff-Chu CAZAC sequence for the preamble sequence
- Both of cyclic-shifted CAZAC and different CAZAC sequence is used.
- Preamble lengths is around 400 usec and around 800 usec
- 1.25MHz is the minimum bandwidth
- One large CAZAC sequence for example N=449 is used to compose preamble sequence.
- The following control information is mapped on the CAZAC preamble signatures.
  - UE Tx power head room or downlink CQI
  - Access type and buffer status
  - Random ID

References

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[17] R1-060909, Nortel Networks, "Consideration on the issues of LTE RACH"
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[20] D. C. Chu, "Ployphase codes with good periodic correlation properties," IEEE Trans. Information Theory, vol.18, pp531-532, July 1972.

Appendix: Preamble detection algorithm

Two receiver antenna diversity reception is used. The 16 different power delay profiles are measured by the 16 matched filters corresponding to preamble sequences in each branch and then combined. Figure A illustrates the preamble detection method. The window size of the peak detection of the delay profile is set to 100usec for WCDMA preamble and CAZAC preamble. The window size for Cyclic-shifted CAZAC preamble is 50 usec to evaluate the detection performance up to 8 cyclic-shifted CAZAC sequences. Noise level is measured from the delay profile but the samples larger than Threshold A are not used for noise level calculation. Threshold B is the preamble detection threshold from the calculated noise level plus an offset value. The offset value is adjusted to achieve 0.1% false alarm probability. The maximum peak power is compared to Threshold B.

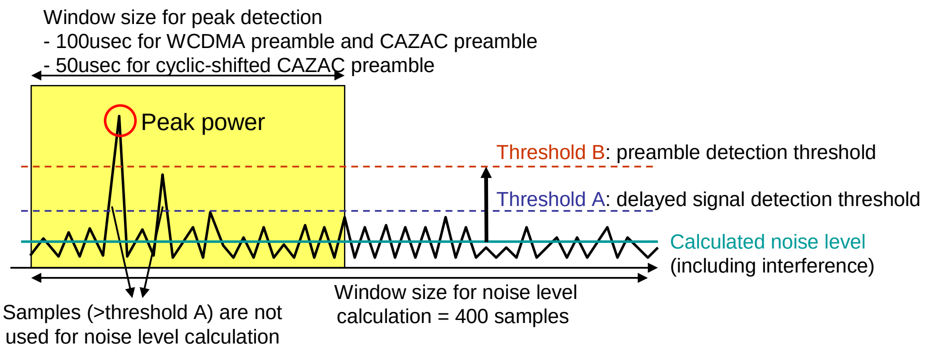

Figure A Output signal of matched filter and preamble detection algorithm