**TSG-RAN WG1 #43** **R1-051445**
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**Source:** Ericsson
**Title:** E-UTRA Random Access
**Agenda Item:** 8.6
**Document for:** Discussion and Decision

# 1. Introduction

An orthogonal uplink, where the Node B scheduler is responsible for rapidly allocating resources among UEs having data for transmission, has emerged as the main candidate for E-UTRA. To maintain uplink orthogonality among UEs, both frequency and time synchronization of the signal transmitted from the UEs are needed.

Frequency synchronization can be achieved by the UE locking its local oscillator to the downlink signal. The remaining frequency misalignment as the Node B is due to Doppler, which is the same situation as for scheduled data transmissions and requires no further consideration.

Time synchronization when the UE is transmitting can be achieved by the Node B measuring on the received signal and sending timing advance commands to the UE, which adjusts its uplink transmission timing accordingly. Through the use of scheduling request, UEs known to the scheduler can request uplink resources and, once the request has been granted, uplink transmissions can take place.

However, in absence of recent uplink transmissions, the Node B cannot control the transmission timing. Hence, there is a need for a (random access) procedure to establish synchronization with the Node B, e.g., at power-on. As uplink synchronization not yet has been established, a guard time is required. The random access procedure should, as a minimum, support time synchronization of the UE transmission timing.

To summarize, the following two cases can be distinguished:

- Synchronized uplink transmissions, e.g., scheduling requests or user data.
- Non-synchronized uplink transmissions, i.e., random access. A guard time is required to account for timing uncertainties.

Scheduling requests are transmitted using a time synchronized uplink and does in principle not differ from other uplink control signaling used by an active UE. Hence, scheduling requests are not further discussed in this contribution.

# 2. Random Access

The main purpose of the E-UTRA random access procedure is to obtain uplink time synchronization within a fraction of the uplink cyclic prefix. In WCDMA, the random access is non-orthogonal to the uplink data transmission. This provides the benefit of not having to semi-statically allocate any resources for random access, but requires a power ramping procedure to control the inter-UE interference. Alternatively, if the random access is made orthogonal to the (scheduled) data transmissions, no power ramping procedure is required to control the interference between random access and data transmissions, thereby allowing for a faster random access. The random access can be separated from data transmissions in the time domain by reserving one sub-frame at regular intervals for random access. This is illustrated in Figure 1, where one sub-frame per $T_{RACH\text{-}REP}$ period is allocated for random access. The value of $T_{RACH\text{-}REP}$ could be signaled to the UE using a broadcast channel.

Within a RACH sub-frame, a random access burst is transmitted. A guard time of $2\Delta t = 6.7$ µs/km is required to not interfere with neighboring subframes. For a UE-NodeB distance less than 15 km, 100 µs is sufficient, leaving approximately 400 µs for the random access burst part (around 700 symbols using the numerology in the TR). In case of very large cell sizes, additional guard time can be obtained by ensuring the scheduler is not using the subsequent subframe for data transmission.

The bandwidth of the random access should be wide enough to allow for a sufficiently accurate timing estimate. An estimation accuracy of less than the cyclic prefix is needed, e.g., the accuracy should be in the order of 1 µs. This requires a bandwidth of the RACH burst of around 1 MHz, which is in line with the smallest supported E-UTRA spectrum allocation of 1.25 MHz. For E-UTRA deployments using larger spectrum allocations, either multiple 1.25 MHz random access channels can be defined (providing an increased random access capacity), or higher RACH bandwidth can be defined for these cases. The former has the advantage of resulting in a single RACH procedure, regardless of the system bandwidth, while the latter may have a diversity benefit. A third possibility is to use part of the spectrum in the RACH sub-frame for scheduled data transmissions, given that the interference from the non-synchronized RACH transmissions is acceptable.

As a minimum, the RACH burst should contain a signature sequence identifying the random access attempt. Additionally, a small payload, e.g., a UE identity (if the UE has been assigned a identity from the system) or user data, could be included. However, the payload size may be limited to a relatively small value as the signature sequence and guard time occupy part f the subframe.

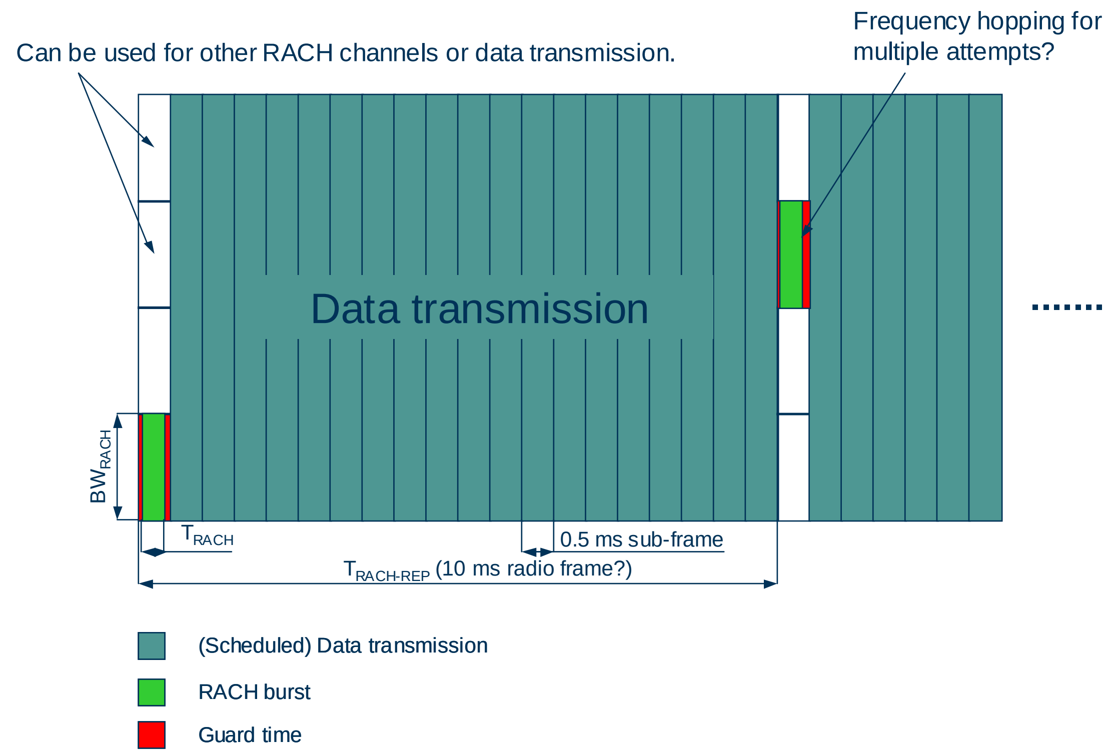


Figure 1: Random access subframe.

The signature sequences used for the random access burst should have good auto-correlation properties to provide good timing estimation accuracy in the Node B. The mutual cross-correlation should also be low to reduce the interference between users in case of simultaneous random access attempts from multiple users. Finally, these properties should also hold at high Doppler as E-UTRA should be functional also at very high UE speeds. The number of signature sequences should be kept reasonable small to reduce complexity as the Node B has to search for all possible signature sequences in a random access subframe.

The same structure and principles can be used for both FDD and TDD.

### 2.1. UE procedure

A UE performing a random access randomly selects one signature sequence from a small set of sequences to use in the RACH subframe. The UE transmission timing (i.e., assumed subframe start) can be obtained from the downlink timing. Open-loop power control can be used to obtain a suitable transmission power.

Once the random access burst has been transmitted, the UE monitors the appropriate downlink control channel for response from the Node B. It may be possible to reuse the downlink control channel normally used for scheduling assignments ("HS-SCCH-like") in which case no additional downlink control channels are required. As a minimum, the downlink control signaling includes information for timing control of the UE. Additionally, it may also contain a resource reservation ("scheduling grant"), providing the UE with resources for transmission of the payload. If no resource reservation information is included, a subsequent scheduling request can be used instead.

Finally, if the UE does not receive a response from the Node B within a certain time interval, a new random access attempt can be performed at a subsequent RACH sub-frame, possibly after a random back-off time. In case of multiple RACH sub-channels are defined on separate frequencies, a different frequency may be used for different attempts to avoid being stuck in a deep fading dip.

### 2.2. Node B procedure

The Node B correlates the received signal in the RACH subframe with all possible signature sequences. Once the Node B detects a sufficiently strong correlation peak, the timing of the (unidentified) UE performing the random access is known. In response, the Node B sends a timing adjustment command on the downlink control channel, possibly along with a resource assignment. The identity included on the downlink control channel is linked to the identity of the identified signature sequence in the uplink (or the UE ID if included), thus indicating in response to which random access attempt the downlink control signaling relates.

### 2.3. Example

An example of a random access procedure followed by regular scheduled data transmission is found in Figure 2. In this example, if the UE has no data to transmit, dummy data (e.g., an empty scheduling request) is transmitted at regular intervals to maintain uplink synchronization. This allows for rapid transmission of a scheduling request and a corresponding resource assignment. When no user data has been transmitted for a certain time, the transmission of dummy data stops and the uplink is allowed to go out-of-sync.

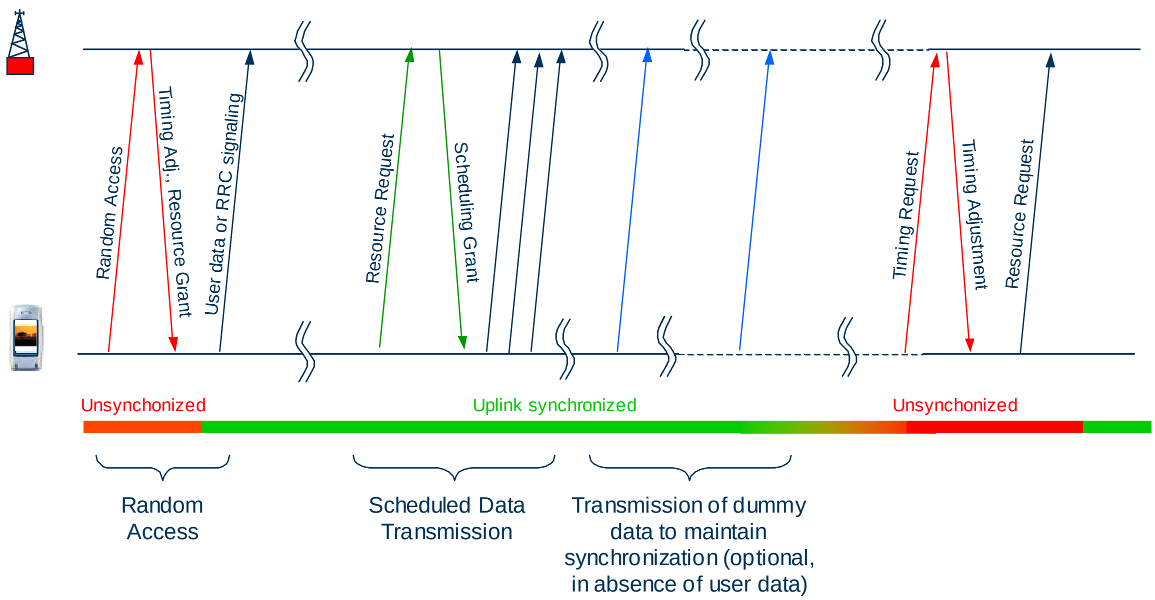


Figure 2: Example of random access and scheduled data transmission.

## 3. Conclusion

A framework for E-UTRA random access has been outlined:

- Orthogonal separation of user data and random access
- Using the random access burst for timing estimation at the Node B
- Responding with a timing adjustment and (optionally) a resource assignment.

It is proposed to include the text proposal in Section 4 in TR 25.814.

## 4. Text Proposal

--- Begin text Proposal ---

### 9.1.2.1 Random access procedure

The random access procedure is used when the UE uplink has not been time synchronized and shall allow the Node B to estimate, and if needed adjust, the UE transmission timing within a fraction of the cyclic prefix. The random access burst consists of at least a signature sequence. Inclusion of additional data symbols is FFS.

Random access and data transmission are time multiplexed as illustrated in Figure X, where certain subframes are reserved for random access transmissions.

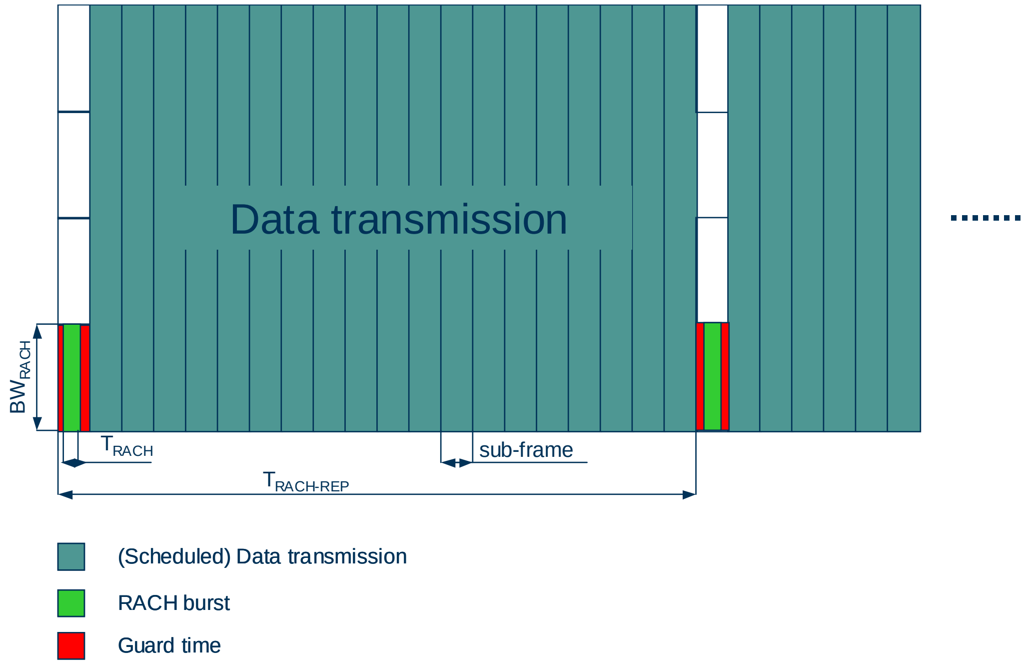


Figure X: Reserving a subframe for random access attempts.

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