

EXHIBIT 1012

Source: Ericsson, NTT DoCoMo
Title: E-UTRA Uplink Control Signaling – Overhead Assessment
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1. Introduction

This contribution addresses the required E-UTRA uplink control signaling, aiming at providing some insight into the amount of overhead to be accounted for in the evaluation phase of the E-UTRA study item. A companion paper [4] addresses the downlink control signaling overhead.

The uplink transmission timing can be either unsynchronized or synchronized. In the former case, a (random access) procedure for obtaining uplink synchronization is required [2] prior to any data transmission. This is not discussed further in this contribution as the overhead is believed to be modest (in [2], one subframe per radio frame is used for random access).

For the case the uplink is time-synchronized, the uplink control signaling can be grouped into the following categories:

- **Scheduling requests**, i.e., control signaling transmitted by the UE to request resources for uplink data transmission. Scheduling requests are only transmitted when the UE does not have a valid scheduling grant as inband signaling can be used otherwise.
- **Data-associated control signaling**, e.g., hybrid ARQ redundancy version and transport format information. This signaling is only transmitted in conjunction with scheduled uplink data.
- **CQI**, transmitted by the UE for the purpose of downlink scheduling and link adaptation. CQI transmission is independent of uplink data transmissions.
- **ACK/NAK**, related to downlink data transmissions. ACK/NAK transmission is independent of uplink data transmission.

Furthermore, diversity is important for scheduling requests, ACK/NAK, and CQI as no frequency-dependent scheduling can be used for these quantities.

2. Scheduling Request

The scheduling request is used to request uplink resources from the Node B scheduler. Outband scheduling requests are only required when the UE does not have a valid scheduling grant; more detailed inband scheduling information, e.g., in the form of a MAC header, can be used when the UE has a valid grant.

Two different possibilities can be envisioned:

- dedicated signaling, where each active UE is assigned an orthogonal resource of its own, or
- non-orthogonal (contention-based) signaling, where collisions may occur between the UEs.

As the Node B cannot know in advance which UE(s) that will request resources at a particular time, contention-based access is a natural choice. Using orthogonal resources is less attractive as the resources in most cases would be unused. No fast closed loop power control can be used for the scheduling request.

Note that a non-orthogonal scheduling request is similar to a random access [2] with one major exception – uplink time synchronization is present. Therefore, no large guard intervals to account for timing uncertainties are required. Based on the similarities between the two, a design similar to the random access can be used for the scheduling request.

As a minimum, the scheduling request must include the identity of the UE requesting resources. This can be implicitly included by UE-specific scrambling of the request message. Additionally, information on priority, buffer status, etc might be useful to the scheduler although it is far from obvious whether it is required. The scheduler could, upon receiving a scheduling request, issue a grant and once the transmission has started obtain more information about the UE status through inband signaling. Furthermore, note the tradeoff between low delays (i.e., the possibility for frequent scheduling requests) and the amount of information included in the scheduling request. The smaller the request message is, the more often resources orthogonal to user data can be

reserved for scheduling requests or, in case of non-orthogonal separation of requests and user data from different users, the larger the processing gain. Therefore, a scheduling request consisting of 1-2 bits¹, excluding the UE identity, is assumed.

The time/frequency resources a UE is allowed to use for transmission of scheduling requests can be made configurable. Thus, the system can either make the scheduling requests orthogonal to uplink data transmissions by restricting the requests to certain subframes/frequencies only (possibly the same subframes used for random access); subframes that are avoided by the uplink scheduler for data transmission. Alternatively, to reduce delay but at the cost of some interference, scheduling requests may overlap with uplink data transmissions.

As the uplink is time-synchronized, distributed transmission can be considered to multiplex (groups of) users and reduce the risk of collisions at the cost of a reduced processing gain. The UE could (randomly) pick one of a small set of “combs” for distributed transmission in the uplink.

3. Data-associated Control Signaling

Data-associated control signaling (hybrid ARQ information, transport format information, etc) is only transmitted together with user data. Hence, time-multiplexing of data and control is a logical choice if the single-carrier properties are to be maintained. Preferably the first part of the subframe is used for data-associated control signaling in order to minimize delays. Note that the fraction of the 0.5 ms subframe duration used for control signaling has to be selected keeping coverage in mind. As an example, 10 bits of data-associated control signaling (the same amount as in WCDMA enhanced uplink) transmitted in 1/10 of the subframe corresponds to 200 kbit/s, which is a fairly high data rate at the cell edge in large cells. Relying on retransmissions and soft combining also for control signaling as discussed for enhanced uplink can be used to handle this. Alternatively, multiple subframe formats with different amounts of the subframe devoted to control signaling can be envisioned.

An initial estimate of the approximate amount of uplink control signaling is given in Table 1. The uplink transport format (payload size and modulation scheme) need only to be signaled in case the UE is not mandated to follow a transport format signaled in the scheduling grant². Similarly, the hybrid ARQ process number is only required if an asynchronous hybrid ARQ scheme is selected. Omitting the transport format and the hybrid ARQ process number from the uplink control signaling could significantly reduce the control signaling overhead and result in a corresponding increase in coverage. This speaks in favor of a synchronous hybrid ARQ protocol and a scheme where the UE must follow the transport format signaled by the Node B.

Field	Approx. size	Comment
Transport format (payload size, modulation scheme)	0 or 8	Only required if the UE does not have to obey a transport format given in the scheduling grant.
Hybrid ARQ process number	0 or 3	Only required in case of an asynchronous hybrid ARQ protocol.
Redundancy version	2-3	To support incremental redundancy. Also serves as a ‘new data indicator’.

Table 1: Data-associated control signaling.

4. CQI

Transmission of CQI is independent of uplink data transmissions, i.e., the user may or may not transmit data simultaneously with the CQI. The CQI consists of several bits. For HSDPA, 5 bits each 2 ms is used (at the highest reporting frequency). In order to convey also information about the frequency domain properties, a larger number of bits than for HSDPA may be needed for LTE. As an example, the schemes discussed in [3] use 9-11 bits per report for 5 MHz. Furthermore, the size of the CQI may depend on the antenna arrangements; MIMO and/or beamforming are likely to require additional bits compared to the single antenna case. Depending on the CQI reporting scheme used, a single CQI report may span multiple subframes (‘progressive update’) to reduce the overhead.

Coverage for CQI reporting can be solved in similar ways as for the data-associated control signaling. A simple approach, present already in HSDPA, is to repeat the same CQI information in several subsequent subframes.

¹ In the simplest case, the presence or absence of the scheduling request would convey a single bit of information.

² In case the amount of data in the UE buffer is not sufficient to fill up the assigned uplink resource, padding can be used.

As the CQI reporting instants (typically) are known to the Node B a priori, orthogonal as well as non-orthogonal CQI transmission could be considered. In an orthogonal scheme, each UE is assigned a dedicated orthogonal resource for CQI reporting. Non-orthogonal transmission may provide more flexibility in supporting variable CQI reporting formats. The CQI reports may also be used by the Node B as a signal to measure upon for estimation of the uplink channel quality (within the bandwidth covered by the CQI) in order to implement uplink channel-dependent scheduling.

5. ACK/NAK

ACK/NAK transmission is independent of uplink data transmission. Typically, only one or a few UEs signal ACK/NAK in the uplink at the same time as the number of simultaneously scheduled UEs in the downlink direction is relatively small. The ACK/NAK is a single bit (or possibly a “three-state bit”), but with strict error requirements ($\Pr\{\text{ACK}|\text{NAK}\} \leq 10^{-3}$ and $\Pr\{\text{NAK}|\text{ACK}\} \leq 10^{-2}$ were assumed for HSDPA). To provide a small roundtrip time, the ACK/NAK duration may need to be shorter than one subframe.

Similarly to the CQI, ACK/NAK is transmitted independently of uplink user data. Hence, similar aspects on the multiplexing of the control signaling within the UE apply. Furthermore, if the uplink resource used for ACK/NAK is (indirectly) given by the downlink scheduling commands, orthogonal multiple access for the ACK/NAKs could be envisioned.

6. Conclusion

In Table 2, the uplink control signaling is summarized. It is proposed to take this as a guideline when modeling the uplink control signaling overhead in the system simulations.

Information	Approx. size	Simultaneous transmission												Comment
Scheduling request	1-2													
Data-associated control signaling	2-3 or 10-14													Once per TTI. See Table 1 for assumptions.
CQI	10													Transmission of one CQI may span multiple subframes.
ACK/NAK	1													Once per transmitted downlink data block.

Table 2: Initial estimate of the amount of uplink control signaling for a single UE. Grey boxes indicate whether different control signaling can be transmitted simultaneously or not.

7. References

- [1] R1-060581, “Uplink Scrambling for E-UTRA”, Ericsson
- [2] R1-060584, “E-UTRA Random Access”, Ericsson
- [3] R1-060018, “Performance Evaluation of EUTRA Downlink CQI Feedback Schemes”, Motorola
- [4] R1-060573, “E-UTRA Downlink Control Signaling – Overhead Assessment”, Ericsson