TSG-RAN Working Group 1 meeting #3 **TSGR1#3(99)188**
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Agenda item:

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Title: **Dimensioning of RACH capacity for UTRA TDD mode: Packet Delay, Large Cell Radius, Capacity Requirements**

Document for:

(This is an extended version of an earlier distributed paper)

Abstract

The RACH behaves quite differently for UTRA TDD and FDD modes. It is often argued that the available RACH capacity for the TDD mode is too low and that the number of available resources for TDD RACH is much lower than for FDD, cf. Ref [1]. This contribution tries to clarify some of these issues. Simulation results for the TDD RACH indicate that the mean delay (under the worst case assumptions discussed below) remains below one frame count. Finally, it is stressed that the TDD mode RACH can serve cells with large radius without sacrificing RACH resource units.

1. Discussion of TDD RACH

The current proposal for the physical layer structure of the TDD Mode RACH is based on a special time-slot and burst/midamble structure: a RACH burst occupies half of a slot ("short access burst" corresponding to 312.5µs). The physical layer structure is designed for allowing joint-detection of RACH bursts. The RACH is very well isolated from other signaling and user traffic. These short bursts carry 42 channel symbols of uplink information (payload + CRC). Information on the access bursts is sent with interleaving 1 due to delay constraints and for minimizing collision probability per message. CRC checksums are appended for error-detection and the coding-rate will be close to 1 (e.g. 7/8).

Thus, such a 625µs time-slot creates a space of 32 RACH collision groups (16 codes $\times$ 2 half-slots). However, the current joint-detection and midamble scheme can resolve up to 8 different users which gives the number of available RACH resource-units of 16 per 625µs time-slot. Assuming a figure of 37% throughput of a Slotted ALOHA channel gives an average of 5.8 successfully received access bursts per 625µs time-slot dedicated to the RACH. Capture effect studies have indicated in simulations that this figure can increase to 9.4 successful accesses.

1.1 Flexibility in capacity dimensioning

The number of RACH resources offered to the users can be configured flexibly within the multiframe structure broadcasted on the BCCH. This allows both for a *reduction* and an *increase* of the average number of RACH resources per frame with respect to the figure given above. Reduction is achieved by restricting the number of codes used for random access (through selection of a dedicated code-set). On the other hand, an increase is achieved by dedicating more time-slots for random access within a frame.

1.2 Large cell radius

Due to lack of a timing-advance mechanism on the RACH, we need to consider the effect of large propagation delays (two-way travel time) and channel delay spread. Two possible problems can be identified:

1. **Guard period overflow**: The two-way travel time (TWT) plus delay spread exceed the guard period of approximately 25µs. This effect creates adjacent time-slot interference. It is capable of

causing RACH collisions between short access bursts on the first and second half-slots. Additionally, it creates interference (inter-cell & intra-cell) between access bursts and other traffic on the adjacent time-slot.
2. **Impaired channel estimation**: Due to the current channel estimation principle which is based on a single matched filter and cyclic-shifts of one and the same midamble code, a second constraint is given by the time-window at the output of the matched filter. If the TWT plus DS exceeds the available time-window, channel estimates are corrupted. The corruption gradually increases with TWT and DS. The subsequent JD algorithm suffers from poor channel estimates.

Large cells can be accommodated in the following ways:

1. **Code-set restriction**: The code-set on the RACH can be restricted at the expense of capacity allowing fewer access bursts to be resolved by JD. (E.g. restricting to 4 codes leads to a doubling of the time-window used in the channel estimator). This is an easy solution for implementation which sacrifices some capacity.
2. **More midamble code sets:** instead of using 8 cyclic shifts of one periodic code together with a time-window, different codes can be used. To reduce the number of correlators needed for channel estimation, a compromise can be constructed: 8 midambles can be constructed by 4 cyclic shifts of 2 different periodic codes. This is a slightly more expensive solution which does not sacrifice capacity/flexibility of the original concept.

Note that 16 collision groups per frame can be implemented in all environments and cell types.

We give an example which is based on a 512 chip midamble and on a 5μs delay spread channel. From the midamble length with periodic shifts of one code (according to solution one) we reach 57 chips or 13.9μs per user. Subtracting the channel delay spread leads to 8.9μs, that has to cover the two way delay between BS and UE. With 3km/μs we finally get a cell radius of approximately 1.5 km. Taking into account the second solution, we can double the figures given above, i.e. 114 chips, 27.8μs, 22.8μs for the two way delay which finally leads to a **cell radius of 3.8km**. This figure is close to the link budget results that was achieved for the best case speech services in the vehicular environment.

1.3 Brief Discussion of FDD RACH

To begin with, FDD RACH capacity is essentially a soft capacity. Packets sent on the FDD RACH cause interference for traffic sent over other channels. Conversely, FDD RACH packets suffer from interference caused by other services and signaling traffic. The FDD RACH is dimensioned such that "collisions are expected to be very rare though still possible", see Ref. [2]. It can be concluded under low/medium load conditions that the main reason for message loss on the FDD RACH is due to fading and interference (not collisions!). This is not true for the TDD RACH which is very well isolated from other traffic.

1.4 Remarks on RACH usage and loading

Due to these basic differences on the physical layer and the associated difference in behavior, the RACH will be loaded differently by the protocol in FDD and TDD modes. Besides the RACH, the Uplink Shared CHannel (USCH) was proposed recently, cf. Refs. [3a-c].

2. Predicted capacity requirements due to traffic scenarios

Predictions of future packet services and how they might shape the traffic in the UTRA are subject to large uncertainties. Nevertheless, some insight can be gained from current traffic measurements (on mobile/wireless and wireline networks) and traffic models used in simulations.

Results are summarized in the table below. It can be seen that high-volume uplink packet data transmission makes by far the largest contribution to RACH traffic. Given the fact that scenario "Packet 1" appears to be rather worst case with respect to the number of RACH accesses, an upper bound of 3 to 4 successful RACH accesses per frame of 10 ms appears to be realistic.

Scenario (note **Error! Unknown switch argument.**)	**Description**	**Assumptions**	**Required RACH Capacity** (note **Error! Unknown switch argument.**)
Packet 1	Substantial amount of packet data (UDD), transmitted in uplink direction.	60% of time slots allocated for uplink, 100% usage for packet data. 1 successful RACH access per layer 3 (typically IP) packet. Average packet size is 500 byte. (note **Error! Unknown switch argument.**)	3
Packet 2	Typical "web browsing": traffic is highly asymmetric, uplink packets transmit HTTP "GET" commands	2 Mb/s is transmitted over radio interface: uplink and downlink together. 1 uplink "GET" packet per 1 kByte of transmitted data.	2.5 ≤1
Speech	"Voice only" scenario	64 voice channels, 90s mean duration of a call.	0.014
SMS	Short message service, assuming very high usage	Every user sends 10 short messages per voice call (corresponds to 4 short messages per subscriber in busy hour)	0.14
Location update 1	Periodic location update	12000 subscribers/km²; periodic location update every 30 min. cell size 0.25 km² (note **Error! Unknown switch argument.**)	0.017
Location update 2	Location update due to change of location area; macro cell environment	12000 subscribers/km²; change of location area every 30 min	0.017
Location update 3	Location update due to change of location area; micro cell / indoor environment.	100 subscribers/cell; location area comprises one cell; cell change rate 0.01/sec (UMTS 30.03 traffic model)	0.01

Note 1 Note that out of the scenarios "Packet 1", "Packet 2", "Speech", only one is applicable at a time, as they are all assuming 100% usage of the available traffic channels.

Note 2 The "Required RACH capacity" is given in "mean number of successful random access requests per frame" (frame duration is 10ms).

Note 3 Details of calculation: 100 RU x 120 bit/(RU x frame) = 12 kb/frame which leads to 3 successful random accesses per frame

Note 4 The figure of 1 uplink packet/kByte transmitted data is based on internet traffic measurements. It comprises the full sequence of messages exchanged in an HTTP connection, including connection setup and connection release.

Note 5 This corresponds to a macro cell environment in a very densely populated area. The average cell size is about the maximum cell size in such an environment. Assuming voice service only, the figures would correspond to 13 mErl/subscribers, approx.

Note

3. Conclusions

- Plausible worst case assumptions based on current internet traffic and ETSI's UMTS 30.03 traffic model lead to the system requirement of up to 3 *successful* RACH messages per frame (10ms duration assumed).

- Due to the uncertainty of future traffic behavior, the RACH capacity must be scalable in a flexible way. Flexibility is achieved by broadcasting the RACH configuration on the BCCH.

- Scalability implies that more than one time-slot per frame may be reserved for the RACH if this proves desirable.

- In all environments (indoor, pedestrian, and vehicular), 16 collision groups are available. This means that the RACH is loaded with 19% for supporting the worst case of 3 successes per frame. *Packet delay and the number of retransmissions are of no concern at this RACH loading*. The RACH capacity for the UTRA TDD-Mode is sufficient under worst case assumptions (even if only one timeslot is reserved for the RACH).

- The spreading factor of the RACH bursts can be changed from 16 to 8. This will double the number of channel symbols, i.e. the number of channel symbols per short burst will become 84.

- Allocated (signaling and user data) uplink traffic can coexist on the RACH time slot if it uses the same short burst as the RACH. Allocated traffic and RACH messages can be segregated in different half-slots. Without this segregation, coexistence can be recommended if there are only few RACH attempts and if an ARQ scheme can be used.

References

[1] Some applications requiring uplink packet transmission, ETSI SMG2 UMTS L1 Expert Group Meeting #10, Espoo, Finland, Jan 18-20 1999, source: Philips, Tdoc SMG2 UMTS-L1 008/99, File: 2X99-008.doc, contact: Tim Moulsley <moulsley@prl.research.philips.com>

[2] Performance Results for the RACH, ETSI SMG2 UMTS L23 Expert Group Meeting, Stockholm, Sweden, June 23-26, 1998, source: Philips, Tdoc SMG2 UMTS-L23 104/98

[3a] Methods for Operating the Uplink Shared Channel, 3GPP RAN Workgroup 2, Helsinki, Finland, Jan 20-22 1999, source: Motorola, Tdoc 3GPP RAN WG2 031/99.

[3b] Benefits of the Uplink Shared CHannel (USCH), 3GPP RAN Workgroup 2, Helsinki, Finland, Jan 20-22 1999, source: Motorola, Tdoc 3GPP RAN WG2 032/99.

[3c] Change requests related to the Uplink Shared CHannel (USCH) , 3GPP RAN Workgroup 2, Helsinki, Finland, Jan 20-22 1999, source: Motorola, Tdoc 3GPP RAN WG2 033/99.

[4] Text proposal for S1.21 document concerning RACH, TSG-RAN Working Group 1 meeting #3
??, source: Siemens, March 22-25, 1999.