3GPP TSG RAN WG2 #4 **RAN WG2 400/99**
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Source:	**InterDigital**
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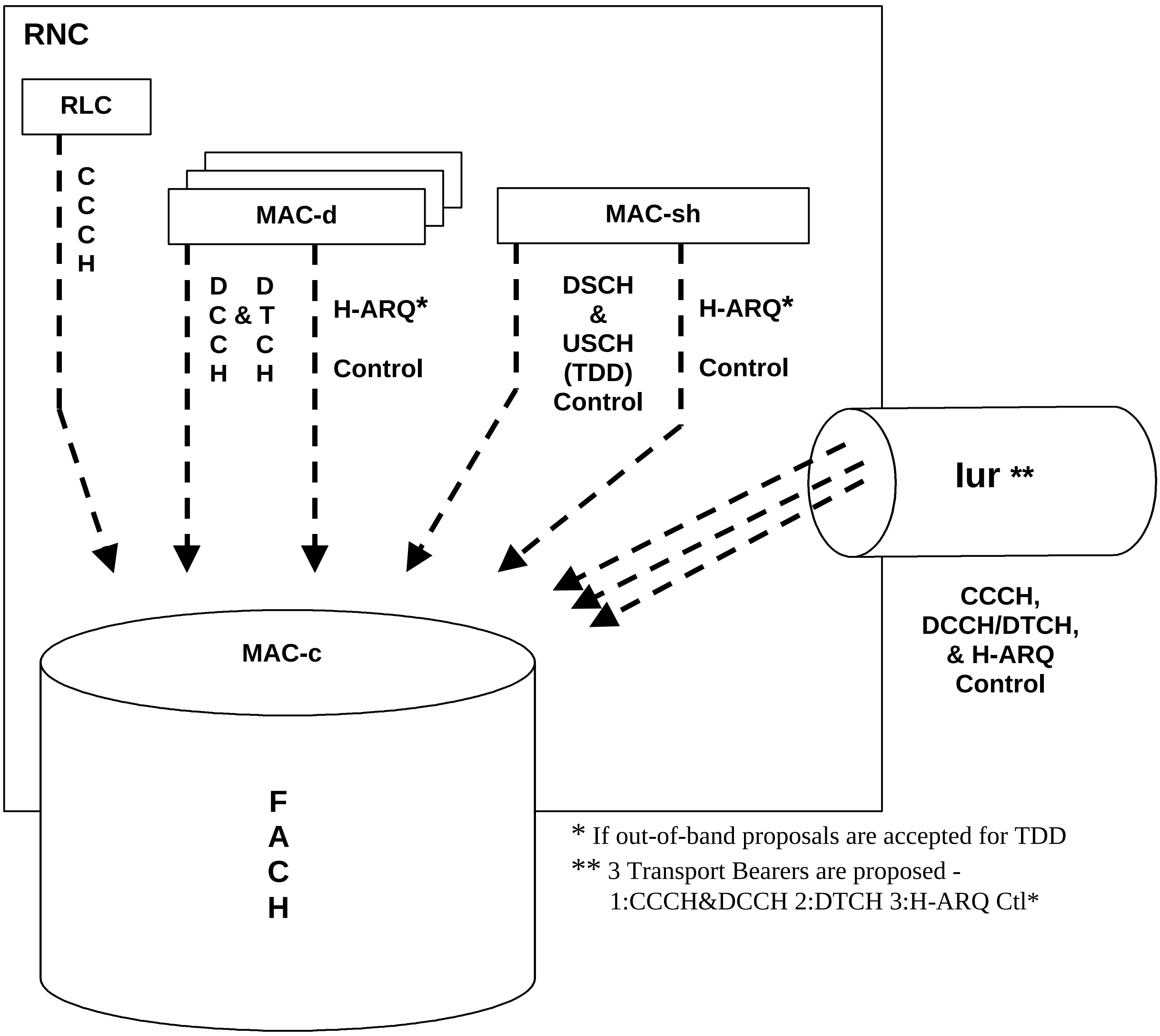
Title:	**FACH Scheduling, Prioritization and Queue Management**
Document For:	**Decision** **Suggested Agenda Item: 6**

1. Introduction:

WG3 has identified the need to prioritize data streams and manage buffering between MAC-d and MAC-c entities when common channels exist over the Iur. This contribution proposes a general mechanism is needed within an RNC between RLC/MAC-d/MAC-sh and the MAC-c entity, and that the common channel over the Iur case is a MAC-d to MAC-c subset of the general mechanism.

Mechanisms need to be in place to handle the possibility of FACH congestion. There are several types of FACH data that have different prioritization/QoS requirements, which need to be taken into account when FACH congestion occurs. Buffering in FACH transmission queue's also needs to be minimized (at the MAC layer!) to reduce signaling latency, the possibility for any one data stream to monopolize the FACH, and the amount of retransmitted/discarded data when switching to DCH mode as a result of FACH congestion.

Routing of FACH Data:



2. The Need for Prioritization of DL Common Channel Data Streams:

The FACH supports several types of data streams, which have different latency/throughput (QoS) requirements. In addition some data streams are “best effort” common channel transmissions and can be re-routed across dedicated channels, and for other data streams transmissions over common channels is “mandatory”.

Types and Classifications of FACH data:

Type	Source	Destination		Class	Suggested Priority
		No Iur	Across Iur		
CCCH – RRC Signaling	S-RNC (RLC)	X	X	Mandatory	Medium
DCCH – RRC Signaling	S-RNC (MAC-d)	X	X	Best Effort	Medium
DTCH – Traffic Data	S-RNC (MAC-d)	X	X	Best Effort	Low
DSCH Control (TDD – FDD ffs)	C-RNC (MAC-sh)	X		Mandatory	Highest
USCH Control (TDD)	C-RNC (MAC-sh)	X		Mandatory	Highest
H-ARQ Control (DCH) **	S-RNC (MAC-d)	X	X	Mandatory	High
H-ARQ Control (U-DSCH) **	C-RNC (MAC-sh)	X		Mandatory	Highest

** If out-of-band proposals are approved for TDD

Signaling data (DCCH & CCCH) has a greater sensitivity to latency then NRT data (DTCH) and needs to be prioritized accordingly. Additionally DSCH (FDD/TDD) & USCH (TDD) shared channel capacity allocations and hybrid ARQ PDU identifiers (if current out-of-band proposals are approved) require even higher priority since delayed or discarded FACH transmissions effectively halt the primary data channels (DSCH/USCH/DCH).

3. MAC Modifications for DL Common Channel Scheduling, and Multiplexing of Traffic & Control Data:

It is proposed that a DL (FACH) scheduling function should be added to the MAC-c.

When channels are established from MAC-d (DCCH/DTCH) the relative priority and class of traffic is identified to the MAC-c “scheduler”. For NRT traffic it will be beneficial to identify the priority of each MAC PDU (FFS).

The MAC-sh generates DSCH and USCH capacity allocation messages, which are transmitted on the FACH by the MAC-c (For TDD – FDD is FFS). Prioritization between UL and DL capacity allocation can be managed in the MAC-sh, therefore separate MAC-sh to MAC-c UL&DL control data streams are not needed. This DSCH/USCH control data will then have a common priority in MAC-c and the MAC-c scheduler will recognize the relative priority with respect to other MAC data streams without the need to identify this in individual MAC-sh to MAC-c capacity allocation transmissions.

It is expected that the most probable system configuration will have only one MAC-c and one MAC-sh within an RNC per cell. In this case there is only one channel connecting both entities and there is no need for setting priorities of individual MAC-sh channels to the MAC-c scheduler.

It is proposed that MAC-c scheduler should have the ability to prioritize DCCH data over DTCH data. To allow this capability the MAC-d C/T mux (for FACH transmission) needs to be relocated to the MAC-c entity. This is required since buffering between MAC-d and MAC-c entities can not be guaranteed, especially for the Iur transit case.

Additionally if proposals for H-ARQ (w/out-of-band PDU identifiers) are accepted, independent channels from the MAC-sh and MAC-d entities are needed for prioritized scheduling in MAC-c. MAC-d PDU identifiers can take the advantage of individual priority setting relative to other MAC-d PDU id’s, but this may not be possible for the MAC-sh PDU-id’s (FFS).

4. Iur Transport Bearers for Common Channels

The need to separate logical signaling channels (DCCH & CCCH) and traffic channels (DTCH) also exists over the Iur. It is also important to separate signaling data of different priorities.

Therefore, it is proposed that across the Iur 3 AAL transport bearers are established between RNC's for MAC-d to MAC-c transmission. One for all MAC-d DCCH and RLC CCCH data, one for all MAC-d DTCH data, and one for all MAC-d H-ARQ (if approved) control data. It is suggested this should be identified in response to the WG3 LS on Common Channel Management over the Iur.

5. The Need for Controlling DL Common Channel Data Flow:

DL common channel (FACH) MAC layer buffering needs to be minimized.

For layer three signaling (DCCH/CCCH) and user traffic data (DTCH) it is better to buffer within the RLC rather then between (or within) the MAC-d and MAC-c entities.

FACH to DCH Transitions as a Result of FACH Congestion:

When congestion on the FACH invokes a switch to a dedicated channel, PDU's already on the MAC-c transmission queue are lost (at layer 2), or retransmitted on the DCH if ARQ is supported on the logical channel. Without MAC-d to MAC-c (DCCH/DTCH) flow control, the possibility exists for large amounts of data to be lost or retransmitted (once loss is recognized by the receiver). Also if the possibility of large FACH queues exists, there will be a need to flush large individual data streams from the FACH queue when a DCH transition occurs. So that other data streams are not further affected and to avoid FACH transmission when the UE is no longer listening (now on DCH).

Exactly how individual data streams could be flushed from the FACH queue in advance of transmission is unclear, but this function is not required if a flow control mechanism is employed. It should also be considered that his effects all connections on the common channel at the same time and duplicate-transmissions, re-transmissions and requests for retransmissions further aggravate the DL congestion.

Shared Channel Capacity Allocations and Hybrid-ARQ (if approved) Control Signaling Delay Requirements (for TDD):

For TDD it is proposed that DSCH & USCH capacity allocations and Hybrid-ARQ (if out-of-band proposals are accepted) signaling will be supported by the FACH. Any delay in transmission of this L2 control signaling effectively halts or fails the transmission on the "primary" channel (DSCH, USCH or DCH).

Shared channel capacity allocations have no tolerance queuing delays. The capacity allocation must arrive at a set time in advance of the actual allocation and this time period must be minimized for the shared channel service to be effective. In the DL there is tolerance for H-ARQ PDU identifiers, but this can result in excessive physical layer buffering. In the UL a delay in H-ARQ PDU identifiers halts the uplink transmission.

The MAC-sh (and MAC-d for H-ARQ) must maintain direct and immediate access to the FACH for these services. For these data streams, signaling data becomes old very quickly and queued data must be discarded, therefore it is better just to enforce a mechanism that does not allow any queuing between these entities. The flow control mechanism can be the same as what is suggested for the MAC-d to MAC-c DCH case with a window or credit of 1.

RLC ARQ Mode Control Signaling Efficiency:

For layer two signaling MAC layer buffering (as opposed to buffering within the RLC or above) causes latency in RLC signaling procedures. Acknowledgements, retransmission requests and retransmitted

PDU's can be considerably delayed if there is no control over the amount MAC layer buffering. It is also difficult to approximate (optimize) acknowledgement timers at the transmitter.

A supporting consideration for the current working assumption not to require the FACH-ACK (C-RNC MAC-c case), is that the RLC in ARQ mode provides an equivalent function (at least without Iur). Without RLC/MAC-d to MAC-c buffering management, RLC acknowledgements for UL data could be queued following large DL transmissions causing delays that a MAC-c based FACH-ACK would not experience, since the MAC-c would have the ability to "intercept" the queue.

RLC to MAC-c Flow Control for CCCH data:

CCCH data is different than DCCH data in the respect that DCH transport is not possible. Therefore when the RLC to MAC-c CCCH data stream is congested there is really no option to resolve the problem. A flow control function would not have any useful purpose in this case. The only consideration may be to have the ability to flush the queue when the data's "life span" is exceeded.

6. Requirements for Managing DL Common Channel Data Flow:

a. During periods of congestion there must fairness between data streams of common priority. No one user should be capable of monopolizing the FACH and incur delays on data streams of equal priority.

b. During periods where the FACH is relatively idle it should be possible for one data stream to fully utilize the entire FACH. This is primarily intended for a DTCH and to avoid the need to the need to switch to a DCH and make the most efficient use of the FACH resource.

c. Fairness should exist between data streams, which transit the Iur and data streams internal to the RNC. Latency between MAC-d/MAC-d(DCCH/DTCH) and RLC/MAC-c(CCCH) should not effect he ability to allocate the FACH.

d. It must be possible to limit the depth high priority queues, which require immediate transmission. It is expected that for DSCH & USCH control channels it will be beneficial to limit the queue depth to a single capacity allocation so that transmission is guaranteed in advance of the actual allocation.

7. Methods for Controlling DL Common Channel Data Flow:

Potentially there are two general methods for controlling data flow to the FACH. A reservation mechanism could be incorporated where each FACH data source requests access to be used within a given time period or each data stream (queue) could maintain a window/credit to limit the maximum outstanding data. Note that methods to control FACH data flow are independent of FACH admission control, which manages access at a "higher level" (not on a PDU basis).

A FACH reservation mechanism will generate initial transmission delays. The reservation method request access over a period of time for several transmissions (multiple PDU's), but the first transmission is delayed. Fairness between users is not achieved since requests & confirmations will have to transit the Iur for some users. Delays is reservations may also result in unused capacity even when data queued exceeds the given capacity.

Incorporating a protocol, which allows a variable window for outstanding data will not incur initial transmission delays. There is an increased probability for FACH congestion as compared with the reservation approach, but this can be minimized by defining a small initial default window or credit which is dynamically increased or decreased depending on FACH availability (details ffs).

The window/credit size can also be used to manage different data stream requirements. Since MAC-d DTCH is tolerant of transit delays five to ten outstanding PDU's are acceptable. For DSCH/USCH control the maximum is likely to be one (ffs).

8. Proposed Changes to the MAC Protocol Specification (S2.21)

Figure 4.2.4.2 shows the UTRAN side MAC-c entity. The following functionality is covered:

- The Scheduling – Priority Handling box manages FACH resources between the UE's and between data flows according to their priority. DL flow control is also provided to MAC-d and MAC-sh data sources.
- The C/D box represents the insertion and detection of the field in the MAC header, indicating whether a common or dedicated logical channel is used.
- For dedicated type logical channels, the c-RNTI field in the MAC header is used to distinguish between UEs.
- In the downlink, transport format selection might be done if FACH is variable rate.
- The C/T MUX box is used when multiplexing several dedicated logical channels onto one transport channel is used. This entity exists in the MAC-c so that the FACH scheduling function can take into account the relitave priorities of user traffic (DTCH) and control (DCCH) data streams.

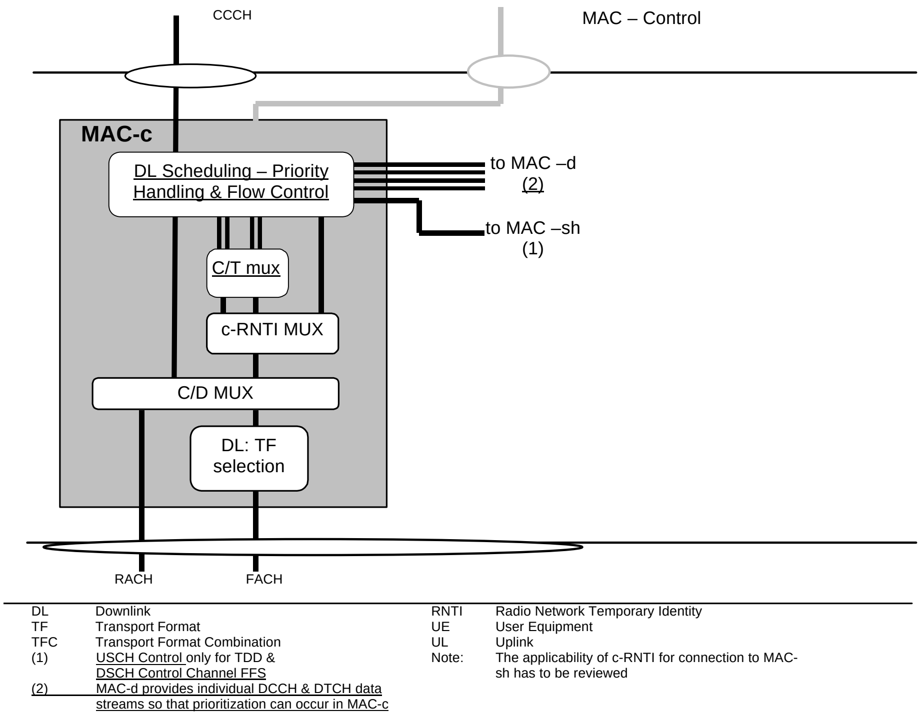
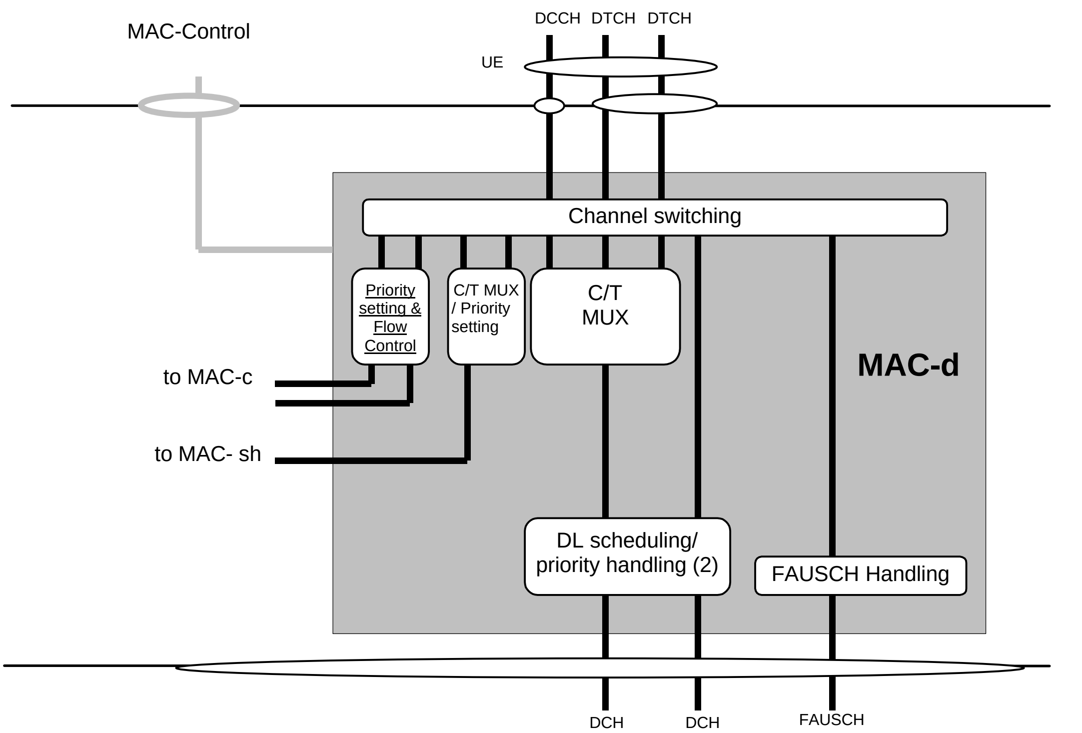


Figure 4.2.4.2 UTRAN side MAC architecture / MAC-c details

Figure 4.2.4.3 shows the UTRAN side MAC-d entity. The following functionality is covered:

- Dynamic transport channel type switching is performed by this entity, based on decision taken by RRC.
- The C/T MUX box is used when multiplexing of several dedicated logical channels onto one transport channel is used. For common channels this function exists in the MAC-c so that scheduling prioritisation between traffic and control logical channels can be performed.
- Each MAC-d entity using common channels is connected to a MAC-c entity that handles the scheduling of the common channels to which the UE is assigned and DL (FACH) priority identification to MAC-c (priority identification of each PDU for DTCH NRT data is FFS).
- Each MAC-d entity using downlink shared channel is connected to a MAC-sh entity that handles the shared channels to which the UE is assigned and indicates the level of priority of each PDU to MAC-sh.
- In the downlink, scheduling and priority handling of transport channels is performed within the allowed transport format combinations of the TFCS assigned by the RRC. This function supports the TFCI insertion in Node B .
- FAUSCH Handling indicates the function in the MAC-d supports the FAUSCH, details are ffs.
- A flow control function exists toward MAC-c to limit buffering between MAC-d and MAC-c entities. This function is intended to limit layer 2 signalling latency and reduce discarded and retransmitted data when switching to dedicated channels as a result of FACH congestion.



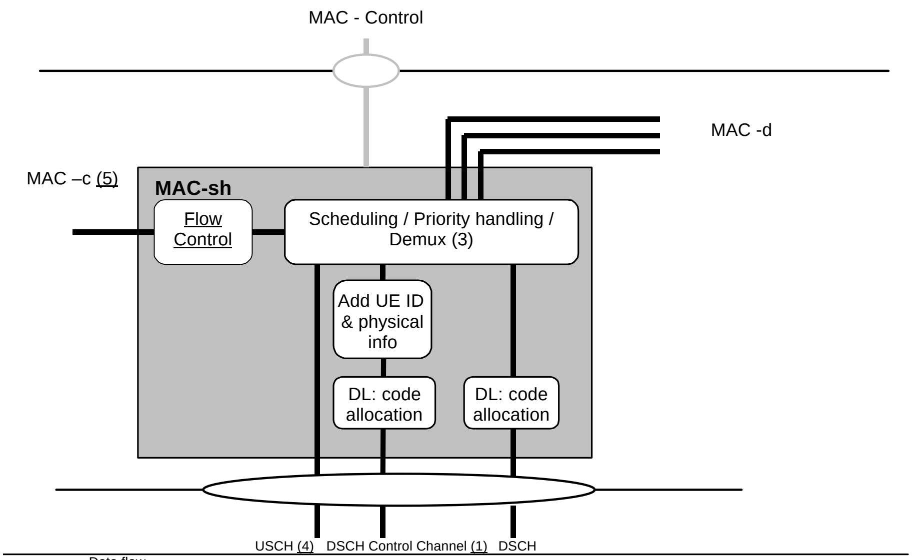
DL	Downlink	RNTI	Radio Network Temporary Identity
TF	Transport Format	UE	User Equipment
TFC	Transport Format Combination	UL	Uplink
Note1 :	*for DCH and DSCH different scheduling mechanisms apply*	*(2)*	*Support TFCI insertion in Node B*

Figure 4.2.4.3 UTRAN side MAC architecture / MAC-d details

Figure 4.2.4.4 shows the UTRAN side MAC-sh entity. The following functionality is covered:

- A specific UE ID is needed when using the DSCH Control Channel to identify the UE on the DSCH. This specific UE ID may be optimised for DSCH and will be allocated when a RAB is mapped onto a DSCH. Additionally, some timing information is needed to tell the UE when to listen to DSCH.
- The scheduling /priority handling box in MAC-sh shares the DSCH resources between the UEs and between data flows according to their priority. For TDD operation the demultipex function is used to support the USCH and the connection to the MAC-c.
- The scheduling/priority handling box also prioritises between UL & DL capacity allocation indications when the FACH is used for both DSCH and USCH control channels (FACH is used for TDD – FDD is FFS).
- DL code allocation is used to indicate the code used on the DSCH and the appropriate Transport format on the DSCH.
- A flow control function exists toward MAC-c, so that capacity allocation signaling is synchronized (not delayed in respect to) DSCH/USCH transmissions.

The RLC has to provide RLC-PDU's to the MAC which fits into the available transport blocks on the transport channels respectively.



Data flow
External Control information

DL	Downlink
TF	Transport Format
TFC	Transport Format Combination
RNTI	Radio Network Temporary Identity
UE	User Equipment
UL	Uplink

NOTE(1): The DSCH Control Channel may be represented by the FACH, details are for further study. If supported by the FACH routes through priority/flow box to MAC-c.
NOTE(2): The relation between the scheduling and the adding of RNTI & physical info has to be reviewed
NOTE(3): The Demux functionality is used in TDD
NOTE(4): USCH is TDD only
NOTE(5): USCH Control Channel is represented by the FACH for TDD

Figure 4.2.4.4 UTRAN side MAC architecture / MAC-sh details