TSG-RAN Working Group 3 meeting #6
Sophia Antipolis, France
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TSGR3#6(99)965

Agenda Item: **6.5**

Source: **Siemens, Italtel**

Title: **Study Item (ARC/3) "Overall Delay Budget within the Access Stratum"**

Document for: **Status report**

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1 Introduction

This contribution reports the status of the e-mail discussion on Study Item ARC/3 "Overall Delay Budget within the Access Stratum".

2 Report of the reflector activity

The document has been updated with the results of the discussion hold during last meeting in Helsinki:

- Text change proposed in Nortel Tdoc. TSGW3#5(99)653 has been included;
- References have been updated
- Network assumptions have been explicitly reported in a separate chapter;
- Delay Budget Template values have been updated;
- Delay estimation results, as derived from LS TSGW3#5(99)805 have been added.

3 Results and Conclusion

It is suggested to leave the Study Item open in order to allow a further refinement of the figures proposed until now.

Appendix A

1 Scope, Abbreviations, etc.

2 References

[1]: Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0) - TR 101 112 V3.2.0 (1998-04)

[2]: Requirements for the UMTS Terrestrial Radio Access system (UTRA) (UMTS 21.01 version 3.0.1)- TR 101 111 V3.0.1 (1997-10)

[3]: Quality of Service and Network Performance (UMTS 22.25 version 3.1.0) - TR 22.25 V3.1.0 (1998-03)

[4]: ITU-T Recommendation G.174: Transmission Performance Objectives for Terrestrial Digital Wireless Systems using Portable Terminals to access the PSTN (6/94)

[5] ITU-T Recommendation G.114: Transmission Systems and Media General Characteristics of International Telephone Connections and International Telephone Circuits - One-Way Transmission Time (02/96)

[6]: Technical characteristics, capabilities and limitations of mobile satellite systems applicable to the UMTS (UMTS 30.20 version 3.1.0) - TR 30.20 V3.1.0 (1998-01)

[7]: ITU-T Recommendation I.356: Overall network aspects and functions – Performance objectives (10/96)

[8]: ATM Forum af-vtoa-0113.000, *ATM Trunking using AAL2 for Narrowband Services*, (2/99)

[9]: ITU-T Recommendation I.363.2, *B-ISDN ATM Adaptation Layer Specification Type 2 AAL*, (10/97)

[10] Liu Chunlei, Munir Sohail and Jain Raj, *Packing density of Voice Trunking using AAL2*, paper submitted to Globelcom'99

[11] ATM Forum 98-0630 - Packet Delay Variation in Voice Trunking using AAL2, COMSAT Laboratories, (10/1998)

[12] ATM Forum 98-0830 - Packing Density of Voice Trunking using AAL2, The Ohio State University & NOKIA Research Center (Burlington), (12/1998)

3 External requirements on UTRAN

Reference [1] gives a minimum set of services to be supported in UMTS. The list characterises services by the following set of parameters:

- Range of supported data rates;
- BER requirements;
- One way delay requirements;
- Activity factor.

Table 1 reports the list of services, as provided in [1].

Table 1: List of test data rates for evaluation purposes

	bit rates (kbps)				**BER**	**One way delay**	**Channel activity**
Test environments	**Indoor Office**	**Out- to Indoor and Pedestrian**	**Vehicular 120 km/h**	**Vehicular 500 km/h**			
Representative low delay data bearer for speech*[1]	8				$\leq 10^{-3}$	20 ms	50%
LDD Data (circuit-switched, low delay)*[1]	144-384-2048	64 - 144 - 384	32 - 144 - 384	32 -- 144	$\leq 10^{-6}$	50 ms	100%

LCD Data (circuit-switched, long delay constrained)*[1]						300 ms	

*[1] One-way delay (excluding propagation delay, delay due to speech framing and processing delay of voice channel coding) for all the test services.

NOTE: For LDD services, a BER threshold of 10^{-4} will be considered for the initial comparison phase of the different concepts in order to reduce simulation times. The BER threshold of 10^{-6} will be considered in the optimisation phase.

UDD Data (packet) - Connection-less information types not reported.

According to references [3] and [4], the total one-way end-to-end delay for voice services should be kept within 40 ms.

In the following figure it is reported from [2] the reference model for the computation of the transmission delay.
It should be considered that:

- The error protection contains any FEC, CRC, interleaving coding and macro-diversity processing.
- UTRAN inter-node delays are not taken into account.
- Implementation overheads, such as processing time, are not included in the definition.
- Speech encoding is not included in the radio transmission chain since it is assumed there will be bearer definitions applicable for speech transmission, as well as for video compression etc.

The one-way delay figures are only applicable for defining the radio technology bearers and not for defining the complete access delay for the radio access network. This means that the total delay will be larger. Thus the figures Tt and Ti must be lower than the requirement for total delay in the access network.

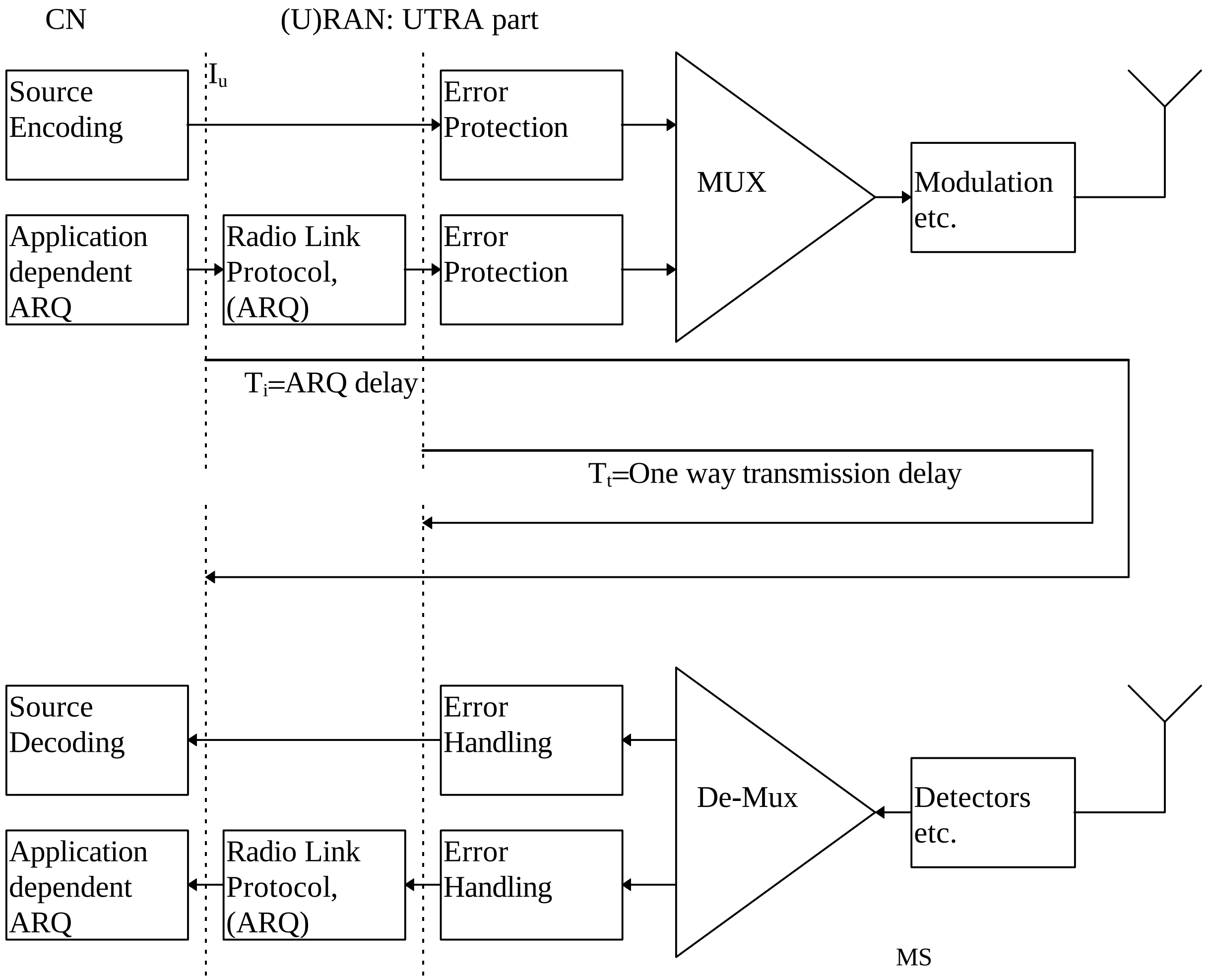


Figure 1: Reference Model for Transmission Delay

4 UTRAN Delay Components: Definitions

In this chapter the transmission delay components across the UTRAN are identified and described.
A short description of each component is given, along with affected services and impacting parameters.
The paper is mainly based on 3GPP RAN WG3 Tdoc. TSGW3#2(99)169 – UTRAN Delay Estimation

4.1 Symbols used

⬆ = Direct proportionality
⬇ = Inverse proportionality
RT = Real Time
NRT = Non Real Time
CBR = Constant Bit Rate

4.2 UTRAN Network Components

4.2.1 Packetisation, De-packetisation and End-System Play-Out Delay

RT **NRT** The originating terminal adds a packetisation delay. Factor influencing this delay is the ⬇ instantaneous source data rate and the allowable transmission rate, i.e. PCR and SCR.
CBR When a real time CBR data stream terminates at an application end-point, play-out buffering is required to remove the CDV caused by the statistical sharing effects of the packet network. Once this variation is removed and de-packetisation applied, the resulting traffic stream from the protocol stack can be fed to higher layers as a constant stream of data. This delay is dependent on the bit-rate of the connection, the ⬆ play-out buffer depth (dimensioned on the maximum CDV allowed) and the packet size.

[Evaluation part ffs.]

4.2.2 Macro-diversity Combining Delay

RT **NRT**The Macro Diversity Combination function may require additional switching and processing in the RNC. Even though the delay introduced is heavily implementation-dependent, it has to be considered as a component of the overall delay evaluation.
The MDC function combines signals together at the same moment in time. Therefore, the main delay component in this function is dependent on the difference path delays of each branch involved in a single connection.

[Evaluation part ffs.]

4.2.3 Interleaving and Turbo Coding

RT **NRT** Interleaving is a physical layer function that segments transport blocks over several radio frames. These blocks can be interleaved over 1, 2, 4, and 8 transport blocks. Thus, the interleaving will add a large transmission delay to the data stream over the air interface ⬆ proportional to the interleaving factor.
RT Turbo coding has it own internal interleaving mechanism, for data services this is an additional delay depending on the ⬆ block dimension and on the ⬇ service data rate.

[Evaluation part ffs.]

4.2.4 MAC Scheduling Delay

RT For real-time services, a set of resource units will be allocated on a deterministic basis. This implies that a delay no bigger that one transport block is foreseen.

NRT Non-real-time services using shared channels require statistical scheduling, the delay introduced may become important: even though delay guarantees will not be applicable, the delay introduced has an impact on acknowledgement delay and on the resulting QoS. The component depends on ⬆ the load factor of the used resource and possibly the round trip delay between the UE and the RNC.

[Evaluation part ffs.]

4.2.5 Re-transmission Delay

NRT The retransmission of data streams will not take place over real time bearers. When retransmission is used in non-real time services, guaranteed delivery over the radio interface is performed by the RLC. The amount of retransmissions needed for a single transport block is a multiplication factor for delay, i.e. if it take two re-transmission to transfer a transport block successfully then twice the physical layer delay would be added: interface ⬆ the maximum number of allowed re-transmissions defines the weight introduced by this component.

[Evaluation part ffs.]

4.3 Transport Network

In this sub-chapter the delay components are described, which are introduced by the transport network interconnecting UTRAN nodes.

To help defining the performance of the transport network, the following delay and bandwidth performance parameters shall be used:

- *Packet Transfer Delay* (**PTD**) defines the elapsed duration between two measurement points. Mean packet transfer delay is the arithmetic average of a specified number of packet transfer delays.

- *Packet Delay Variation* (**PDV**) is introduced in [8]. Across the AAL2 CPS, a 2-point measurement defines PDV: the 2-point PDV for a packet between two measurement points (MP) is the difference between the absolute packet transfer delay of this packet between the two MPs and a defined reference packet transfer delay between those MPs.

- ***Packing density*** is defined in [11] and [12] as the ratio of the average user byte number (excluded ATM and CPS headers) in a cell onto the ATM cell length.

In the present evaluation End-to-end PTD and PDV shall be considered: in other words a measurement point shall correspond to one CPS Service Access Point (SAP) at which a CPS-SDU is submitted to the CPS. The second measurement point is localised at the peer SAP delivering CPS-SDU, as shown in Figure 2.

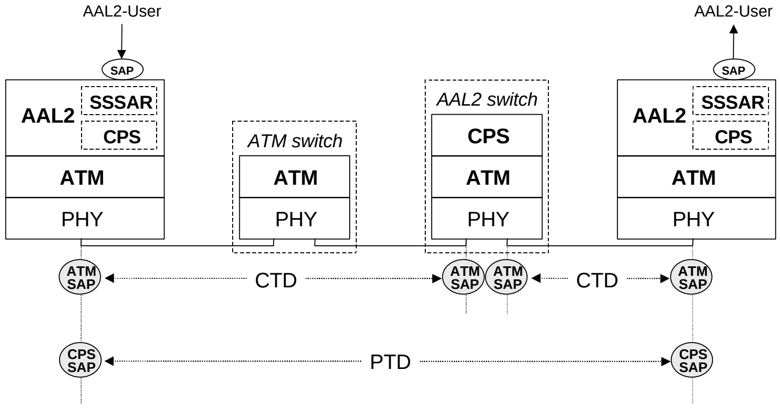


Figure 2 - The differences between CTD and PTD

The packing density results from characteristics of AAL2 user traffic: larger the length of submitted user data is, more significant packing density is. However, there is a theoretical limit of packing density equal to $45/48 \cdot 47/53 \approx 83.14\%$.

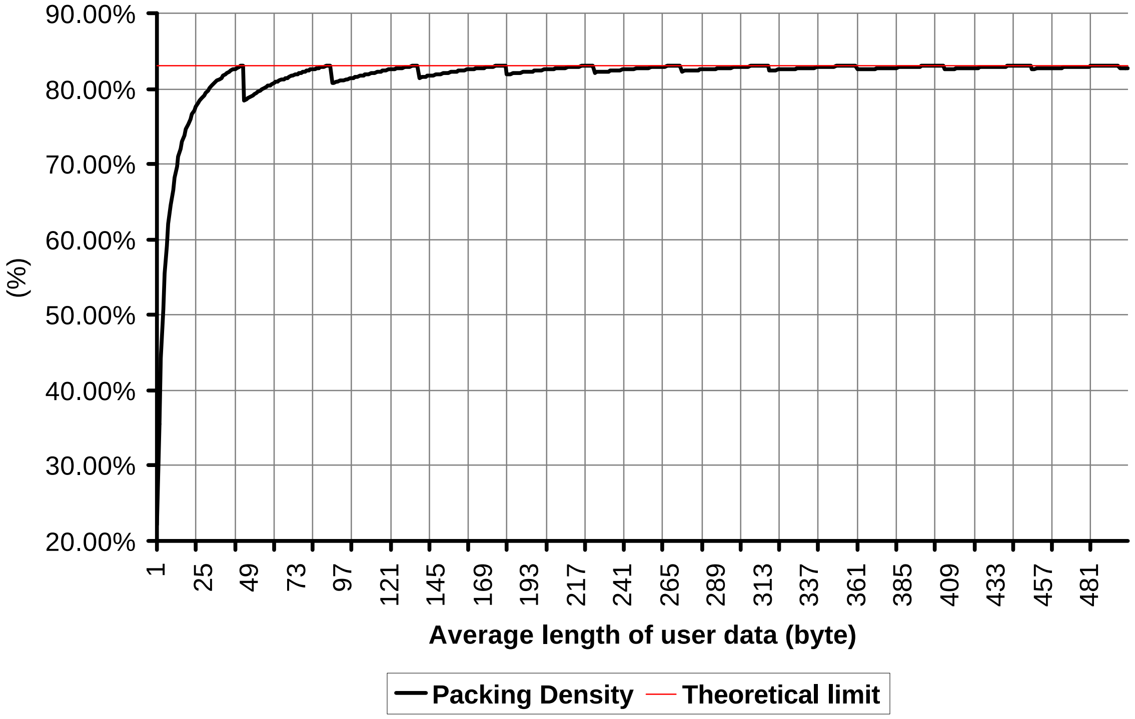


Figure 3 depicts the evolution of average packing density according to average length of AAL2 user data (CU_Timer = ∞)

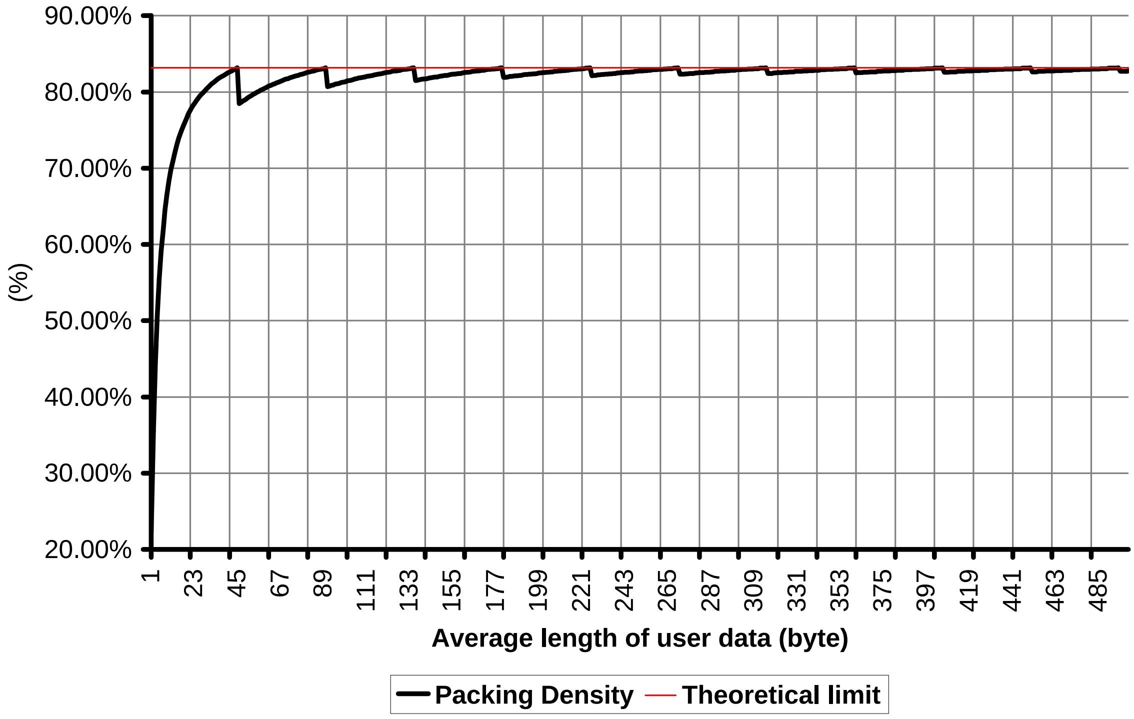


Figure 3 - Evolution of packing density according to average length of user data

According to [10], the CU_Timer also affects packing density: if the cell is not completely packed within the time period determined by the CU_Timer value, the timer expires and the partially packed cell will be sent. Consequently, the number of VCs on which AAL2 traffic is distributed can also impact packing density.

4.3.1 AAL Packetisation, Multiplexing and De-packetisation Delay

RT NRT This component, considered on a point-to-point link, is due to the ATM SAR sub-layer action and to the multiplexing of cells and sub-cells (for AAL2) on the ATM link. link performed in the CPS (Common Part Sub-layer). ~~This delay depends on⬆ the number of connections on a single link, on ⬇ the data-rate of the link, on the adaptation layer and type of virtual connections (VC/VP) selected.~~
The PTD and PDV are especially impacted by the *packet queuing delay* in the CPS transmitter buffer. This queuing delay depends on:

- the negotiated *QoS of the ATM connection* (especially ⬇ the Peak Cell Rate (PCR));

- the *number of active multiplexed AAL2 connections* ⬆ due to an increase of ATM connection load.

- Considering a low ATM connection load, the *CU_Timer* value affects ⬆ the PTD and the PDV in the extent that probability of CU_Timer expiration is no null. Defined in [9], CU_Timer is optionally used to ensure that a CPS packet does not wait for a too long time before transmission. Besides, [9] has not specified any value for CU_Timer.

- Due to the CU_Timer effects, the *number of selected VCs* ⬆ to carry AAL2 user data also affects the AAL2 performance. By distributing AAL2 traffic over several VCs, each ATM connection load decreases (and consequently, probability of Timer_CU expiration increases). Consequently, the PTD and PDV tend to increase.

Moreover, PTD and PDV are impacted by ATM cell queueing at the network switches:

- *The* data-rate of the physical link ⬇ and the physical protocol *(IMA upon PDH, SDH, …),*
- *Included in the QoS, the CTD and the CDV of the corresponding ATM connection* ⬆ *also affect AAL2 performance.*
- *The ATM link load* ⬆ *obviously impacts AAL2 performance.*

In this component it is also considered the delay introduced by fractional ATM, i.e. by the partitioning of a physical resource into different interfaces. As an example, it could be considered the case of the share of a PCM E1 interface into one Abis interface and one I_{ub} interface, in order to link over a single physical interface a site supporting both GSM and UMTS services.
The delay introduced by this component is inversely proportional to the grade of fractionalisation, in case of an E1 link the component is about:

$$\text{Delay} = \frac{220}{\%\ \text{used}}\ \mu\text{s}$$

[Evaluation part ffs.]

4.3.2 Media Delay

RT NRT The propagation delay over cabled networks can assumed to be fixed and proportional to the ⬆ connection length.
The same can be assumed for microwave and satellite connections, but to the medium delay a further component must be added, which considers the technology used for the link, e.g. point-to-multipoint, point-to-point, radio ATM.
For satellite links, the delay can be time-dependent, in accordance with the orbit eccentricity .

The following delay can be assumed, according to [5]:

Coax cable: 4 µs/km;
Optical fibre: 5µs/km.

In case µwave links are used, the following indicative values can be considered (ffs):

PDH microwave link: 1.5 ms
SDH microwave link: 1 ms
Point-to-multipoint microwave link: 5 ms

According to [5] and [6] the delay introduced by a satellite link can range between 60ms (max. value for LEOs) and 310 ms (max. value for HEOs).
It is therefore suggested to allow a single satellite hop along a link over the UTRAN between a UE and the Core Network.

4.3.3 Switch Delay

RT NRT This is the component due to switching nodes (Cross-Connects and Switches) along UTRAN terrestrial interfaces, only. Its value is proportional to ⬆ the number of intervening nodes and has a heavy dependence on ⬆ the traffic load of each node. [7] defines 300 µs as the maximum delay for real-time services through ATM switches. Even if the definition of this component is not clear in the quoted reference, this assumption is accepted as a worst case.

5 UTRAN Delay Estimation

6 UTRAN Overall Delay Budget (conclusion to be included in Ch. 13.1 of S3.01)

Appendix B

1 Delay Budget Template

1.1 Delay Components

1.1.1 UTRAN Nodes

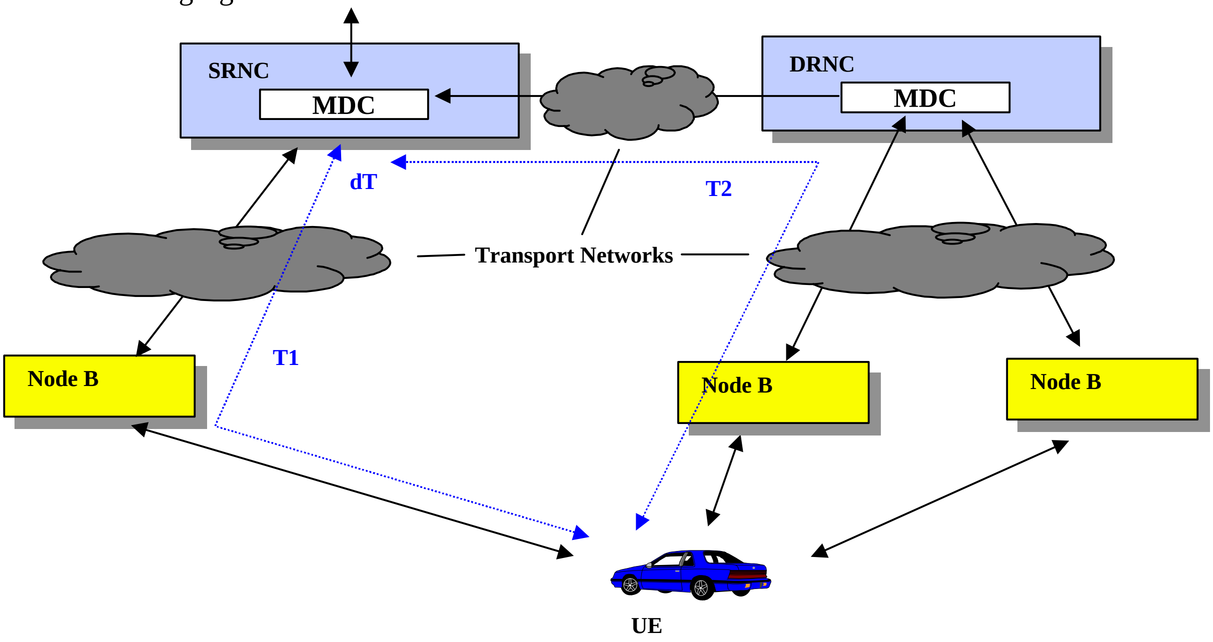
U1): Packetisation, De-packetisation and End-System Play-Out Delay
~~U2): Macro-diversity Combining Delay~~
U3): Interleaving and Turbo Coding
U4): MAC Scheduling Delay
U5): Re-transmission Delay
U6): Uu delay

1.1.2 Transport Network

TN1): AAL Packetisation, Multiplexing and De-packetisation Delay
TN2): Media Delay
TN3): Switch Delay

1.2 UTRAN Reference Configuration

In the following figure the reference model and branch definitions used in the document are shown.



Network Assumptions

For the evaluation of delay components introduced by the transport network the following assumptions for a typical worst case scenario have been made:

Iub interface: 6-hop PDH µwave link
6-hop SDH µwave link

Iur interface: 600 km STM-1, optical fiber
9 ATM switches/cross-connects

Iu interface: 200 km STM-1, optical fiber
4 ATM switches/cross-connects

For a best case scenario, branch T1 is assumed to consist of co-located RNC and Node B.

1.3 Delay Budget Template

Service (kbit/s)	**8 (RT)**	**32**	**64**	**144**	**384**	**2048**	**Source/Reference**
Delay Component	Delay (ms)						
T1 Branch							
U3	~~40~~20	100	100	100	100	100	
U6	0.05						
TN1 – I_{ub}	1	1	1	1	1	1	
TN2 – I_{ub}	14						TSGR3#3(99)313, Nokia
TN3 – I_{ub}	0						
U1	~~22~~<14	1	1	1	1	1	
U4	0	10	10	10	10	10	
U5	0						
T1 Branch Delay	***49***						
T2 Branch							
U3	~~40~~20	100	100	100	100	100	
U6	0.5						
TN1 – I_{ub}	1	1	1	1	1	1	
TN2 – I_{ub}	14						TSGR3#3(99)313, Nokia
TN3 – I_{ub}	-						
U1 – DRNC	~~22~~<14	2	2	2	2	2	
TN1 – I_{ur}	1	1	1	1	1	1	
TN2 – I_{ur}	3						
TN3 – I_{ur}	2.7						
U1 – SRNC	~~22~~<6	2	2	2	2	2	
U4	0	10	10	10	10	10	
U5	0						
T2 Branch Delay	***62.2***						
I_u Interface							
U1 (packetisation only)	0~~1~~	1	1	1	1	1	
TN1 – I_u	0.5	0.5	0.5	0.5	0.5	0.5	
TN2 – I_u	1						
TN3 – I_u	2.5						
Iu Delay	***4.5***						

Note 1) processing times are not considered, their evaluation requires further study; TN1 has still to be integrated with CPS scheduling component.

In the following table the delay estimation results are reported; delay definitions are reported after the table.

Service (kbit/s)	**8 (RT)**	**32**	**64**	**144**	**384**	**2048**
Delays (processing time to be added)	Delay (ms)					
α) Total delay T1 worst case	53.5					
β) Total delay T2 worst case	67					
γ) Total delay T1 best case	20					
δ) Max T2-T1 delay difference	47					
ε) SRNC delay	15					
θ) DRNC delay	15					
η) Node B delay	21					

Definitions (with reference to template):

α = T1 Branch Delay + Iu Delay

β = T2 Branch Delay + Iu Delay

γ = T1 Branch Delay + Iu Delay

> The evaluation of γ) assumes that components U3, U6 are unchanged and components TN1 TN2 TN3 U1, U4 and U5 are neglectable.

δ = β – γ

> The maximum delay difference between T1 and T2 branches has been compared, T1 being the best case and T2 being the worst case.

ε = U1 + U4 + TN1

θ = U1DRNC + TN1

η = U3 + TN1