Project	**IEEE 802 Executive Committee Study Group on Mobile Broadband Wireless Access** **C802.2-03/106** <**http://ieee802.org/20**>	
Title	Implication of End-user QoS requirements on PHY & MAC	
Date Submitted	**2003-11-10**	
Source(s)	Anna Tee	Voice: 972-761-7437 Fax: 972-761-7909 Email: a.tee@samsung.com
	Joseph R. Cleveland	Voice: 972-761-7981 Fax: 972-761-7909 Email: jclevela@sta.samsung.com
	Jin Weon Chang	Voice: +82-31-279-5117 Fax: +82-31-279-5130 Email: jwchang@ieee.org
Re:	802.20 WG Call for Contributions	
Abstract	This document gave a brief overview of the QoS classification and requirements by ITU and 3GPP, and used the information to derive the latency and error rate requirements for 802.20 in support of IETF DiffServ structure.	
Purpose	Contribute to the discussion and development of the 802.20 Requirements on Latency and FER as related to QoS	
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Implication of End-user QoS Requirements on PHY & MAC

Joseph Cleveland
Anna Tee
November 03, Albuquerque

Scope of 802.20

- As described in the PAR and quoted in Section 1.3 of 802.20 Requirements Document Rev. 8c [1]:
  - *"Specification of physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz,* **optimized for IP-data transport***, with peak data rates per user in excess of 1 Mbps. It* **supports various vehicular mobility classes up to 250 Km/h in a MAN environment** *and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems."*

Applications

- Examples of possible applications that are **IP-based data, in mobility environment of up to 250 km/h in a MAN environment**, as described in Section 2 of the Requirements document:

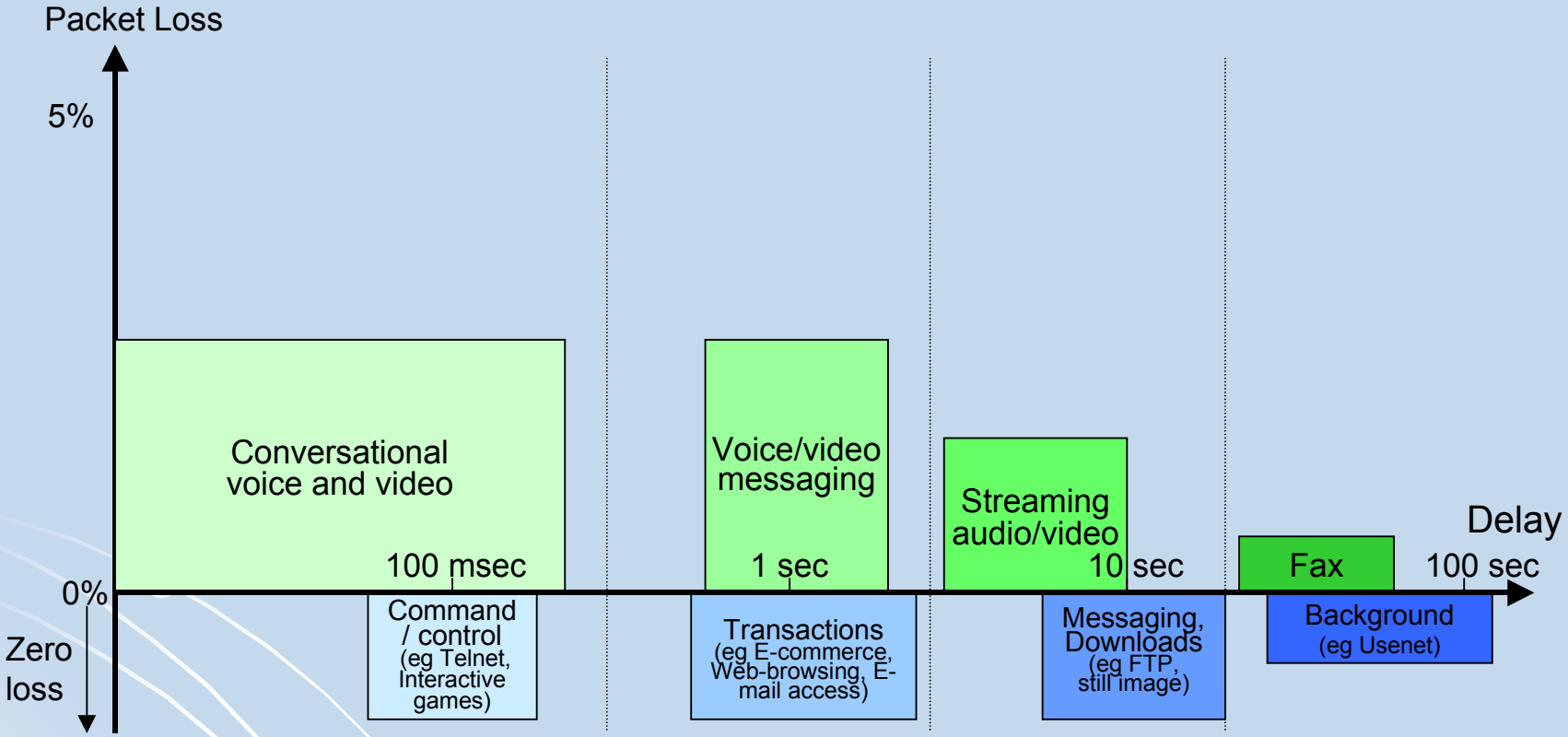
  - VoIP / Video conferencing
  - Audio / video messaging
  - Video (e.g., MPEG2, MPEG4, H.323,…)
  - Web browsing (HTTP, TCP)
  - E-mail (UDP)
  - File Upload and Download (FTP, TCP)
  - Video and/or audio streaming
  - IP multicast
  - Interactive internet gaming
  - Telemetry
  - Location based services (e.g., E-911)
  - Telematics (= a subset of the above + vehicular specific applications)
  - …

Application requirements to the end-users

- Major parameters are:
  - Data Rate
  - Latency
  - Latency variation
  - Information loss ratio

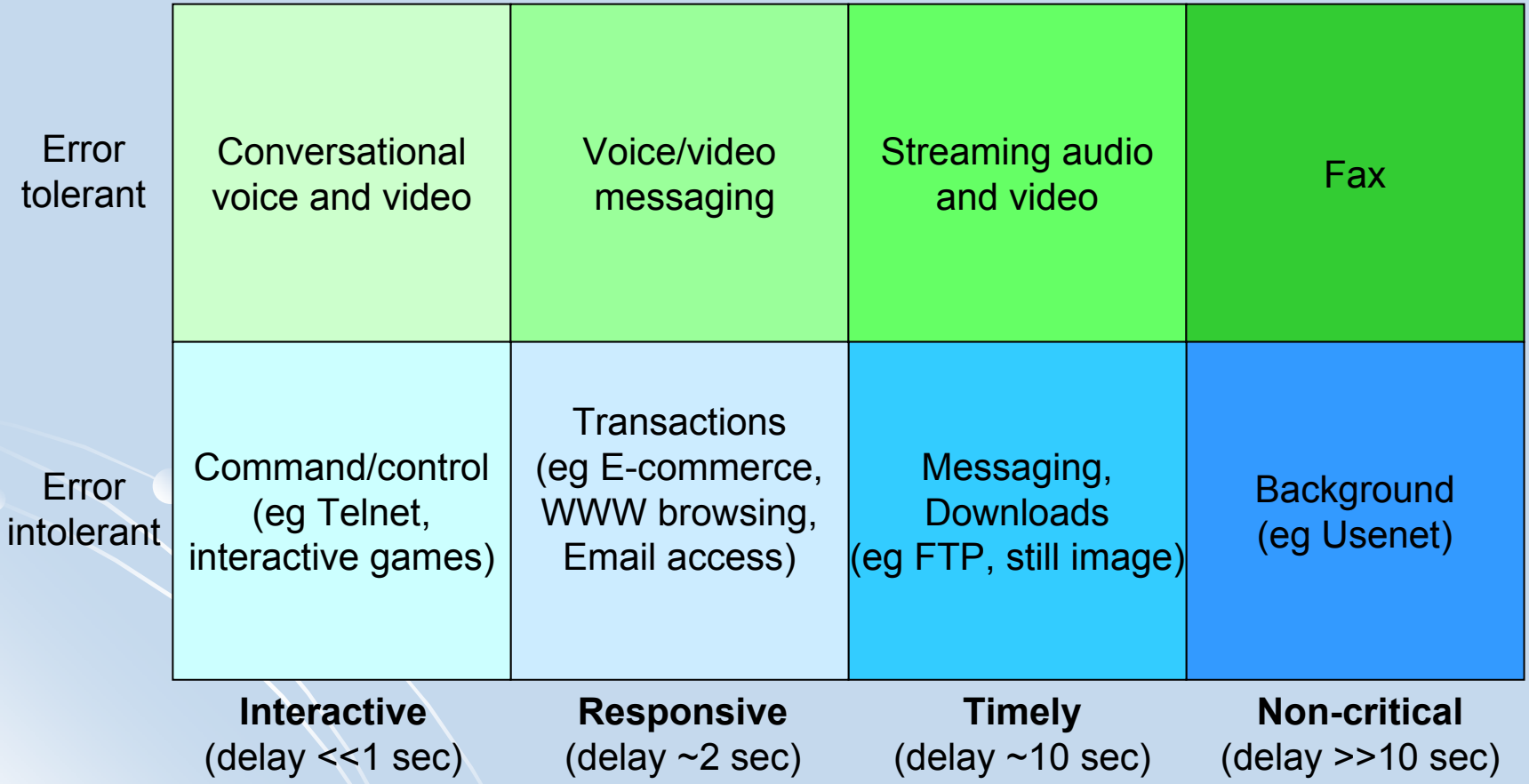
- Various applications can be classified into different groups, based on their latency and error tolerance requirements.

User-centric Delay and Packet Loss requirements – ITU G.1010*



Source: ITU G.1010 [“Draft New Recommendation G.QoSRQT – End-user Multimedia QoS Categories”, ITU-T study group 12, contribution 37, August 2001]

End-user QoS Categories Mapping - ITU G.1010



UMTS QoS classes

- Adopted performance targets similar to ITU-T's collection of information - 3GPP TS 22.105 [3]

- Four different QoS classes are defined in 3GPP TS 23.107 [4], as follows:-

Traffic class	**Conversational class** **conversational RT**	**Streaming class** **streaming RT**	**Interactive class** **Interactive best effort**	**Background** **Background best effort**
Fundamental characteristics	- Preserve time relation (variation) between information entities of the stream Conversational pattern (stringent and low delay)	- Preserve time relation (variation) between information entities of the stream	- Request response pattern - Preserve payload Content	- Destination is not expecting the data within a certain time - Preserve payload content
Example of the application	- voice	- streaming video	- Web browsing	- Background download of emails

Performance targets for Conversational/Real-Time Services (audio and video applications)

- Source: 3GPP TS 22.105 V6.2.0 & G.1010

Medium	Application	Degree of symmetry	Typical Data rates/ Amount of Data	Key performance parameters and target values		
				End-to-end One way Delay	Delay Variation within a call	Information Loss**
Audio	Conversational voice	Two-way	4 - 64 kb/s	<150 msec Preferred* <400 msec limit*	< 1 msec	< 3% Packet Loss Ratio
Video	Videophone	Two-way	16 -384 kb/s	< 150 msec preferred <400 msec limit Lip-synch : < 100 msec		< 1% Packet Loss Ratio
Data	Telemetry - two-way control	Two-way	<28.8 kb/s	< 250 msec	N.A	Zero
Data	Interactive games	Two-way	< 1 KB	< 250 msec	N.A	Zero
Data	Telnet	Two-way (asymmetric)	< 1 KB	< 250 msec	N.A	Zero

* Assumes adequate echo control

** Exact values depend on specific codec, but assumes use of a packet loss concealment algorithm to minimise effect of packet loss

Performance targets for Interactive Services

– source: 3GPP TS 22.105 & ITU G.1010

Medium	Application	Degree of symmetry	Typical data rate/ Amount of data	Key performance parameters and target values		
				One-way Delay (response time)	Delay Variation	Information loss
Audio	Voice Messaging	Primarily one-way	4-32 kb/s	< 1 sec for playback < 2 sec for record	< 1 msec	< 3% Packet Loss Ratio
Data	Web-browsing - HTML	Primarily one-way	~ 10 kB	< 4 sec /page	N.A	Zero
Data	Transaction services – high priority e.g. e-commerce, ATM	Two-way	< 10 kB	< 4 sec	N.A	Zero
Data	E-mail (server access)	Primarily One-way	< 10 kB	< 4 sec	N.A	Zero

Performance targets for Streaming Services

– source: 3GPP TS 22.105 & ITU G.1010

Medium	Application	Degree of symmetry	Data rate/ Amount of data	Key performance parameters and target values		
				Start-up Delay	Transport delay Variation	Packet loss at session layer
Audio	Speech, mixed speech and music, medium and high quality music	Primarily one-way	5-128 kb/s	< 10 sec	< 1 msec	< 1% Packet loss ratio
Video	Movie clips, surveillance, real-time video	Primarily one-way	16 -384 kb/s	< 10 sec	< 1 msec	< 1% Packet loss ratio
Data	Bulk data transfer/retrieval, layout and Synchronisation information	Primarily one-way	10 kB – 10 MB	< 10 sec	N.A	Zero
Data	Still image	Primarily one-way	< 100 kB	< 10 sec	N.A	Zero

Value ranges for UMTS Bearer Service Attributes

- 3GPP TS 23.107 V5.10.0

Traffic class	Conversational class	Streaming class	Interactive class	Background class
Maximum bitrate (kbps)	<= 16 000	<= 16 000	<= 16 000 – overhead	<= 16 000 – overhead
Delivery order	Yes/No	Yes/No	Yes/No	Yes/No
Maximum SDU size (octets)	<=1 500 or 1 502	<=1 500 or 1 502	<=1 500 or 1 502	<=1 500 or 1 502
Delivery of erroneous SDUs	Yes/No/-	Yes/No/-	Yes/No/-	Yes/No/-
Residual BER	$5*10^{-2}$, 10^{-2}, $5*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}	$5*10^{-2}$, 10^{-2}, $5*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}	$4*10^{-3}$, 10^{-5}, $6*10^{-8}$	$4*10^{-3}$, 10^{-5}, $6*10^{-8}$
SDU error ratio	10^{-2}, $7*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}	10^{-1}, 10^{-2}, $7*10^{-3}$, 10^{-3}, 10^{-4}, 10^{-5}	10^{-3}, 10^{-4}, 10^{-6}	10^{-3}, 10^{-4}, 10^{-6}
Transfer delay (ms)	100 – maximum value	280* – maximum value		
Guaranteed bit rate (kbps)	<= 16 000	<= 16 000		
Traffic handling priority			1,2,3**	
Allocation/Retention priority	1,2,3	1,2,3	1,2,3	1,2,3
Source statistic descriptor	Speech/unknown	Speech/unknown		
Signalling Indication			Yes/No**	

*If the User Equipment (UE) requests a transfer delay value lower than the minimum value, this shall not cause the network to reject the request from the UE. The network may negotiate the value for the transfer delay.
**If signalling indication is set to ‘Yes’, the UE should set the traffic handling priority to ‘1’.

Current QoS requirement in 802.20

- Support of IETF DiffServ (DS) [5] is described in Section 4.4.1 of the draft 802.20 requirements [1]
- IETF DiffServ – classes of services specified in the DS codepoints
  - Expedited Forwarding (EF) [6]
  - Assured Forwarding (AF) – 4 subclasses with 3 levels of drop precedence through the mapping of DS codepoints [7]
  - Best Effort
- IETF DiffServ defined the QoS structure for IP packets at the Network Layer
- How should the End user QoS requirements be mapped into the DiffServ classes at the Network layer?
- How should the DiffServ requirements at the Network layer be translated to the related requirements at PHY and MAC layers in order to achieve the end-to-end QoS requirements?

Information Flow between End-users

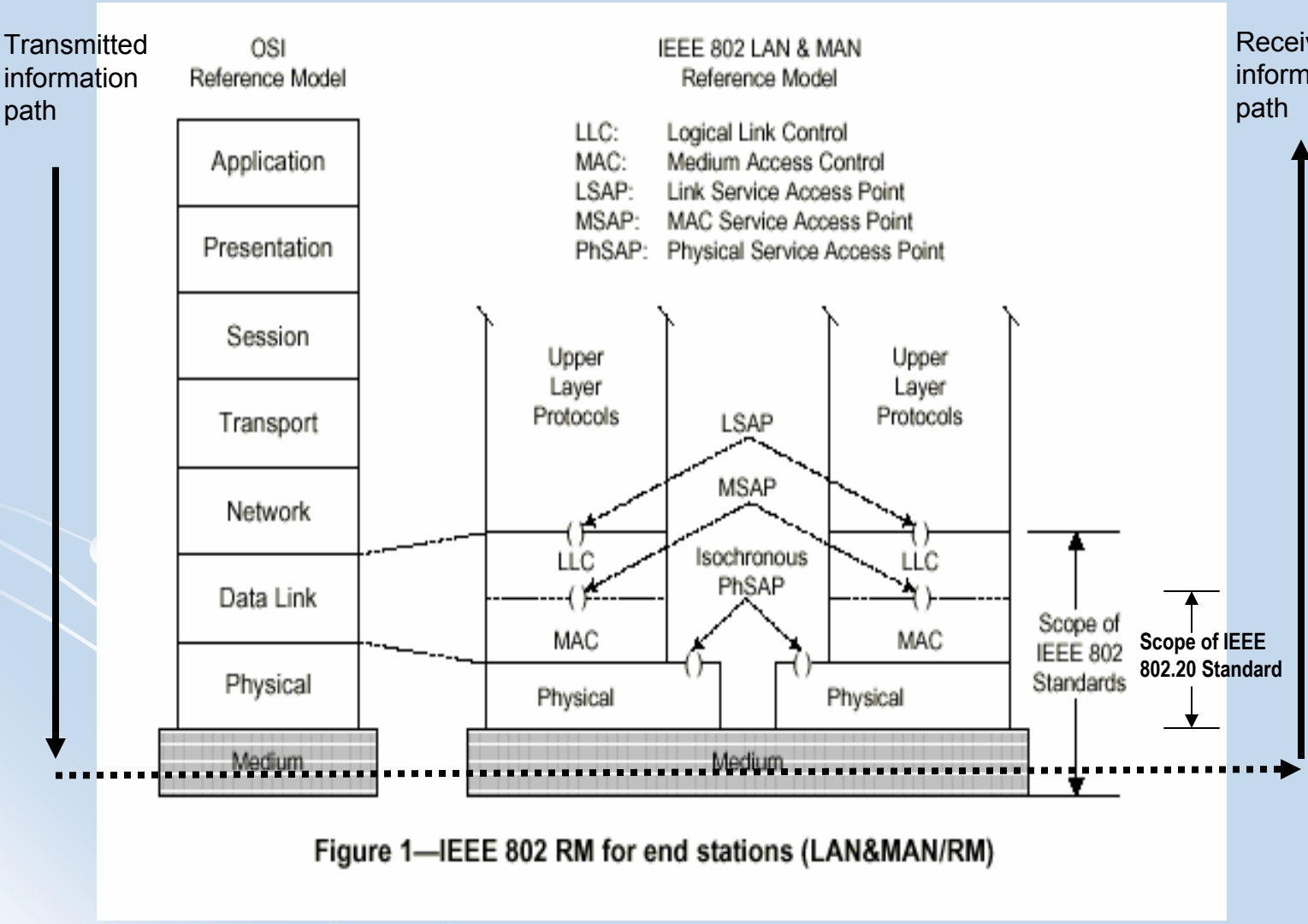


Figure 1—IEEE 802 RM for end stations (LAN&MAN/RM)

802.2 Logical Link Control (LLC)*

- Three forms of service supported, as viewed from the network layer:
  - Unacknowledged Connectionless mode
    - No need to establish data link level connection
    - For point-to-point, multicast and broadcast applications
  - Connection mode
    - Need to establish a data link level connection
    - Provides data link layer sequencing, flow control and error recovery
    - For point-to-point applications
  - Acknowledged connectionless mode
    - No need to establish data link level connection
    - LLC acknowledgement required
    - For point-to-point applications

∗ Source: IEEE 802.2 Standard [8]

QoS Implication on PHY and MAC

- User-perceivable performance described by QoS requirements
- QoS requirements need to be accomplished from the transmitting to the receiving end
- Impact of each layer along the transmission path need to be considered for an optimized system
- => Derive PHY and MAC layer requirements from User-driven performance requirements, based on reasonable assumptions on the apportionment between different layers.
- Latency, Delay Variation and Error Rate are the main performance parameters related to the PHY and MAC layers.
- Tradeoff between Latency and Error Rate performance in an optimized dynamic system.

QoS Implication on PHY and MAC

- Information loss
  - Error correction at the PHY layer, may correct errors through re-transmissions
  - Error detection at the MAC sublayer, corrected through re-transmissions, with increased latency ~ *n* x ARQ loop delay, where *n* = number of re-transmisisons
  - Possible error detection at the LLC sublayer, corrected through LLC re-transmission, depending on the mode of operation at LLC sublayer
  - Error detection at TCP layer, corrected through re-transmission, but with increased latency ~ *M* x Round Trip Time (RTT), *M* = number of TCP re-transmisisons
  - For UDP, error packets will be detected and discarded without re-transmission

- End-to-end Latency

$$End-to-end\ Latency \approx \sum_{i=1}^{7}\{Delay\ in\ Layer\ i\} + \Pr opagation\ \ Delay + \Pr ocessing\ Delay$$

$$\approx \left[Delay\ in\ PHY/MAC/LLC\ Layers + \underbrace{\sum_{i=3}^{7}\{Delay\ in\ Layer\ i\}}_{(A)} \right] + \underbrace{\Pr opagation\ \ Delay}_{(B)} + \underbrace{\Pr ocessing\ Delay}_{(C)}$$

Notes:
(A) Dependent on traffic loading, protocols, and delay in the lower layers, in some cases
(B) Dependent on distance between user terminal and base station
(C) Dependent on Implementation

IEEE 802 Error Rate Requirement

IEEE Std 802-2001 specified the error rate performance for IEEE 802 LANs and MANs in section 7.3 [9, 10]:

- Probability of error of data delivered to the MAC Service Access Point (MSAP) at the receiver < 8×10^{-8} per octet of MAC Service Data Unit (SDU) length

- For MAC SDU length = 1024 octets,

$\Rightarrow$ MAC SDU packet error rate, P_e < ~ 8×10^{-5}

$$Error\ rate\ for\ a\ packet\ with\ K\ Octets \approx 1-(1-Octet\ error\ rate)^{K}$$

Assume the same packet size and independent PER for each re-transmission,

$$Packet\ \ error\ rate\ after\ n-1\ retransmissions \approx P_e^{\,n}$$

Number of retransmissions	1	2	3
Residual Packet Error Rate for $P_e = 8 \times 10^{-5}$	6.4×10^{-9}	5×10^{-13}	4.096×10^{-17}
Residual Packet Error Rate for $P_e = 0.25$	6.25×10^{-2}	1.56×10^{-2}	3.9×10^{-3}

Recommended Latency and Packet Error Rate Performance Targets for IEEE 802.20

Latency & Error Rate for different application classes	Expedited Forwarding (EF)	Assured Forwarding (AF)	Best Effort (BE)
	~ 30 ms (TBR)	~ 30 ms – 10 s (TBR)	>> 10 s (TBR)
Error Tolerant	3×10^{-2}	$10^{-2} – 2.5 \times 10^{-1}$ (TBR)	2.5×10^{-1} (TBR)
Error Intolerant	5×10^{-13} (TBR)	$5 \times 10^{-13} – 8 \times 10^{-5}$ (TBR)	8×10^{-5}

- Assured Forwarding class can be further sub-divided into 4 subclasses
- Mapping of applications to the various classes depend on implementation
- Requirements for the proposal: to demonstrate that the error rates can be achieved with the corresponding latency

Industrial QoS Related Activities

- Standards organizations that are working on QoS issues:
  - IEEE 802.11e, 802.11n (High Throughput WLAN Standard)
  - IETF
  - ITU-T, ITU-R
  - 3GPP
  - T1A1
  - 3GPP2

- Some of the Issues: [11]
  - allocation of performance requirements along the transmission path traversed by the information packets, to achieve the end-to-end performance targets.

  - IP QoS interoperability – differences in the definition of QoS classes by different standards for different technologies across the network that connects the two end-users.

List of References

[1] Draft 802.20 Requirements Document – Ver. 8c, Oct. 28, 2003.

[2] ITU G.1010 [“Draft New Recommendation G.QoSRQT – End-user Multimedia QoS Categories”, ITU-T study group 12, contribution 37, August 2001]

[3] 3GPP TS 22.105, "Services and service capabilities“

[4] 3GPP TS 23.107, "QoS concept and Architecture"

[5] RFC 2475, “An Architecture for Differentiated Services”

[6] RFC 2598, “An Expedited Forwarding PHB”

[7] RFC 2597, “Assured Forwarding PHB Group”

[8] ANSI/IEEE 802.2(ISO/IEC 8802-2:1998), “Part 2, Logical Link Control”, 1998 edition

[9] IEEE Std 802 -2001, “IEEE standard for Local and Metropolitan Area Networks: Overview and Architecture”

[10] C802.20-03/83r1, “FER: Do We Need It?”, J. Cleveland et. al., Sept. 8, 03.

[11] http://www.itu.int/ITU-T/worksem/qos/index.html