QoS-Issues
&
their Resolution
in evolved 3G and
Next Generation Networks

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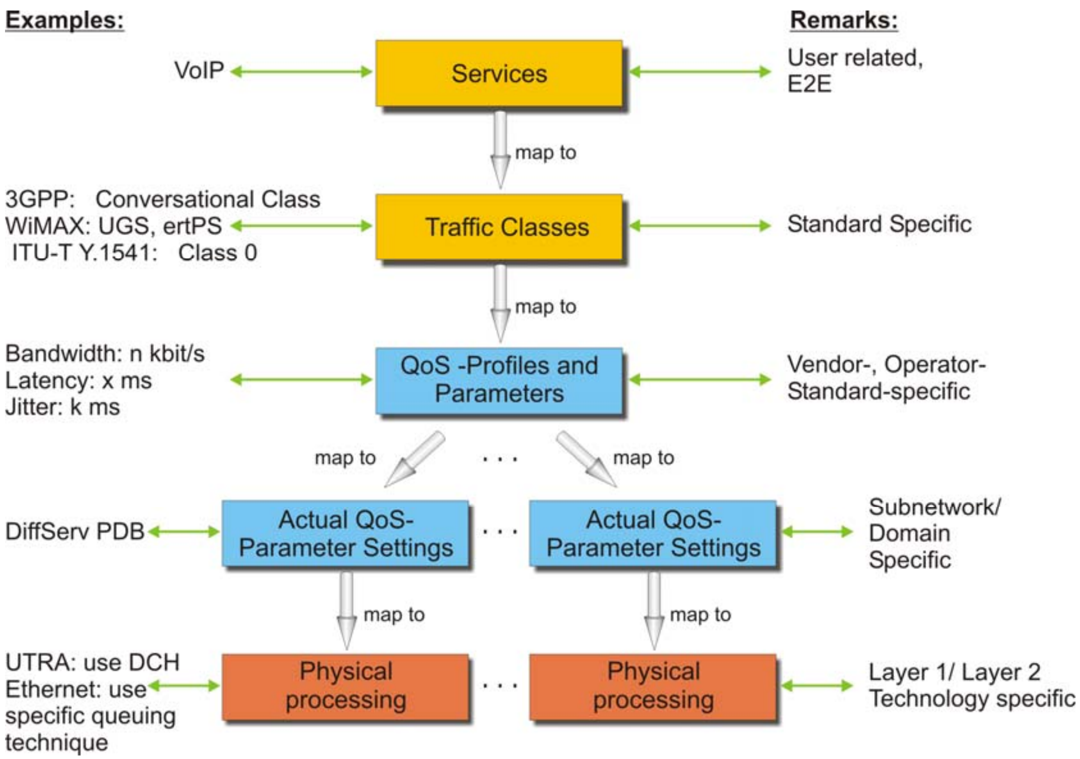
1.1 Our Playground / Scope of this Course

1.1.1 The QoS-Hierarchy



The objective of this section is to illustrate the different layers that are important for QoS and the terminology that is applied.

Ultimate QoS cannot be achieved through partial measures, neither horizontal nor vertical. An end-to-end approach is required.

Image Description

- Services that customers use like for instance VoIP can be mapped to specific traffic classes.
- Typical examples for traffic classes are indicated above.
- The different traffic classes are then mapped to QoS-profiles and actual QoS-performance parameter settings or setting ranges (target values).
- The mapping is organization specific whereas organization may relate to e.g. a certain operator or vendor or to another standard organization.
- Depending on the underlying layer 1 / layer 2 transport network, the physical processing needs to be different for the different QoS-performance targets.

1.1.1.1 Services
Typical examples for services are VoIP, VoD or AoD, web browsing, FTP or e-mail transfer.

1.1.1.2 Traffic Classes
Traffic classes need to be pre-defined by standardization committees and similar organizations. They usually consist of the description of typical characteristics of a certain type or class of service. Consider for example the typical characteristics of VoIP vs. e-mail transfer.

1.1.1.3 QoS-Profiles and Parameters
Usually strongly related to the defined traffic classes, a standardization organization specific QoS-profile consists of a set of performance related parameters like bandwidth, error rate or delay time.

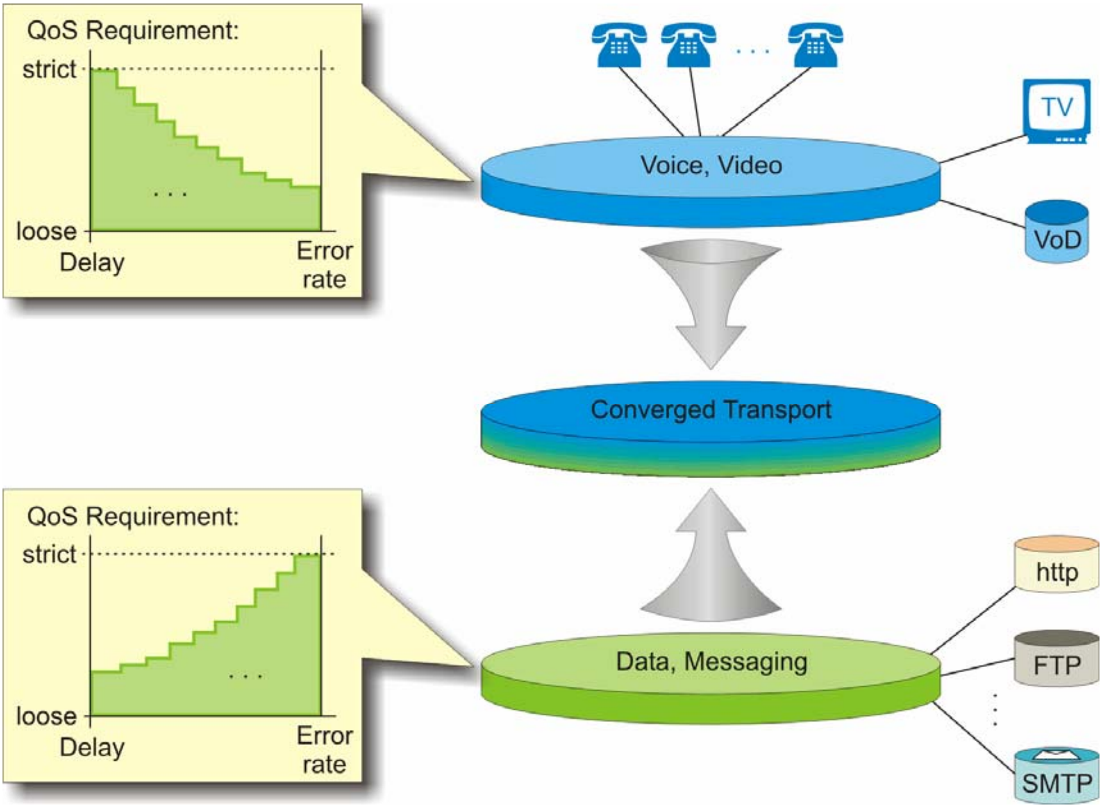
1.1.1.4 QoS-Parameter Settings
Some organization (operator, vendor, standardization committee) needs to assign measurable target values to the different parameters of the used QoS-profile. Please note that these settings do not reflect the customer experience since each QoS-parameterization only covers one part of the overall distance.
What is really done here is to say for example: “For VoIP-services the jitter must not exceed is 30 ms in our network.”

1.1.1.5 Physical Processing Rules
Finally, the physical layer needs to operate along the previously defined rules. That typically results in the different prioritization of packets to achieve a certain delay time or in the amendment of CRC-checks to packets and use of forward and/or backward error correction rules to achieve a certain error rate.

- **Abbreviations of this Section:**

3GPP	Third Generation Partnership Project (Collaboration between different standardization organizations (e.g. ARIB, ETSI) to define advanced mobile communications standards, responsible for UMTS)	**QoS**	Quality of Service
AoD	Audio on Demand	**SLA**	Service Level Agreement
CRC	Cyclic Redundancy Check	**UGS**	Unsolicited Grant Service (IEEE 802.16 Traffic Class)
DCH	Dedicated Channel (Transport)	**UTRA**	UMTS (Universal Mobile Telecommunication System) Terrestrial Radio Access
FTP	File Transfer Protocol (RFC 959)	**VoIP**	Voice over IP
ITU-T	International Telecommunication Union - Telecommunication Sector	**WIMAX**	Worldwide Interoperability for Microwave Access (IEEE 802.16)
PDB	Per Domain Behavior (DiffServ Term)	**ertPS**	Extended Real-Time Polling Service (IEEE 802.16 Traffic Class)

1.3.3 Transport Network Convergence

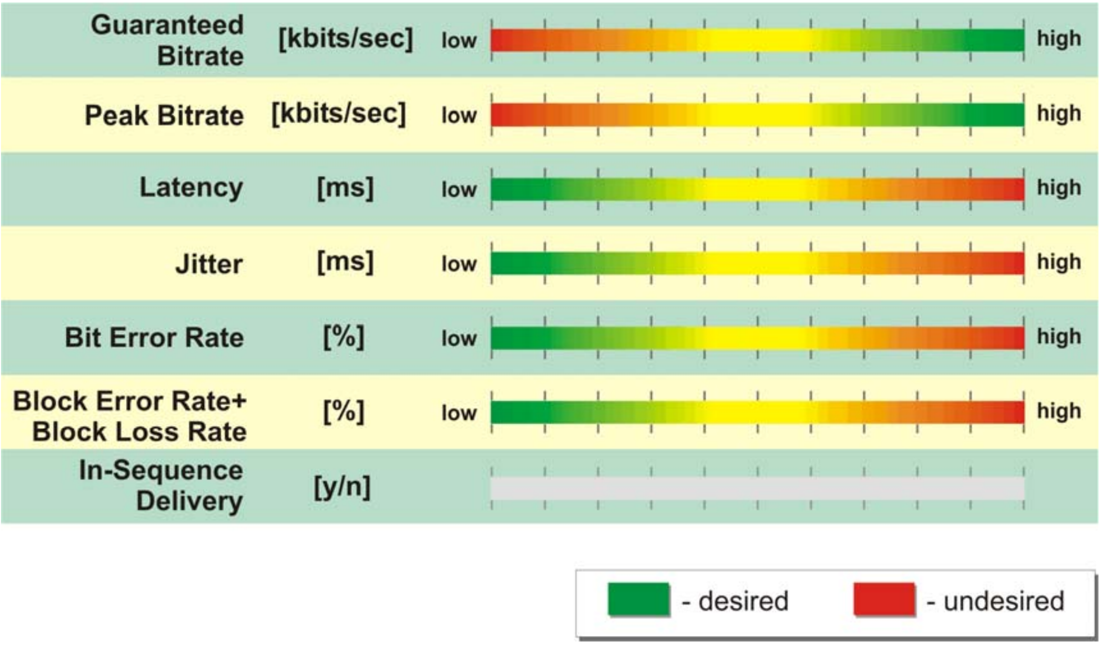


The objective of this section is to illustrate that different applications have different and even contrary QoS-requirements on the transport network.

Image Description

- The image illustrates at the top (blue network) that conversational applications like voice and video typically have very stringent delay requirements but do not care too much about packet loss.
- Opposed to this, typical data applications like e-mail transfer or FTP are not sensitive against delay and jitter but are heavily affected by bit errors and packet loss.

2.1 Generic QoS-Profile Definition



The objective of this and the following section is to provide a generic QoS-profile definition.

The key point of this section is that any QoS-profile contains a number of attributes or parameters to describe performance related behaviour.

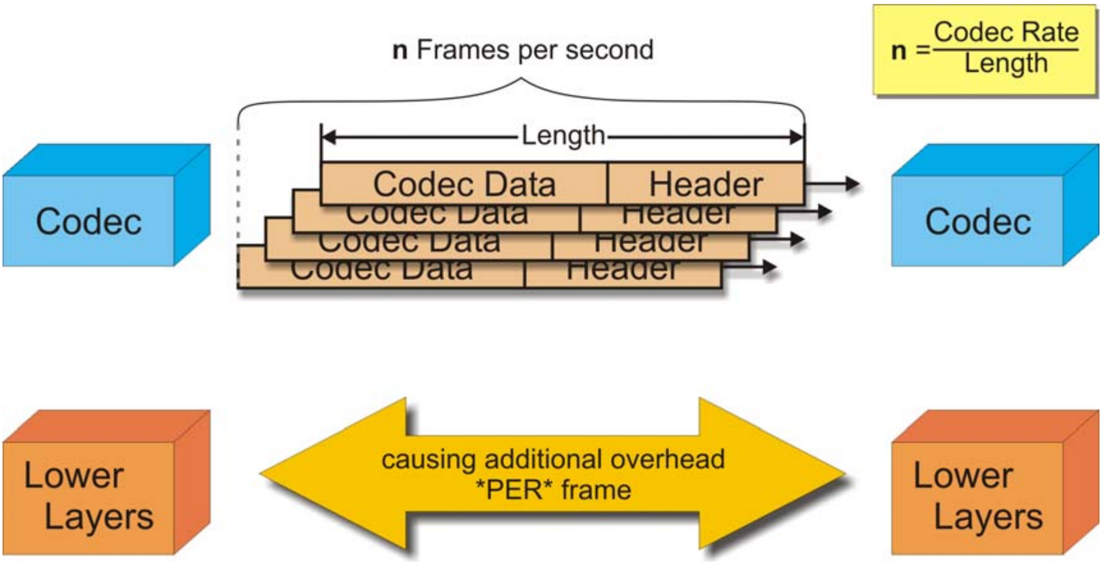
Image Description

- The image illustrates the parameters that we selected as parts of the generic QoS-profile.
- It also illustrates the units of these parameters and whether small or high parameter values are desired.

> Usually, the parameters for guaranteed and peak bitrate are included twice to distinguish uplink and downlink direction. This of course only applies in case of bidirectional media transfers.

2.1.2 Mapping Services to the generic QoS-Profile

2.1.2.1 How to determine the necessary Bandwidth



The objective of this section is to illustrate how the necessary bandwidth needs to be determined for an audio or video codec.

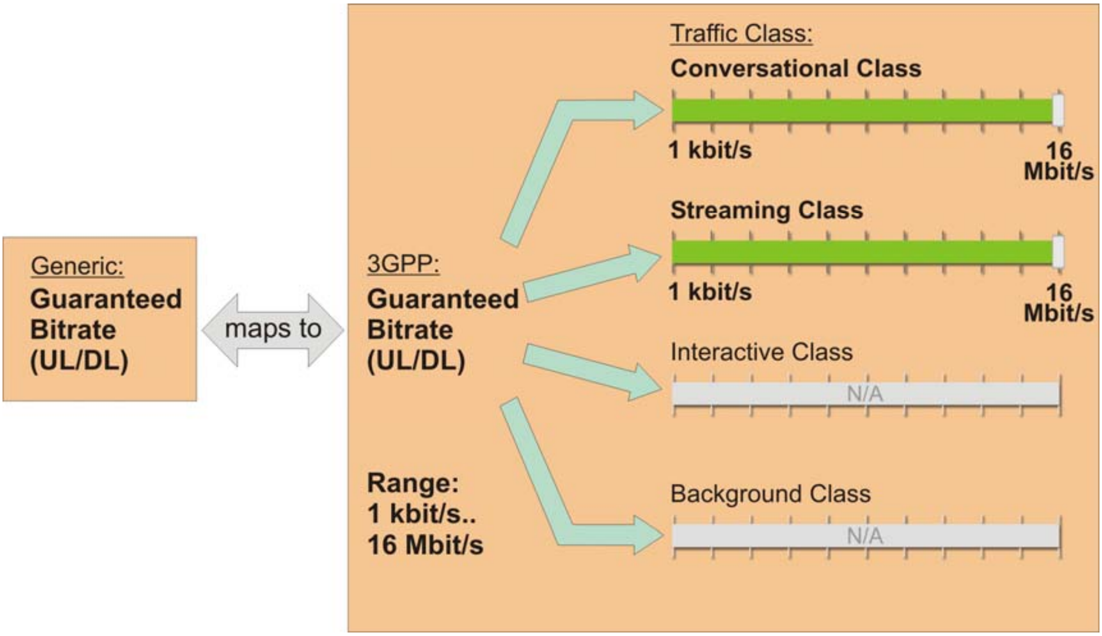
Keypoint of this section is that the final bandwidth figure does not only depend on the net throughput rate required by the specific codec type. It also depends on the number of frames transmitted per second because the overhead of the lower layers plays an essential role in the bandwidth calculation.

Image Description
The image illustrates the protocol stacks at the two peers together with the sequence of codec data frames which are conveyed from the left peer to the right peer.
Lower layers require and essential part of the bandwidth as each codec data frame also needs to be equipped with a complete protocol stack header.

The related numbers are hard to find and require a sophisticated analysis of the codec specifications.

The lower layer overhead depends on whether header compression can be applied.

2.2.1.3 Guaranteed Bitrate



The objective of this section is to map the “Guaranteed Bitrate” parameter of the generic QoS-profile to the best matching parameter within the 3GPP-QoS-profile.

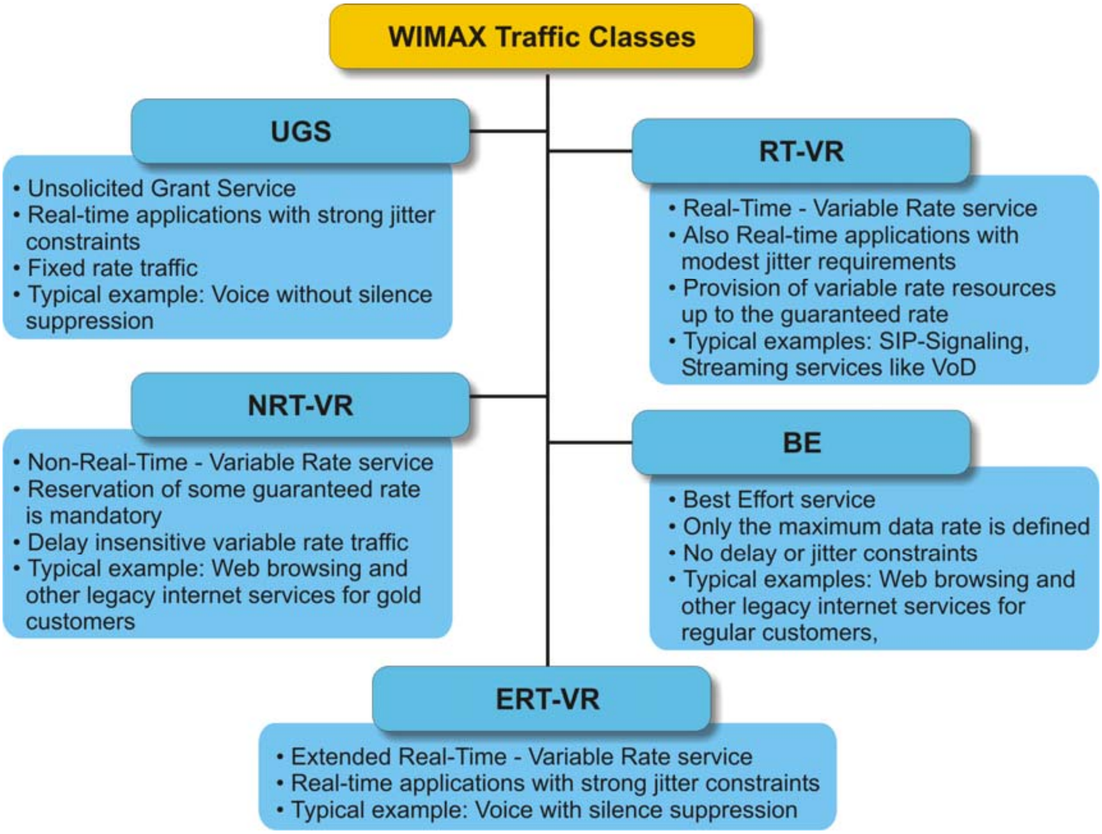
Key point of this section is that the “Guaranteed Bitrate” parameter needs to be split and differentiated into uplink and downlink direction.

Image Description

- The image illustrates within the left rectangle the QoS-attribute of the generic QoS-profile.
- Within the right rectangle we illustrate the related 3GPP QoS-attribute, its value range and the mapping to the 3GPP traffic classes.
- Note that there is no “Guaranteed Bitrate” for neither the interactive traffic class or for the background traffic class.

[3GTS 23.107 (6.5.1)]

2.2.3.2 WIMAX-Traffic Classes

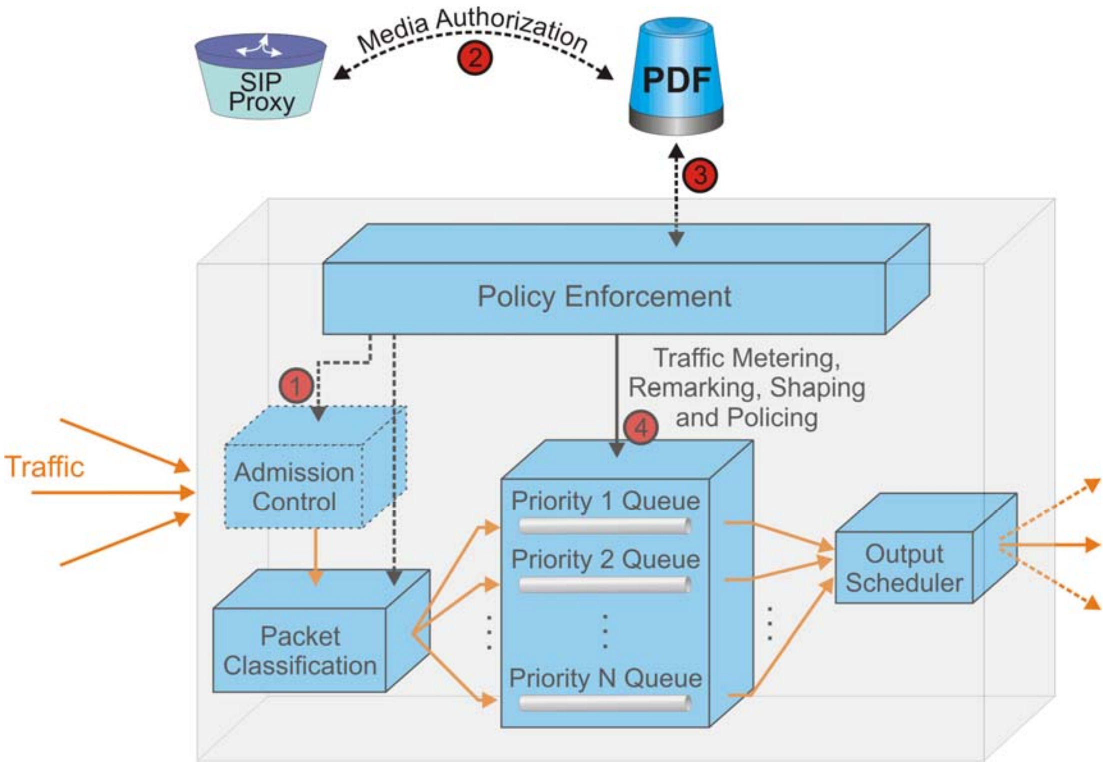


The objective of this section is the presentation of the various WIMAX traffic classes.

Keypoint of this section is that neither the IEEE nor the WIMAX-forum defined parameter ranges to be applicable for the different WIMAX traffic classes.

Accordingly, we will not provide the individual mappings between the legacy QoS-profile and the WIMAX-traffic classes and parameters.

2.3.1 Traffic Administration in Operation



The objective of this section is to illustrate the operation of the aforementioned means and procedures of traffic administration.

Key point of this section is that the illustrated device may be a QoS-aware router but it may also reflect any other device like for instance an RNC or a WIMAX BS.

Image Description

- The image illustrates some device (router, gateway, base station, …) that is in charge to route incoming traffic downstream.
- The incoming traffic will come from various sources which may be preceding network entities or single users.
- We don't want to classify this in any more detail to keep all options open.
- Inside this network element we see various functions like admission control for the incoming traffic, packet classification, priority queues and a policy enforcement unit.
- Such a policy enforcement unit may be interconnected to an internal or external PDF to retrieve policy decisions.

- The image illustrates the well-known case of the PDF being interconnected to a SIP-proxy to generate media authorization token.

2.3.1.1 Admission Control

1

It depends on the device how and whether admission control is performed. Admission control may be based on preconfigured rules which may be based on:

- Information within the packet headers (e.g. “only accept traffic from …)
- Actual traffic load (e.g. as performed by the UMTS RNC based on the uplink interference level or by an edge router of a DiffServ domain based on the ingress load of this router).
- On external policy decisions taken by some kind of PDF. The best example is the procedure as proposed by 3GPP for the IMS-interworking with IP-CAN’s: The SIP-server communicates with the PDF whether this session can be authorized in the first place. The PDF allocates a media authorization token. Later, the policy enforcement point (PEP) retrieves this media authorization token when the traffic starts entering the network or when the resource shall be reserved (e.g. during secondary PDP-context activation in 3GPP-networks). In chapter 3 we will show this as part of an e2e-procedure. 3

- **Abbreviations of this Section:**

BS	Base Station (IEEE 802.16)	**PDP**	Packet Data Protocol
DSCP	Differentiated Services Code Pointer	**PEP**	Policy Enforcement Point (3GTS 23.209)
GPRS	General Packet Radio Service	**PFI**	Packet Flow Identifier
IEEE	Institute of Electrical and Electronics Engineers	**QoS**	Quality of Service
IMS	Internet Protocol Multimedia Core Network Subsystem (Rel. 5 onwards)	**RNC**	Radio Network Controller
IP	Internet Protocol (RFC 791)	**SIP**	Session Initiation Protocol (RFC 3261)
IP-CAN	Internet Protocol - Connectivity Access Network (e.g. DSL, TV-Cable, WIMAX, UMTS)	**TFT**	Traffic Flow Template
e2e	End-to-End	**UMTS**	Universal Mobile Telecommunication System
MPLS	Multi Protocol Label Switching	**WIMAX**	Worldwide Interoperability for Microwave Access (IEEE 802.16)
PDF	Policy Decision Function (Part of the IP Multimedia Subsystem)		

2.3.1.2 Packet Classification

Packet Classification relates to the process of distributing the incoming packets to the differently prioritized output queues.
Packet classification may be based on

- DSCP's (in case of DiffServ)
- Priority tags within MAC-headers (as in IEEE 802.1p)
- Labels (as in MPLS)
- PFI's (in case of GPRS)
- IP-address / port number combinations

And many other things. This classification may be based on information received from the policy enforcement unit or on preconfigured information (e.g. DSCP decides over the classification).

4

2.3.1.3. Traffic Conditioning

Traffic conditioning relates to different sub-functions. The most important ones are:

- Traffic Metering which relates to measuring the incoming traffic. We will provide more details within the following sections.
- Remarking relates to tagging incoming frames suitably for the next hop. This may for instance relate to a new DSCP or to attaching some other QoS-tag (e.g. TFT-information in GPRS).
- Shaping and Policing relate to discarding or delaying packets based on traffic metering. We will provide more details within the following sections.

Room for your Notes

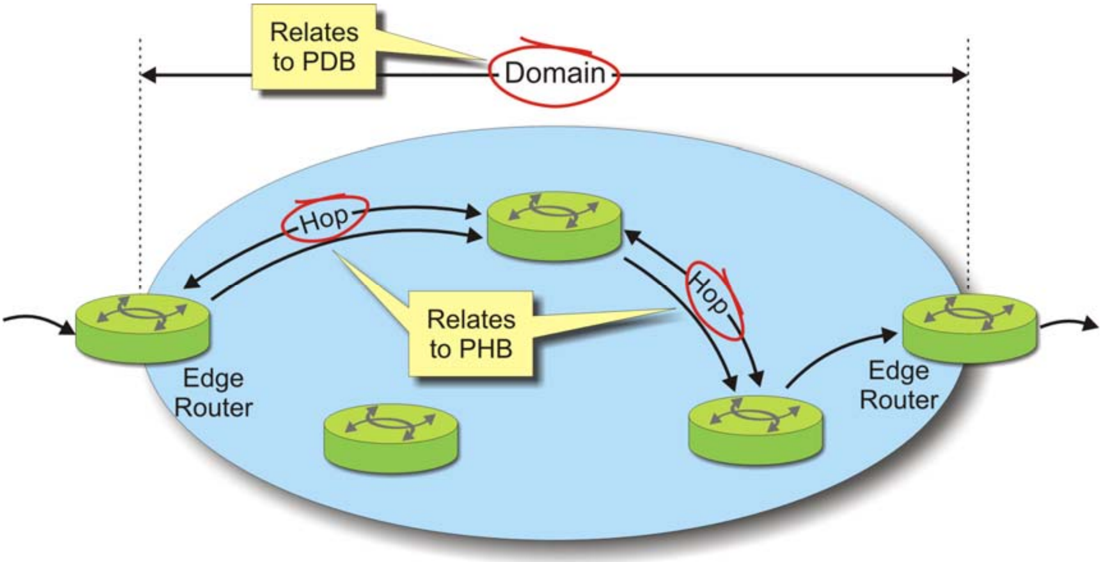
2

- **Abbreviations of this Section:**

3GPP	Third Generation Partnership Project (Collaboration between different standardization organizations (e.g. ARIB, ETSI) to define advanced mobile communications standards, responsible for UMTS)	**PDF**	Policy Decision Function (Part of the IP Multimedia Subsystem)
3GTS	3rd Generation Technical Specification	**PDP**	Packet Data Protocol
BS	Base Station (IEEE 802.16)	**PEP**	Policy Enforcement Point (3GTS 23.209)
DSCP	Differentiated Services Code Pointer	**PFI**	Packet Flow Identifier
DSL	Digital Subscriber Line	**QoS**	Quality of Service
GPRS	General Packet Radio Service	**RFC**	Request for Comments (Internet Standards)
IEEE	Institute of Electrical and Electronics Engineers	**RNC**	Radio Network Controller
IMS	Internet Protocol Multimedia Core Network Subsystem (Rel. 5 onwards)	**SIP**	Session Initiation Protocol (RFC 3261)
IP	Internet Protocol (RFC 791)	**TFT**	Traffic Flow Template
IP-CAN	Internet Protocol - Connectivity Access Network (e.g. DSL, TV-Cable, WIMAX, UMTS)	**TV**	Television
MAC	Medium Access Control	**UMTS**	Universal Mobile Telecommunication System
MPLS	Multi Protocol Label Switching	**WIMAX**	Worldwide Interoperability for Microwave Access (IEEE 802.16)
		e2e	End-to-End

2

2.4.2.2 PHB vs. PDB



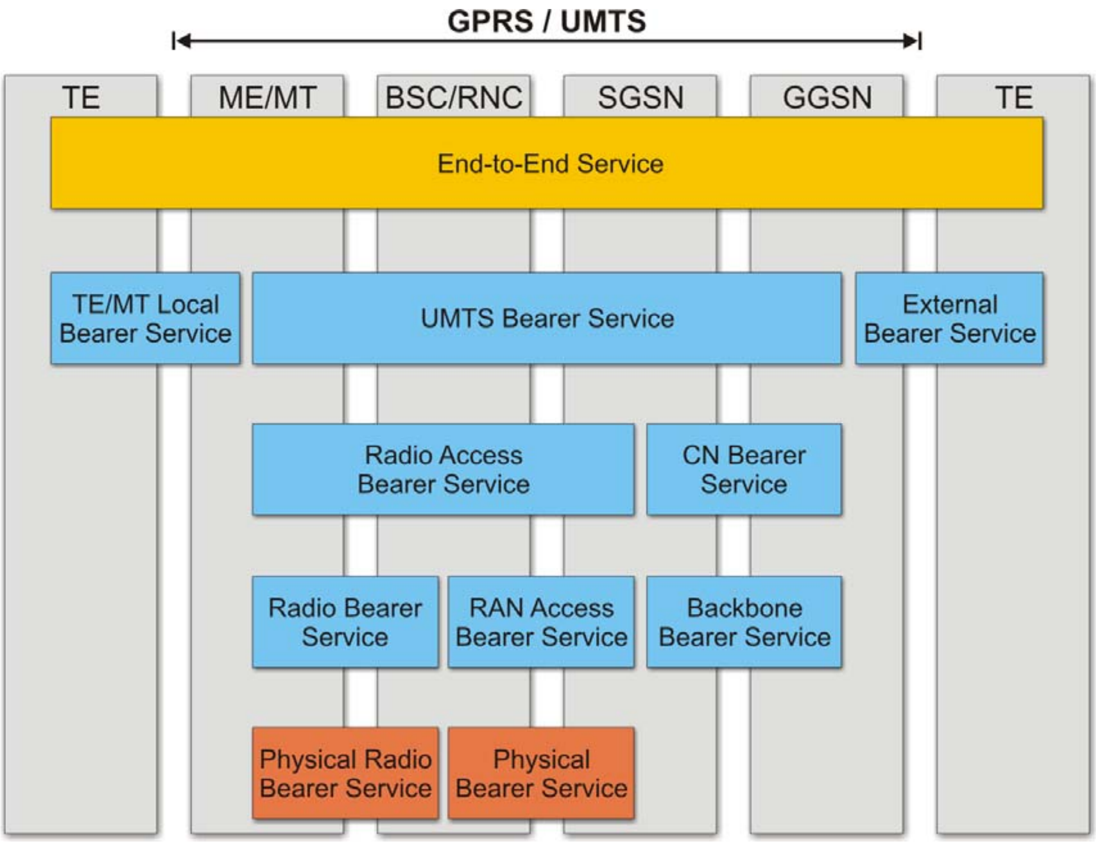
The objective of this section is to introduce and differentiate the two important DiffServ terms PHB [RFC 2475 (2+3)] and PDB [RFC 3086].

Keypoint of this section is that a PHB only provides relative QoS while a PDB provides absolute QoS.

Image Description

- The image illustrates a DiffServ aware network with a number of routers inside.
- Each router will process IP-frames according to the PHB which is stored within that router and which relates to a certain DSCP-setting.
- Such PHB relates to the treatment of that IP-frame compared to other incoming or already queued IP-frames.
- Opposed to that there is the PDB which provides the measurable and cumulative aggregation of all the PHB's that an IP-frame experienced inside the network.

2.5.3 GPRS and UMTS



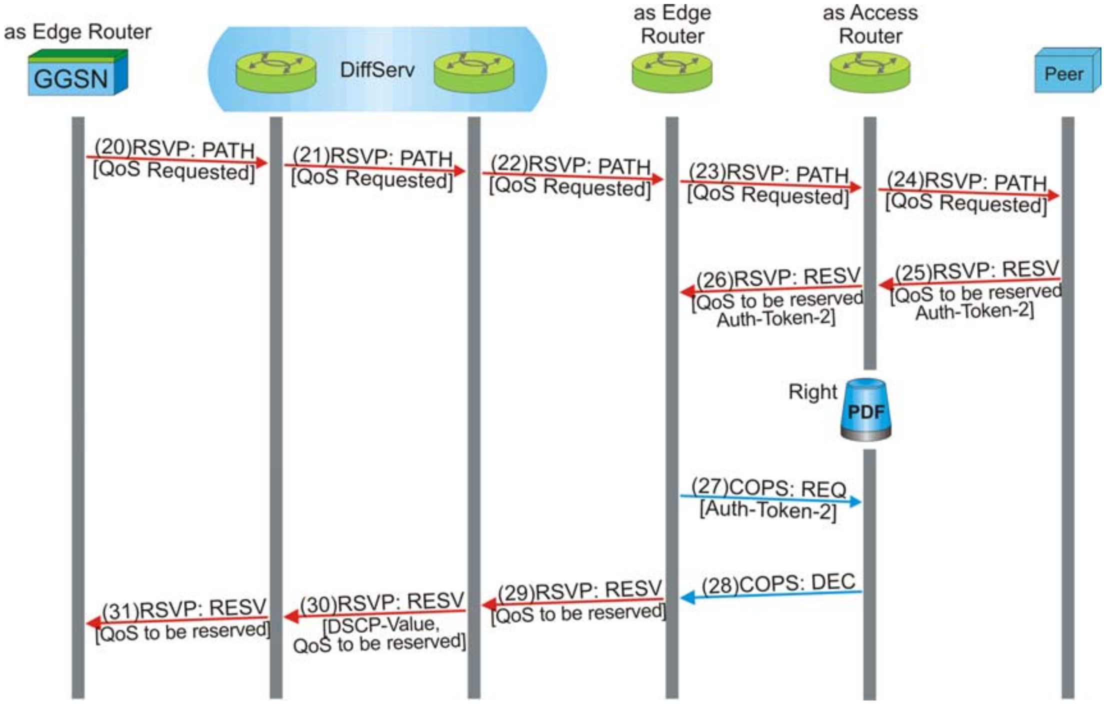
The objective of this section is to illustrate the perspective of 3GPP with respect to e2e- and step-by-step service and quality of service provision.

Key point of this section is that 3GPP provided a very detailed and layered view for the bearer services and network parts that 3GPP is responsible for. However, the external bearer services may be as complex.

Please note that we reused the color codes from section1.1

[3GTS 23.107 (6.1)]

3.1.2 Scenario Overview (continued)



The objective of this section is to illustrate the next phase of this message flow, with emphasis on the actual resource reservation for unidirectional traffic, flowing from the GGSN through the intermediate networks and the right IP-CAN and to the right peer.

Image Description

- The GGSN sends the RSVP: PATH-message (No 20) to the ingress router within the DiffServ-environment. This ingress router will also perform admission control and relay the RSVP: PATH-message to the egress router (No 21). This relaying occurs directly or indirectly but in any case according to RFC 2998 (IntServ over DiffServ).

How can the GGSN identify the right peer as final destination?

- The terms “egress” and “ingress” make obviously only sense because we right now only focus on traffic from the right peer to the left peer and not on the other direction.
- RSVP: PATH-messages (No 22, 23 and 24) will traverse the different network edge routers and the access router within the right access network and will finally reach the right peer.

- The right peer issues an RSVP: RESV-message (No 25) and sends it to its access router. The access router reserves the necessary resources and sends another RSVP: RESV-message (No 26) to the edge router.

One (of many) possible alternative to the indicated procedure would apply in a WIMAX-network. In this alternative, the RSVP-PATH-message would only reach the edge or the access router within the WIMAX-access network. Within this access network, the WIMAX-base station acts as replacement of the access router, using IEEE 802.16 specific messaging instead of messages 24 and 25 to allocate the real-time resources. In such case, the applicability of messages 23 and 26 depends on which admission control and QoS-procedures apply in such network.

- Note how the edge router requests a confirmation of the real-time QoS from the PDF before it actually grants the resources (No 27 and 28).
- Then the edge router sends its RSVP: RESV-message (No 29) to the egress router of the DiffServ-domain.
- This egress router adds a DSCP-value according to RFC 2996 to the object list within the RSVP: RESV-message (No 30) and relays it towards the next hop address (which possibly already is the ingress router).
- Finally, the GGSN receives an RSCP: RESV-message (No 31), confirming that resources for the traffic from the GGSN and to the right peer have successfully been reserved.

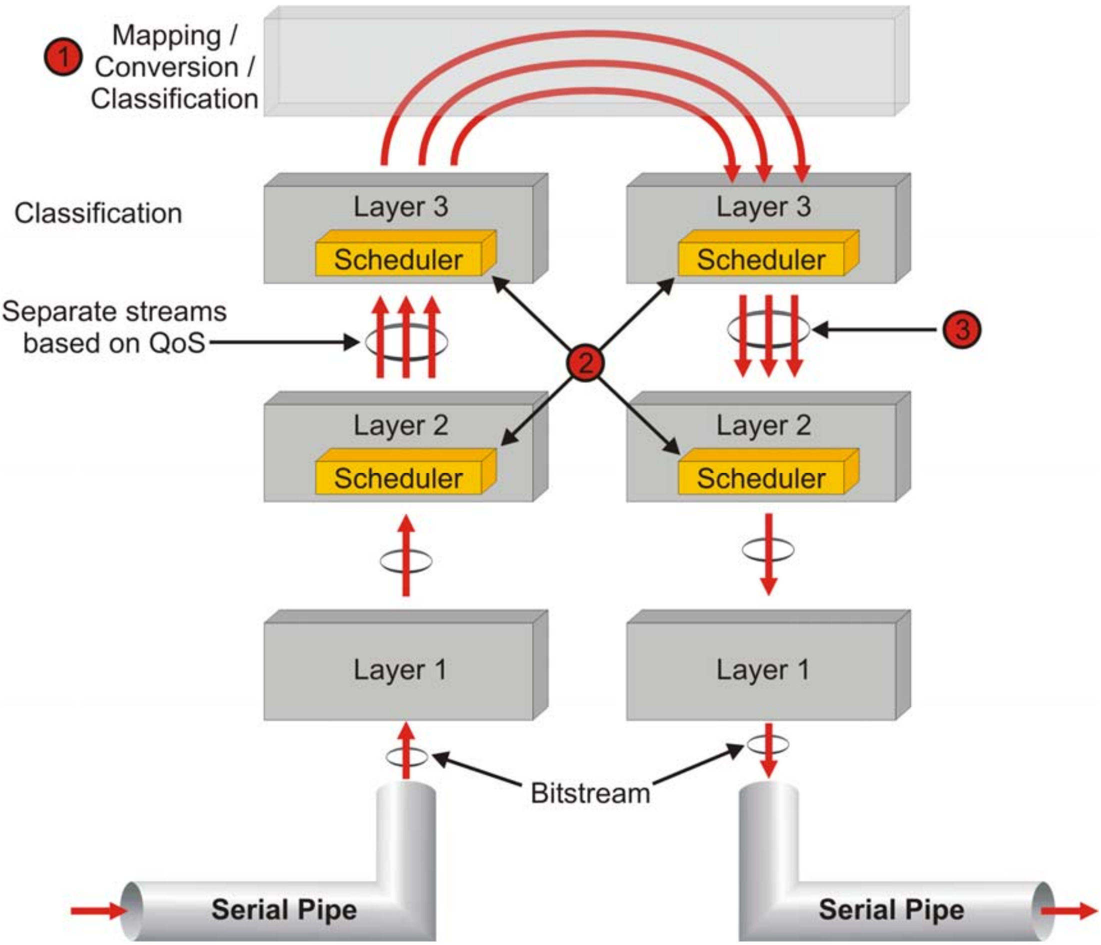
Note that there are still no real-time resources reserved between GGSN and right peer in send-direction from the right peer to the GGSN.

- **Abbreviations of this Section:**

COPS	Common Open Policy Service Protocol (RFC 2748)	**PDF**	Policy Decision Function (Part of the IP Multimedia Subsystem)
DEC	Decision (COPS message type)	**QoS**	Quality of Service
DSCP	Differentiated Services Code Pointer	**REQ**	Request (COPS message type)
GGSN	Gateway GPRS Support Node	**RFC**	Request for Comments (Internet Standards)
IEEE	Institute of Electrical and Electronics Engineers	**RSCP**	Received Signal Code Power (3GTS 25.215)
IP	Internet Protocol (RFC 791)	**RSVP**	Resource Reservation Protocol (RFC 2205)
IP-CAN	Internet Protocol - Connectivity Access Network (e.g. DSL, TV-Cable, WIMAX, UMTS)	**WIMAX**	Worldwide Interoperability for Microwave Access (IEEE 802.16)

4

4.1 Generic View / Important Rules



The objective of this section is to reduce all QoS-tagging techniques and QoS-architectures into a single image and section that allows the comprehension of these different technologies and architectures.

Key point of this section is that within the layer 1, QoS becomes nothing more and nothing less than a plain scheduling function for a serial bitpipe of whatever notion.

Image Description

- The image illustrates a given network device that embodies layer 1, layer 2, layer 3 and an upper layer.
- Whether the two stacks at the two network interfaces use the same protocols is arbitrary. It is for instance possible that at a router the layer 2 changes from ATM-based to Ethernet.
- The transmission lines are presented as plain serial bit pipes.

It us worthile

- Focus of the image is on the information flow that is multiplexed at the receiver into various flows, differentiated by their QoS-requirements.
- The schedulers may or may not be present in the indicated layer 2 and 3 entities.

Room for your Notes

- **Abbreviations of this Section:**

ATM	Asynchronous Transfer Mode (ITU-T I.361)	**QoS**	Quality of Service
ITU-T	International Telecommunication Union - Telecommunication Sector		

Important Remarks

- Whether the indicated layer 3 is present in a network node depends on the type of network node.

?

Please state two network node examples each with and without layer 3.

1

4.1.1 Mapping and Conversion Function

- When the layer 3 is not present, the mapping function at the top is still present but will be placed on top of the layer 2.
- The mapping function converts QoS-attributes of a given layer 1/2 to QoS-attributes of another layer 1/2 or it converts QoS-attributes of a given layer 3 to QoS-attributes of another layer 3.

!

At a network edge, the mapping function is also in charge to convert QoS-profiles to one another.

2

4.1.1 Scheduler Function (Layer 2 / Layer 3)

!

The scheduler function within the layer 2 and/or layer 3 tracks the QoS-tags of the packets to be processed and treats and forwards these packets accordingly.

?

Please state two different tags each for scheduler functions (protocols) within layer 2 and layer 3.

!

The scheduler function may be present only in layer 3 or layer 2 or it may be present in both protocol layers.

- If the scheduler function is only present in layer 3, then layer 3 will only receive one packet stream from layer 2 and it will only send one packet stream towards layer 2.

3

- Please compare with the image where we indicated three streams between layer 2 and layer 3: If the scheduler is only present in layer 3, then there would be only one stream between the two protocol layers.
- Typically, the layer 2 is responsible for QoS-relevant issues like acknowledged or unacknowledged transmission, in-sequence delivery or maximum and minimum packet sizes.