



## **Interactive Realtime Multimedia Applications on Service Oriented Infrastructures**

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### **WP 7 Intelligent Networking**

#### **D7.3.2 Final version of Flow Control Architecture**

**IRMOS\_WP7\_D7\_3\_2\_PU\_ALUD\_v1\_0**

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## Glossary of Acronyms

Acronym	Definition (Context)
ACC	Application Client Component (IRMOS)
ASC	Application Service Component (IRMOS)
ATM PVC	Asynchronous Transfer Mode Permanent Virtual Circuit
ATCA	Advanced Telecommunications Computing Architecture
be	best-effort (QoS class)
bep	best-effort prioritized - means with minimum throughput (QoS class)
CBR	Constant bitrate
CC	Client Component (IRMOS)
DiffServ	Differentiated Services
DSCP	Differentiated Services Code Point
eSC	External Service Component
GRE	Generic routing Encapsulation
IntServ	Integrated Services
IP	Internet Protocol
IQOA	ISONI QoS Overlay Adaptation
IRMOS	Interactive Real-time Multimedia Applications on Service Oriented Infrastructures
ISONI	Intelligent Service-Oriented Network Infrastructure
IXB	ISONI eXchange Box
IXB <sub>N</sub>	IXB Node
IXB <sub>PH</sub>	IXB Physical Host
MPEG	Moving Picture Expert Group
MPLS	Multiprotocol Label Switching
OAM	Operation and Maintenance
OWL	Ontology Web Language
PH	Physical Host (ISONI)
PHB	per-hop behaviour (DiffServ)
PM	Path Manager (ISONI)
PM <sub>D</sub>	Path Manager Domain
PM <sub>N</sub>	Path Manager Node
PoP	Point of Presence
QoS	Quality of Service
RM	Resource Manager (ISONI)
RM <sub>D</sub>	Resource Manager Domain
RM <sub>N</sub>	Resource Manager Node
RSVP	Resource Reservation Protocol
rt	Real-time (QoS class)
rtia	real time interactive audio
rtiv	real time interactive video
rtsa	real time streaming audio

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<b>Acronym</b>	<b>Definition (Context)</b>
rtsv	real time streaming video
SaaS	Software as a Service
SC	Service Component
SDH	Synchronous Digital Hierarchy
SLA	Service level agreement
SOA	Service-oriented architecture
SONET	Synchronous optical networking
ToS	Type of Service (IP header field)
T-SLA	Technical Service Level Agreement (IRMOS)
VBR	Variable bitrate
VL	Virtual Link (ISONI)
VLD	Virtual Link Description (ISONI)
VMU	Virtual Machine Unit (ISONI)
VSN	Virtual Service Network (ISONI)
VSND	VSN Description
WAN	Wide Area Network
WFQ	Weighted Fair Queuing

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# 1. Executive Summary

The Intelligent Service Oriented Network Infrastructure (ISONI) consists of a modular management middleware layer hierarchical structured in domain and node level as presented in the ISONI whitepaper [8].

As presented in ISONI addressing schemes D7.1.1 [4] an application is running in a virtualised isolated context as a so-called Virtual Service Network (VSN). Beside computing and storage capabilities it provides connectivity between Service Components, realized by the ISONI eXchange Boxes (IXB).

Research has been conducted to extend the connectivity in order to make it QoS aware. The goal was to get explicit QoS guarantees like the state-of-the-art Integrated Services (IntServ) approach and having the scalability as in the case of the Differentiated Services (DiffServ) approach in addition. Ensuring QoS means that the network traffic across different Virtual Links does not influence each other as in opposite to normal DiffServ approaches providing statistical QoS. Therefore great importance has been given to scalability and manageability.

This document describes the final version of the Flow Control architecture. The Flow Control is part of the overall ISONI Path Manager functional entity as being described in more detail in Initial version of Path Manager D7.2.1 [5] and ISONI Whitepaper [8]. The deliverable at hand is based on the Initial version of the Flow Control Architecture D7.3.1 [6]. The outcome of this deliverable will be consumed inside the WP on Intelligent Networking and delivered as part of the integrated ISONI prototype D7.5.2 in July 2010 for integration into the IRMOS proof of concept demonstrator.

The main emphasis in the concluding stage of this work has been laid on the proof of concept realization of the flow control concepts developed within D7.3.1. Furthermore this final version contains architectural refinements and updates of node internal flow control management issues, which builds a fundamental basis for the developed flow control mechanisms.

The major task of the ISONI Flow Control is to police running ISONI services, i.e, following the instantiation of an IRMOS service on ISONI, the link-interfaces of the service need to be policed by the ISONI Flow Control, so as to prevent service traffic from interfering with one another , e.g. in case of a misbehaving Service Component.

In the context of this deliverable we especially investigated QoS (Quality of Service) related concepts and related issues such as traffic classification, traffic policing and flow shaping methods of the flow control concept. One target of the ISONI Flow Control Architecture was to base it upon existing network architectures. This means that it can be deployed in today's networks and use their advantages, such as e.g. MPLS (Multiprotocol Label Switching).

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Special attention was required regarding the question of QoS parameters vs. QoS classes. This question was driven with priority as it influences the northbound interface towards the IRMOS Framework Services. ISONI manages link resources that are classified in several ISONI-internal QoS classes. The purpose of this classification is to optimize the usage of the link resources owned by the ISONI. A service creator describes the required properties of the links by giving parameter sets comprising bandwidth, delay, jitter, etc within the VSN description. ISONI will map those parameters onto an ISONI-internal QoS class that provides the requested links with at least the QoS as specified in the VSN description. There are two major reasons for hiding the definition of QoS classes and to allow service creators to describe the link requirements in their VSN descriptions in terms of low-level parameter values.

Firstly, experience shows that there will be no common definitions of QoS classes for all possible ISONI Providers. Describing link properties in the VSN description in terms of QoS classes would force service creators to generate different VSN descriptions for different ISONI Providers.

Secondly, definition of an ISONI QoS class model relies on practice and feedback with the reoccurring necessity to redefine the QoS classes in order to improve resource usage within an ISONI Domain. By specifying the VSN with sustainable low-level parameter values, a VSN description needs not to be updated to mirror the change of QoS class definitions as would otherwise be the case.

Management of networking resources is an inevitable pre-condition for ensuring any real-time capabilities in respect to networking. This document elaborates which aspects need to be taken into account.

ISONI receives individual QoS parameters as input and ISONI assigns ISONI internal QoS classes to it. The main challenges and innovations in the development of the Flow Control Architecture, as presented in the deliverable at hand are:

- Sustaining individual QoS guarantees for co-existing service overlays on ISONI
- Sustaining these guarantees on a shared transport medium
- An application-unaware ISONI Flow Control concept
- A flexible ISONI internal QoS concept allowing network resource optimization.

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## 2. Introduction

This document details how networking real-time aspects are addressed and ensured within an Intelligent Service-Oriented Network Infrastructure (ISONI) beyond addressing and connectivity as introduced with D7.1.1 [4]. The ISONI-internal resource selection, reservation and deployment procedures performed by the ISONI Path Manager components are described in D7.2.1 [5]. This document extends the reservation process, availability reporting and ISONI path selection with regard to network performance control and refers to the involved components where applicable.

The document starts with an overview in chapter 3 that covers the ISONI boundary conditions for flow control, i.e. the network QoS requirements of interactive real-time multimedia application deployments specified in a Virtual Service Network Description (VSND) according to the formal description language for application requirements D6.1.1 [9] and introduces the transport QoS adaptation as established in the Path Manager framework for the simplified handling of technology-specific performance characteristics in a heterogeneous network infrastructure.

Chapter 4 shows how the ISONI uses traffic classification to categorize application interconnections into a generic ISONI QoS class overlay that can be individually adapted to the policy and infrastructure capabilities of an ISONI Provider. First, the motivation for a generic QoS annotation model is presented along with examples for different embodiments of the overlay. Subsequently, the mechanisms for scheduling, policing and flow shaping are introduced which can be selectively applied for the realization of a QoS class.

Chapter 5 describes in more detail how an overlaying ISONI QoS model can leverage traffic control mechanisms on existing transport networks by adapting the virtualized network environment to the provided transport QoS architecture. Furthermore, the segmentation of transport links into ISONI QoS classes is explained along with the related resource selection and resource availability principles.

Conclusively, chapter 6 depicts the incremental extensions of the ISONI functional building blocks to realize the dynamic QoS model overlay in an ISONI Domain. This section explains both, changes to the management building blocks as well as the changes required at the virtualization infrastructure to enforce a distinct QoS for a deployment. It has been extended how to manage the network resources inside a node and adapting transport network.

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## 2.1. Objectives

The ISONI Flow Control Architecture targets to prevent overstraining of the available network resources in an ISONI and to protect deployed services against possible misbehaviour of concurrently running deployments.

While contemporary traffic control mechanisms and QoS architectures apply to plain transport networks, the ISONI provides the creation of co-existing service overlays on a network infrastructure. Hence, the ISONI Flow Control Architecture is expected to provide an innovative solution to sustain individual QoS guarantees on a shared transport medium. The ISONI QoS Overlay Adaptation and in particular, the partitioning of a transport medium into several QoS ranges as presented in chapter 5.2 allows for the multiplexing of concurrently deployed virtual links on a single transport medium. Moreover, the partitioning explicitly allows for a concurrent deployment of virtual links with individual QoS requirements.

At the same time, the solution shall be independent from the applications that run in a specified service overlay, since individual treatment of application connections (sockets) is intuitionally expected to exhaust the acceptable additional load for traffic control in the infrastructure. The application-unaware resource admission isolation has been prepared by the introduction of Virtual Links (VL) [4] which subsume application connections of similar performance requirements for isolation against interference with other service overlays. Accordingly, the presented Flow Control Architecture adopts the concept of virtual links and prescribes their classification onto a domain-wide QoS class model. As a result, the architecture can preserve individual network performance guarantees per virtual link of a VSN without having to consider the application connection behaviour.

A major pain-point in network infrastructure configuration is the optimization of resource usage. The evolution of applications requires network operators to adapt existing QoS models to current application requirements. The Flow Control Architecture provides a flexible QoS concept that can be easily adapted to evolving requirements: The QoS classification of virtual links described in chapter 4.1 is a rule-based mapping of sustainable low-level network parameters (bandwidth, delay, jitter) onto ISONI Provider-specific QoS class models. Furthermore, the QoS class partitioning of transport network resources allows for individual traffic mix configurations at the transport interface-level of an ISONI.

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### 3. Overview

An Intelligent ISONI provides concurrent deployments of network-based applications with application components embedded in an isolated Virtual Service Network (VSN). The applications' performance requirements on the virtual interconnections of application components in a VSN are provided as meta-information in the VSND [9] and negotiated as part of the Technical Service Level Agreement (T-SLA) prior to deployment of the application. The ISONI Path Manager (PM) components, that share the full control over the virtualized network resources, support the creation of isolated address namespaces and need to validate and establish network reservations during resource reservation as explained in detail in D7.2.1 Initial version of Path Manager Architecture [5].

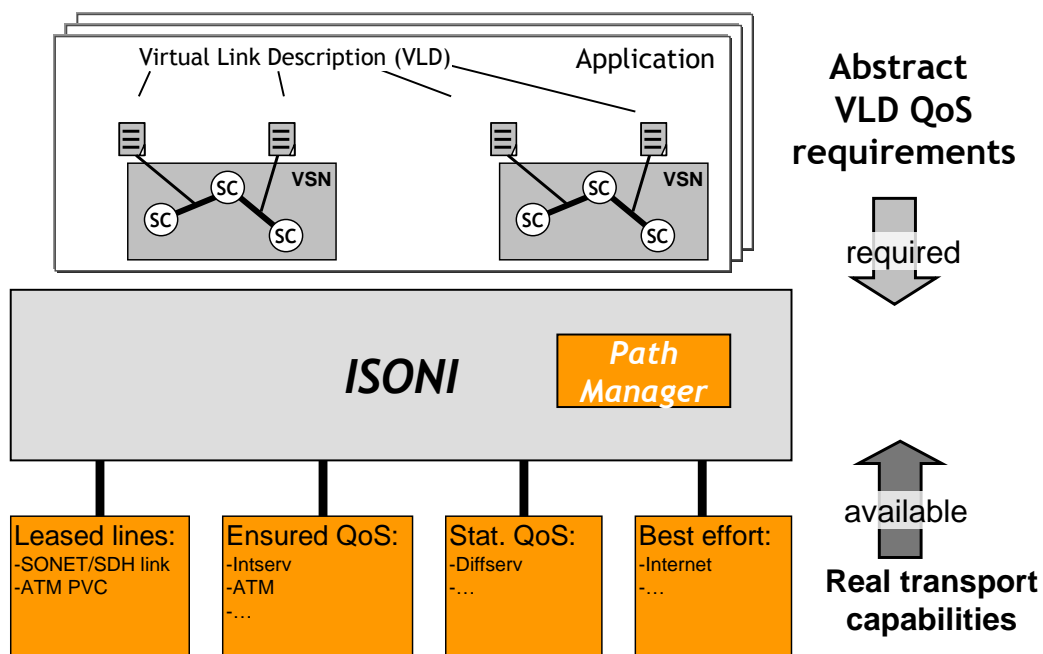


Figure 1 Mapping of VLD QoS requirements

For each VSN deployment, an ISONI has to select adequate transport network resource portions that ensure the Virtual Link Description (VLD) QoS requirements of the VSND to be met as indicated in Figure 1. The transport network resources managed by ISONI can be subdivided into four categories in respect to their QoS capabilities:

- Leased lines (like SONET/SDH links, ATM PVC ...)
- Networks with ensured QoS (like IntServ/MPLS or other connection oriented networks)
- Networks with statistical QoS (like DiffServ networks)
- Best effort (like the Internet)

A crucial task of the ISONI Path Management is to limit the extent of network resource usage by virtual links, both network resources between and within ISONI Nodes without impacting each other. Hence, resource admission control is carried out following the

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ISONI two-level architecture as introduced in [8]. The architecture defines Nodes as an aggregation of Physical Hosts (PHs) to enable a more efficient and light-weight domain-wide management. At the domain-level, the network-based application is classified using the ISONI Domain's QoS model, while at the node-level, flow control mechanisms are applied as required to sustain advertised capacities for a QoS class. The two-level hierarchical organization of management components alleviates the management complexity by letting each ISONI Node autonomously keep the individual QoS guarantees for deployed Virtual Links (VLs) of network based applications.

### 3.1. Network-based distributed application

A network-based application is a composition of software components interacting across networks and orchestrated to provide a customer with services that comprise particular workflows in the distributed application. With network-based application paradigms, such as SOA-enabled SaaS [25], the user experience strongly depends on the flawless interaction of the involved software modules in order to provide adequate response times for the provided service.

The software modules of a network-based application are grouped into Application Client Components (ACC), which provide the consumer interface and Application Service Components (ASC), which reside in the IRMOS platform to collectively perform the tasks requested by a consumer. Application Service Components (ASCs) create a network of services that often operate distributed across a network infrastructure to leverage multiple resources for the task execution.

The network-based application deployment model introduced by IRMOS arranges the planned execution of networks of services in an isolated Virtual Service Network (VSN) for a special purpose, limited in time, location and expansion. Application software modules with abilities to leverage network interface technologies would be grouped along with application logic software modules to define an ISONI Service Component (SC). Upon deployment, the SC is then realized as a Virtual Machine Unit (VMU) that can be run in the ISONI Execution Environment [10].

The real-time enabled applications of IRMOS are described in D4.1.1 [3], which are

- Digital Film Postproduction
- Virtual and Augmented reality
- Interactive real-time eLearning

The communication behaviour of a running VMU depends on the application software bundle, its projected employment and the purposed tasks. Regarding the combined traffic profile of message exchanges between software modules, an outline of the required network resource capabilities for a virtual link between two SCs can be sketched in terms of network parameters (i.e. bandwidth, delay, etc.). The enforcement of the negotiated network performance accounts for the network Quality of Service (QoS).

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Out of the IRMOS application scenarios, the following types of virtual link QoS are addressed:

- no QoS, i.e. links that are not real-time critical to the VSN's core tasks (e.g. customer profile logging).
- guaranteed minimal throughput, i.e. links that require a minimum bandwidth to let the VSN fulfil tasks in a given time.
- Delay- and jitter-critical, i.e. links used during multimedia content processing or user interaction requests that require a certain delay and jitter to meet application response times.

IRMOS applications require the ISONI to provide means for network provision reservations (NET-1) as outlined in the IRMOS Overall Architecture [2]. In particular, it shall be possible to negotiate the maximum jitter (NET-7), delay (NET-8), latency (NET-9) and a minimum throughput (NET-10) for streaming within the VSN. Therefore, the VSND meta-information model of the application uses virtual link (VL) interconnections between SCs / VMUs that can be annotated with the requirements on network resources. Deliverable D6.1.1 [9] describes this VSND meta-information model. The SC interconnections and QoS parameters - which are subject to this document - are described as Virtual Link Descriptions (VLD).

QoS-related VL parameters are:

- Maximum required bandwidth
- Minimum required granted bandwidth
- Maximum allowed delay
- Maximum allowed jitter

The maximum required bandwidth expresses the allowed bandwidth of a virtual link and should be based on the application's expected throughput on a particular SC interconnection in case that the application service network is utilized to the extent of the VSN deployment purpose. The application will never get more bandwidth and this maximum could theoretically be just achieved during runtime, when no other concurrent traffic is present. Usually the running applications do not self-restrict the resource usage and just operate on the available bandwidth.

The minimum required bandwidth is an optional parameter that would be specified for virtual links that sustain the liveliness of the provided services in the VSN. The throughput of the specified minimum bandwidth is ensured during lifetime of VSN, which allows applications to anticipate with a deterministic behaviour of network throughput dependent tasks.

Virtual links that are crucial to the real-time execution of provided services in such a way that the process finishing time depends on the quality of the SC interconnection, can be further marked with a maximum allowed delay and maximum allowed jitter.

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## 3.2. Transport QoS adaptation

The ISONI concept follows the principle of managed resources, which postulates the planning of network resources. As laid out in D7.2.1 [5], the ISONI Path Manager Architecture subsumes all network-related tasks of a managed network infrastructure to isolate concurrently running real-time services on a common infrastructure. As such, the ISONI Path Manager provides network resource related query, selection and required configurations. In order to also sustain individual guarantees and prevent interference among service components of these isolated networks, the utilization of available transport network resources needs to be regulated.

The availability of transport network resources has to be reported to the Path Manager Domain (PM<sub>D</sub>) so that the domain level is able to select concrete network paths for the deployment process. The domain level just wants to make a decision based upon simplified and normalized performance characteristics. Therefore the domain level has not to know about the used transport network technology. This can be reached by a generalisation or abstraction of the diverse transport networks. Therefore the ISONI QoS Overlay Adaptation (IQOA) is introduced.

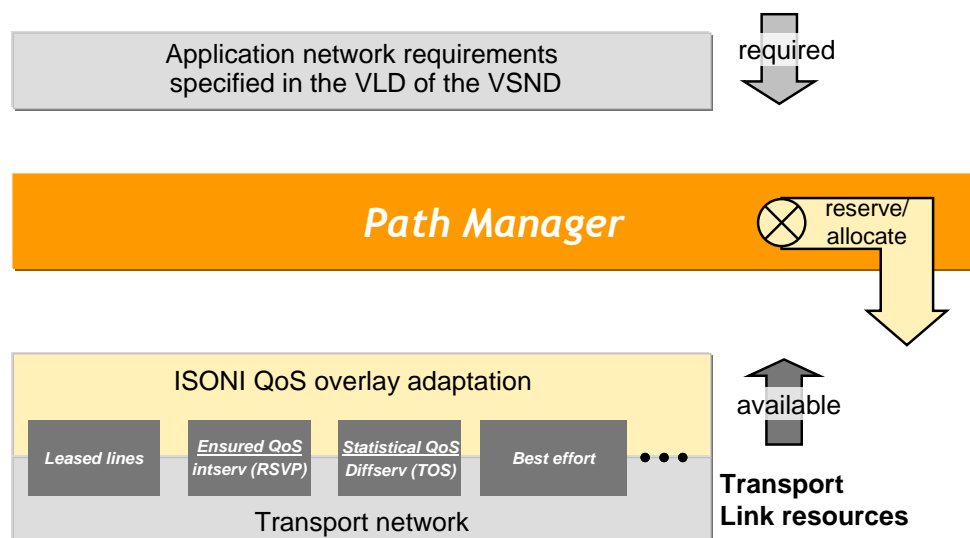


Figure 2 Network resource reservation (abstract view)

Figure 2 shows the Path Manager introduced in D7.2.1 [5] as managing instance during the reservation process responsible to reserve/allocate network resources. It depicts the formal networking requirements of the application provided in the Virtual Link Description (VLD) and most importantly, the ISONI QoS overlay adaptation that concludes the deduced availability to be reported from the employed network resources, such as leased lines, IntServ networks, etc. The responsibility of the Path Manager is to make reservations/allocations adequate to the VLDs which subsequently translate to specific capacity allocations of the networking resources.

The following chapters elaborate on how the requirements for individual VSN deployments are beaked down to different transport networks abstracted by ISONI QoS Overlay Adaptation (IQOA) layer.

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## 4. Traffic control

The ISONI Flow Control Architecture adopts the Differentiated Services (DiffServ) principles for the adaptive ISONI domain-wide traffic control model, since DiffServ scales very well and deals similar to ISONI with aggregated traffic. The intention of the ISONI approach is to be agnostic to application-individual connections. Instead, ISONI treats application traffic in bundles (virtual links). Any application connection individual approach would cause scalability problems as in the IntServ architecture [18], since state information for each reservation needs to be maintained at every network element along the network path. As explained in D7.1.1 ISONI Addressing Schemes [4], virtual traffic is transported on a packet-based, routable network infrastructure. The reach of an ISONI Domain's traffic control is limited by the possibilities of the ISONI Provider to establish traffic control mechanisms on the routable network layer, i.e. the ISONI-external transport network services. Towards the ISONI Service Components, traffic control is limited at the point of delivery, i.e. the virtualization layer of the Execution Environment. Towards ISONI-external endpoints (e.g. Application Client Component - ACC, external Service Component - eSC), the boundary of the QoS-ensured region is the ISONI edge. Besides, an ISONI Domain can leverage resource reservation mechanisms offered by the transport network provider to extend the reach of traffic control. Those mechanisms applied to adapt the ISONI traffic control model to the ISONI architecture are further described in chapter 6 while the following sub-chapters concentrate on the selected mechanisms for traffic control.

### 4.1. Traffic classification

The IRMOS project competes against WAN area best-effort networks providing some kind of real-time guarantees. The Internet just provides best-effort service, i.e. no guarantees. Two opposing approaches have been created by the IETF for adding enhanced network services to the Internet in reaction of the increasing necessity for network guarantees. On the one hand there is the Integrated Services (IntServ) approach [17], which limits the demand per network connection and reserves the resources to meet the QoS. IntServ provides end-to-end QoS but requires keeping states per connection and an individual reservation per connection to ensure QoS in respect to delay, jitter and throughput, and hence does not scale well due to the required context handling per connection. In addition the reservation per connection requires a reservation protocol (RSVP) [16], which is an additional overhead for the application in respect to time and complexity. On the other hand there is the Differentiated Services (DiffServ) approach [13], which classifies traffic in groups, i.e. it allows class-based handling of aggregated connections. The DiffServ approach scales, but it does not provide absolute QoS guarantees, since it does not reserve any network resources. The goal of ISONI is to have both the scalability and absolute QoS guarantees.

The solution shall

- Be scalable by dealing with aggregated traffic and not individual connections
- Ensure QoS by managing capacity reservations
- Avoid run-time application overheads of a reservation protocol

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### 4.1.1. Introduction

The VSN specifies the connectivity requirements among ISONI SCs in form of Virtual Links (VL). The Virtual Link Description (VLD) contains the network requirement details as mentioned before.

An extension to normal best-effort traffic is the best-effort with granted minimum bandwidth. This allows applications to rely on a certain throughput – e.g. a data transfer task could be finished by a given time. This approximates a more deterministic behaviour in favour of real-time characteristics. A system providing best-effort with an ensured minimum bandwidth can already be denoted as networking real-time capable system. For an improved certainty on the application throughput normally associated with the term real-time, other values are implicated in addition - delay and jitter, which are commonly known in the context of audio and video streams. In this chapter, we apply the term real-time on link behaviour with delay and jitter constraints, but underline the fact that also granted minimum bandwidth for best effort is an IRMOS feature, which belongs to real-time systems.

How does ISONI fulfil these requirements?

To start with, bandwidth requirements are simply covered by managing the bandwidth on the network interfaces. Later on this will be elaborated further.

As said, real-time traffic (e.g. video) is characterized mainly by additional requirements in respect to delay and jitter. However, the loss rate is not reflected in the QoS class model, since ISONI implicitly takes care that the real-time traffic befalls a certain level of maximum loss rate by traffic prioritisation. Jitter and loss rate cannot be chosen independently. The jitter goes along with a certain loss rate, since the highest priority traffic receives automatically the lowest jitter and lowest packet loss. In ISONI it has been decided to specify just the jitter, which is correlated with a certain priority. And a minimum loss rate is reached by managing the network traffic anyway.

Delay constraints are mainly met by an appropriate placement of the VMUs, which is done in a first stage by Resource Manager Domain -  $RM_D$  (D6.1.2 [10]) and then confirmed by Path Manager Domain -  $PM_D$ . The entire scenario is described in chapter 6.

Dedicated jitter and loss rate guarantees are translated into prioritisation of concurrent VL network traffic. The problem is that each later deployment of another VSN changes the assumptions made during the previous deployment. So it is impossible to treat the QoS requirements individually. ISONI preserves link capacities for certain categories of VL QoS with individual scheduling behaviours in advance. ISONI introduces therefore ISONI QoS classes, which are described in next chapter.

### 4.1.2. ISONI QoS classes

The usage of ISONI QoS classes has been prepared in the functional building blocks of the ISONI architecture as of D7.2.1 [5]. The ISONI SLA Manager assigns an ISONI QoS class to each VL. This class depends on the adequate scheduling and forwarding behaviour strategy followed within this ISONI Domain. The ISONI QoS classes represent

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the abstract behaviour that persists across the ISONI Domain. The ISONI QoS classification avoids the burden of dealing with the QoS low-level parameter of each flow individually and enables to have enough space for later concurrent deployments.

The idea here is that before any VSN is deployed on ISONI, the network scheduling on IXBs and the network resources are planned in advance in correlation with the ISONI QoS classes. The benefits are manifold:

- Jitter and loss rate requirements shall be covered already with the network resource planning, which is already done during setup of network resources establishing QoS class in conjunction with Path-IDs. Just with the ISONI QoS assignment of the SLA Manager, the jitter and loss rate requirements are satisfied as long as the needed bandwidth is available. (explained in chapter 4.2)
- VL with different assigned QoS classes can follow different network paths/networks. This allows the usage of expensive leased lines e.g. especially for real-time traffic whereas the best effort traffic is leaded e.g. via the Internet. So network resources are used conservatively.
- The selection of network paths on Path Manager Domain level is reduced to match the available reported network capacity based on ISONI QoS classes against the QoS class assignment done by SLA Manager. This effort is reduced to a very simple algorithm. (D7.2.1 already describes the availability reporting by using ISONI QoS classes and the QoS class assignment done by SLA Manager)
- It combines a very efficient degree of network capacity utilisation with easy management and planning flexibility for the ISONI Provider. New network capacity can be easily added.

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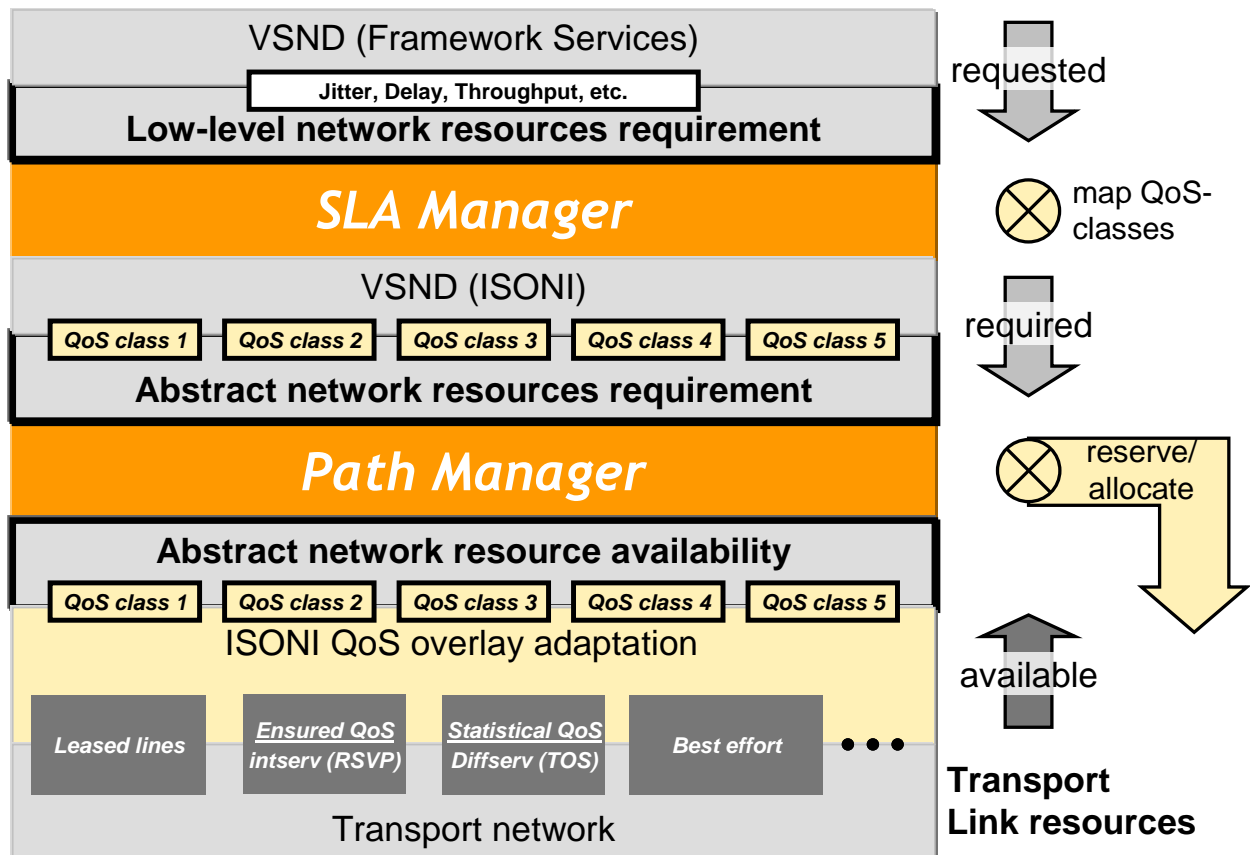


Figure 3 ISONI QoS classification

Figure 3 indicates the extension brought in by ISONI QoS classes, which means the classification of available network resources by the IQOA and the assignment of adequate QoS classes during negotiation process. When new VSNs are deployed, the network resource reservation is based on a simple algorithm matching the VL assigned QoS classes against QoS related available network resources.

The Path Manager acts on two levels, the domain and the node level. The network resources are under the responsibility of the node level, which updates the domain level about changed network resource availabilities. The node internal treatment and the reporting to domain level are based on ISONI QoS classes.

#### 4.1.3. Domain individual QoS classes

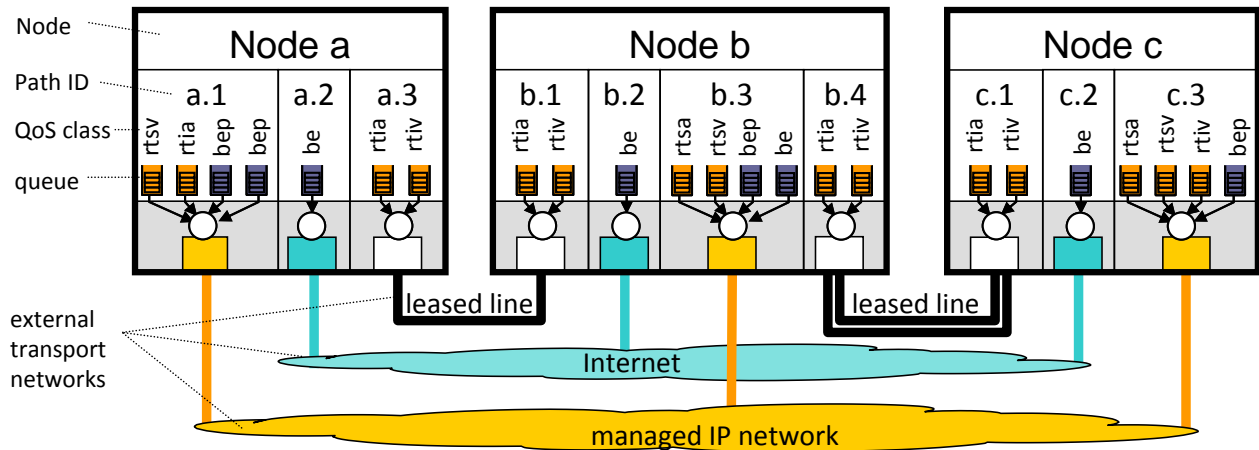
Each ISONI Domain may have its own set of ISONI QoS classes. Below, several examples are given demonstrating the flexibility of the ISONI approach. The ISONI QoS class concept allows adapting to the ISONI operator's wishes.

Example1: ISONI Domain with fine-grained QoS treatment strategy by defining a large set of ISONI QoS classes:

- Best-effort (be)
- Best-effort with granted bandwidth (bep)
- Real-time streaming audio (rtsa) – low bandwidth, high delay
- Real-time streaming video (rtsv) – high bandwidth, high delay

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- Real-time interactive audio (rtia) – low bandwidth, low delay
- Real-time interactive video (rtiv) - high bandwidth, low delay



**Figure 4 Example: QoS class concept fine-grained ISONI**

Example 2: ISONI Domain with fine-grained QoS treatment strategy by defining a medium set of ISONI QoS classes:

- Best-effort
- Best-effort with granted bandwidth
- Real-time streaming – low delay
- Real-time interactive – high delay

Example 3: ISONI Domain with customer price QoS treatment strategy by defining additional business case oriented set of ISONI QoS classes:

- Best-effort
- Best-effort with granted bandwidth (Silver)
- Best-effort with granted bandwidth (Gold) for good paying customer
- Real-time (Silver)
- Real-time (Gold) for good paying customer

Example 4: ISONI Domain with coarse-grained QoS treatment strategy by defining just a small set of ISONI QoS classes:

- Best-effort (be)
- Best-effort with granted bandwidth (bep)
- Real-time (rt)

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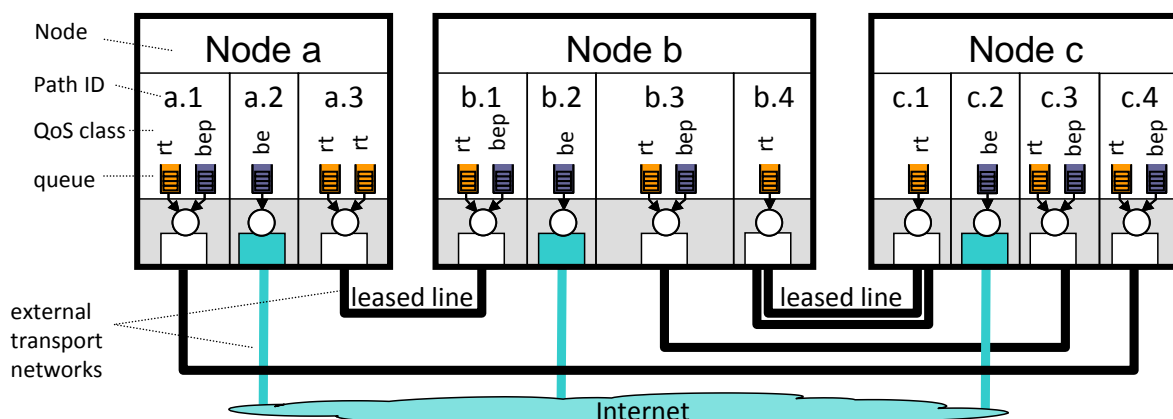


Figure 5 Example: QoS class concept coarse-grained ISONI

Note: A small set of QoS classes does not mean that an ISONI Domain with coarse-grained QoS classes provide less QoS for the individual VLs.

ISONI QoS classes allow the ISONI Provider to adjust the packet scheduling priority and the path within the ISONI Domain. Exclusive treatment of traffic e.g. from good paying customer may also causes additional ISONI QoS classes.

As recognisable from the examples above, the amount of QoS classes are caused by operator's strategy in respect to technical aspects like prioritisation, network path selection and customer service creation.

## 4.2. QoS class scheduling

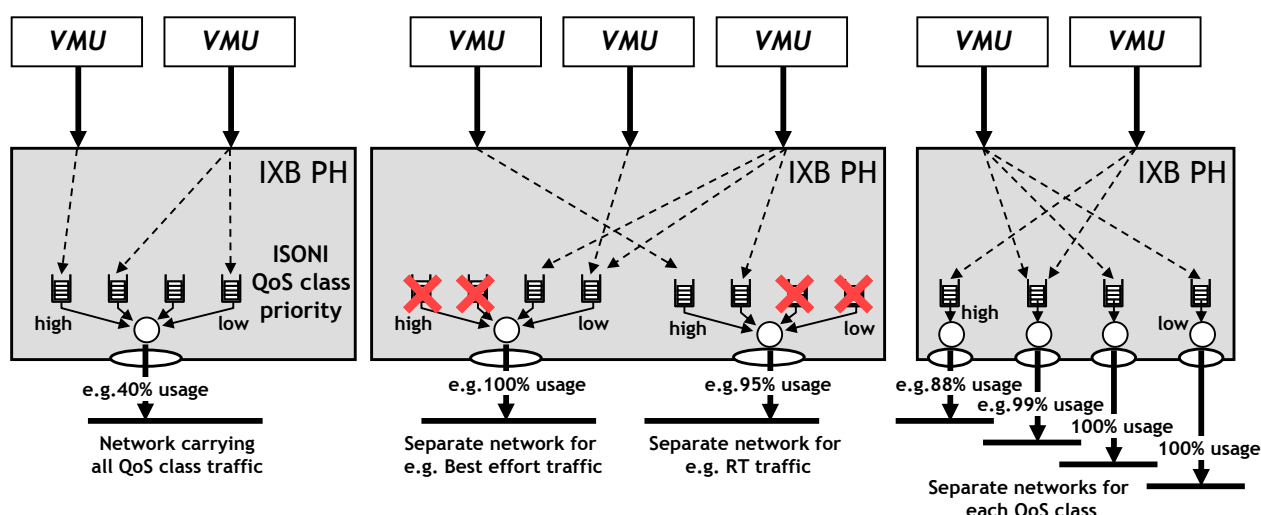


Figure 6 Network scheduling - IXB<sub>PH</sub> outgoing/egress - 4 QoS classes

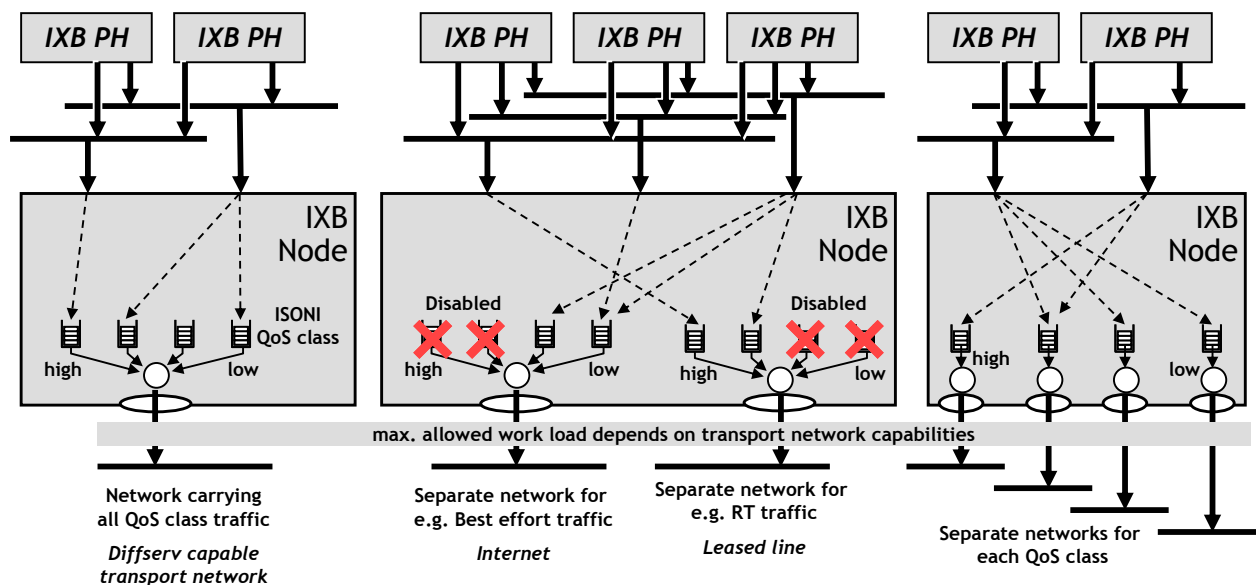
Network scheduling is needed to get deterministic behaviour of prioritized network traffic in respect to reliability, delay, jitter or throughput. By using prioritized scheduling the highest priority traffic receives the lowest jitter and lowest packet loss. The deterministic behaviour is reached by knowing (since it is managed) the amount of concurrent traffic. The limitation of the amount of traffic of same or higher priority level

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allows predicting the maximum jitter caused by concurrent traffic. Just classification as in DiffServ is not sufficient, so in addition it is important that the amount of concurrent traffic is well known, which allows ISONI to make deterministic predictions.

Traffic budgets are just needed in case of multiplexing egress<sup>1</sup> traffic of different QoS levels per interface. Figure 6 shows three scheduling examples of outgoing egress traffic in the case of using 4 QoS classes. The ISONI Node internal realization of QoS traffic treatment may differ from the depicted cases. On the left side (Figure 6) all kind of VMU traffic is interleaved together and carried over one network. In this case the usage of the physical link is expected to be lower (in the figure e.g. 40% ensuring QoS by some kind of over-provisioning), since the workload depends strongly upon ensuring the classified VL requirements. Depending on the traffic mix the total workload of allowed VMU traffic is limited for maintaining the guaranteed QoS. In the middle (Figure 6) the VMU traffic is treated according the QoS class over different networks. Separating best effort from real-time traffic allows higher total allowed workload resulting in a higher degree of efficiency of the used network resources. On the right side (Figure 6) the traffic of each ISONI QoS class is treated over separate physical networks. This case eases the scheduling, but waste resources. Also multiple networks or bonded network interfaces can be used to extend the capacity for intra-node traffic. For a reaching a good load factor of the transport network interfaces rather a separation of the network traffic according to the QoS classes shall be preferred.

Same applies also to the IXB Node (IXB<sub>N</sub>) level as shown in Figure 7.



**Figure 7 Network scheduling – IXB<sub>N</sub> outgoing/egress – 4 QoS classes**

Fouad A. Tobagi has analysed in several papers that total amount of workload maintaining the QoS depends on the mixing of traffic types. He has evaluated [24] the mix of audio, video and data traffic for 10Base-T, 100Base-T amongst others:

<sup>1</sup> “outgoing/egress“ denotes sent traffic (outgoing interfaces) leaving the ISONI Node (egress)

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If voice was given its own QoS class, then real-time video could still be accommodated in the best effort class, if buffers are reasonably sized and average utilization remains below 80%. However, mixing real-time video traffic with real-time voice proves to be more appropriate since, in this case they can together utilize more than 95% of the link bandwidth. However, for 10Base-T, variable bit rate video traffic should be separated from constant bit rate and voice, as well as QoS traffic which should also be separated from best effort traffic. Finally, in the case of small links bandwidth, a significantly higher throughput could be achieved when each traffic type is mapped to its own traffic class. Tobagi also has concluded that in case of higher link bandwidth less QoS classes are needed.

This kind of separation is obtained by using different ISONI QoS classes. It is recommended that at least real-time traffic is separated from best-effort traffic getting at least two ISONI QoS classes. Other reasons for additional QoS classes have been given above. It is the task of ISONI Provider to decide, which ISONI QoS class strategy has to be followed in the ISONI Domain. The ISONI Node manufacturer shall provide the equipment so that the ISONI operator is able to do so.

Adding new QoS classes to an existing used set of QoS classes is possible, but may cause heavy impact on traffic management and planning throughout the ISONI Domain with regard to network scheduling and transport network adaptation described in chapter 5.1 (a new partitioning of network interfaces). A new QoS class has to be covered by the resource availability reporting from node-level towards the domain-level and has to be incorporated into the domain-level correlation table. As described in D7.2.1 [5] the correlation table allows the PM<sub>D</sub> to select a network path for a virtual link as a chain of two or more Path-IDs, which have enough network resource capacity in conjunction with the adequate QoS class available.

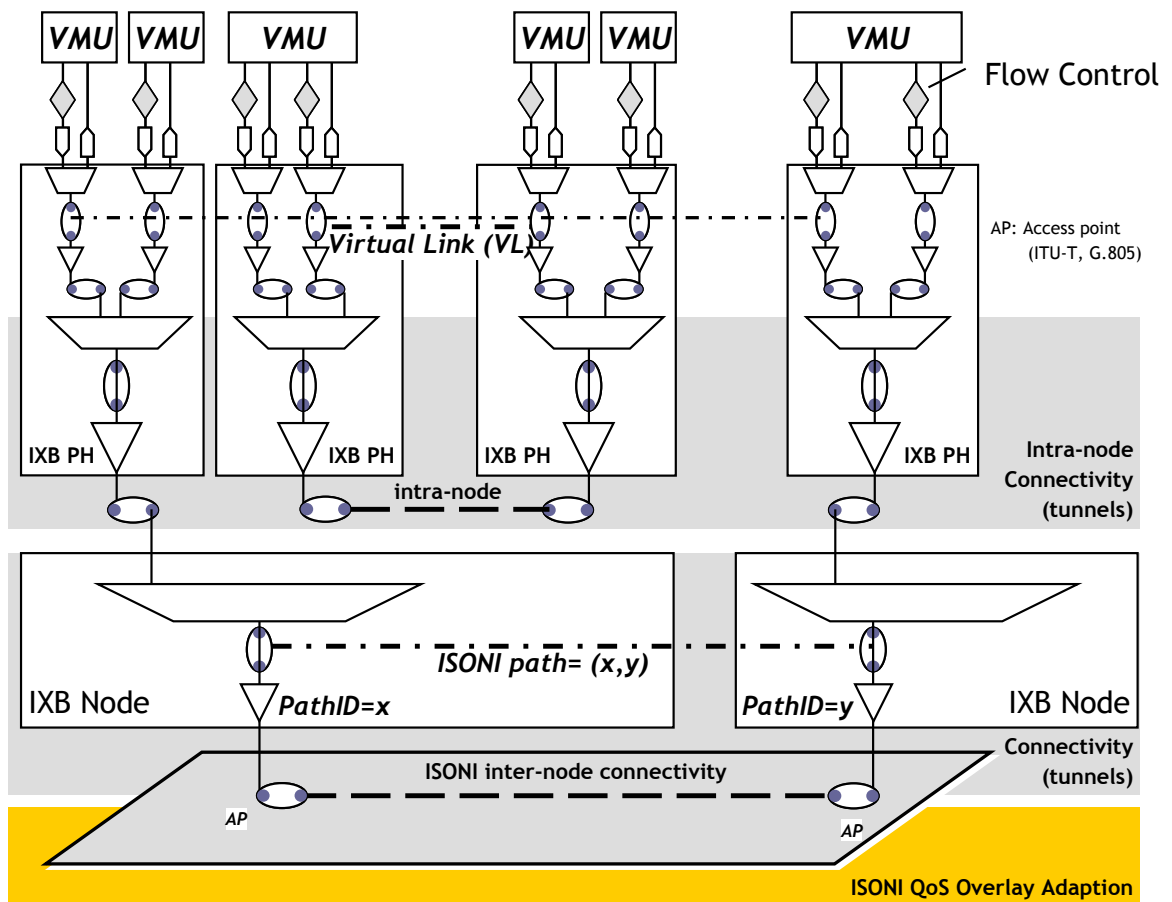
### 4.3. Bandwidth policing

As introduced above the ISONI QoS treatments according ISONI QoS classes adopts the Differentiated Services (DiffServ) principles of aggregated traffic. The packets from different VMUs belonging to the same ISONI QoS class are treated on IXB<sub>PH</sub> and IXB<sub>N</sub> commonly (aggregated). A VL contains a multiplicity of individual flows. ISONI scales well like the DiffServ approach. In addition ISONI ensures QoS by managing the aggregated traffic flows based on the requirements of VLD. To avoid interferences among individual VL traffic sharing the same physical network resources, the traffic of each virtual link is policed by ISONI Flow Control. Policing applies to all entry points ensuring that the packet scheduling layer IXB<sub>PH</sub> and IXB<sub>N</sub> will not be overloaded. A gapless policing ensures that the IXB multiplex stages always get a controlled load of traffic. Therefore bandwidth policing is an essential precondition for ISONI to ensure QoS for the individual VLs.

Entry points are:

- VMU egress traffic (indicated in Figure 8)
- External public traffic via ISONI Point-of-Presence (POP) (indicated in Figure 9)

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**Figure 8 Flow Control within ISONI**

Figure 8 and Figure 9 show simplified ISONI multiplex hierarchies from VMU level down to ISONI QoS Overlay Adaptation layer (IQOA), which hides the access to heterogeneous transport networks as describe in chapter 5.1 in more detail. The exchange points for public VMU traffic called Point-of-Presence (PoP) are introduced in D7.1.1 [4]. The figures use the G.805: Generic functional architecture of transport networks syntax [21].

The flow control of the VMU individual network traffic is done before it needs to be multiplexed with network traffic of other VMUs. The ISONI Flow Control for outgoing traffic can be done inside a VMU for the egress traffic or on IXB PH for the ingress traffic. Doing Flow Control inside a VMU has the advantage that for application using IP stack in blocking mode gets automatically back pressure, so that the maximum allowed bandwidth is not exceeded. In all other cases, the Flow Control policer will drop packets exceeding the maximum allowed bandwidth.

Note: Outgoing/incoming indicates the traffic leaving/entering an ISONI node  
Egress/ingress indicates the traffic transmitting/receiving by an IXB or VMU.

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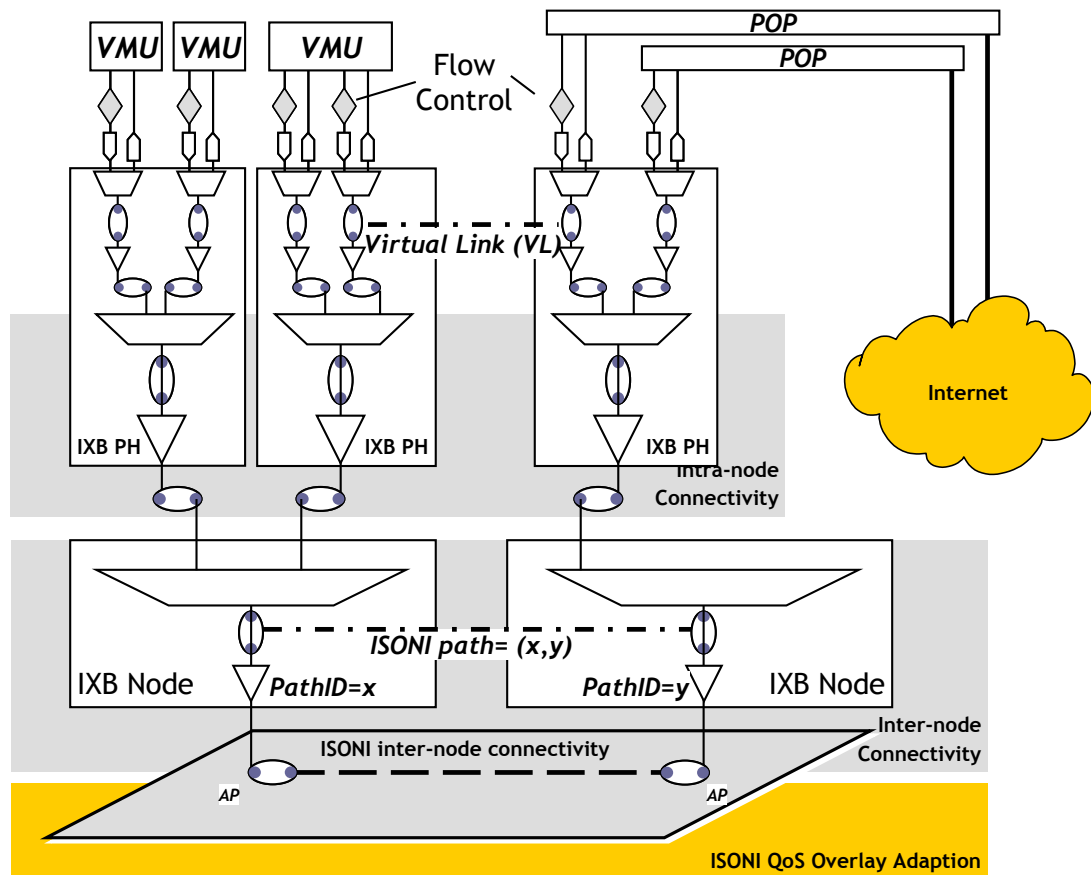


Figure 9 Flow Control for public IP traffic

## 4.4. Flow shaping

Shaping is an additional mechanism of delaying packets within a packet stream to get it conform to a dedicated traffic profile thus improving overall utilization. Figure 10 shows an example of a single video (MPEG2) traffic flow. The coder generates a very uneven packet output. This bursty traffic may cause dropping of packets in later multiplex sections, if the buffers of multiplexer are overloaded. Bursty traffic is characterized by a peak bandwidth much higher than the average bandwidth. To avoid packet drops the peak bandwidth needs to be granted, which wastes network resources. Shaping helps to reduce the needed granted maximum bandwidth to a passable rate.

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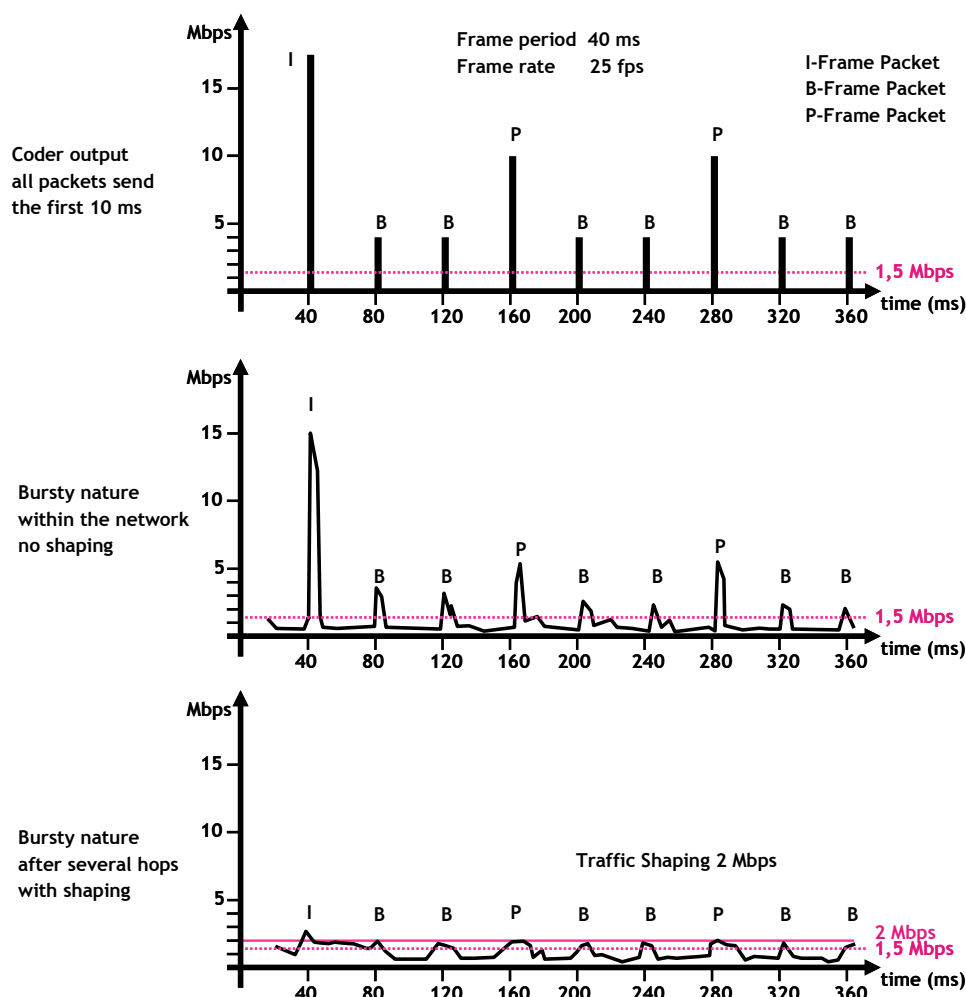


Figure 10 Shaping example of one video flow (MPEG2-1,5 Mbps)

An ISONI Provider may offer a better service to its customer by providing dedicated ISONI QoS classes with additional flow shaping capabilities. Especially bursty real-time applications like variable bit rate video streams may benefit from this additional flow shaping. It may prevent packet loss of egress VMU Flow Control in case of non-blocking IP stack or in case of IXB side Flow Control as outlined in chapter before. Opposite to the usual shaping, the ISONI shapes the aggregated traffic of a VL and not individual application flows inside a VL. The shaping of individual application connections is just a special case of a VL just carrying one application connection.

Possible shaping points:

- VMU egress traffic (indicated in Figure 8)
- External public traffic via ISONI Point-of-Presence (POP) (indicated in Figure 9)

## 4.5. Virtual isolation for QoS

The traffic is carried isolated as described in D7.1.1 [4], which provides just isolation in terms of connectivity. The temporal traffic isolation among VMUs may be treated by several multiplex stages consisting of IXB Nodes and IXB Physical Hosts, which may carry concurrent traffic of other VSNs. IRMOS is formed up to provide also QoS isolation

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by means that concurrent traffic of later deployed VSNs does not impact given guarantees of already deployed VSNs. The ISONI isolation is performed as follows.

First, the ISONI keeps track of all reserved resources requested by each VSN deployment. ISONI refuses any deployment, whose QoS requirements cannot be ensured.

Second, ISONI will police all traffic ensuring that the multiplex stages carrying VMU traffic are not overloaded, so that different VLs cannot impact each other.

Third, ISONI is able to schedule real-time network traffic with higher priority than best-effort traffic at these multiplex sections, which belong to the ISONI ensuring jitter and low packet loss. Each ISONI Provider may extend this scheduling priority levels.

ISONI is an overlay on top of heterogeneous transport networks, which is able to adapt different transport network and is able to lead traffic with different QoS requirements over different network paths. Details about the adaptation of the transport network are further described in chapter 5.

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## 5. Transport network abstraction

The ISONI QoS classes abstract from transport-specific traffic handling to partition the infrastructure into a generalized QoS conception. This chapter explains in more detail how the QoS classes adapt to various types of transport networks and further discusses the partitioning of network interfaces as well as the inclusion of additional network interfaces into the managed infrastructure.

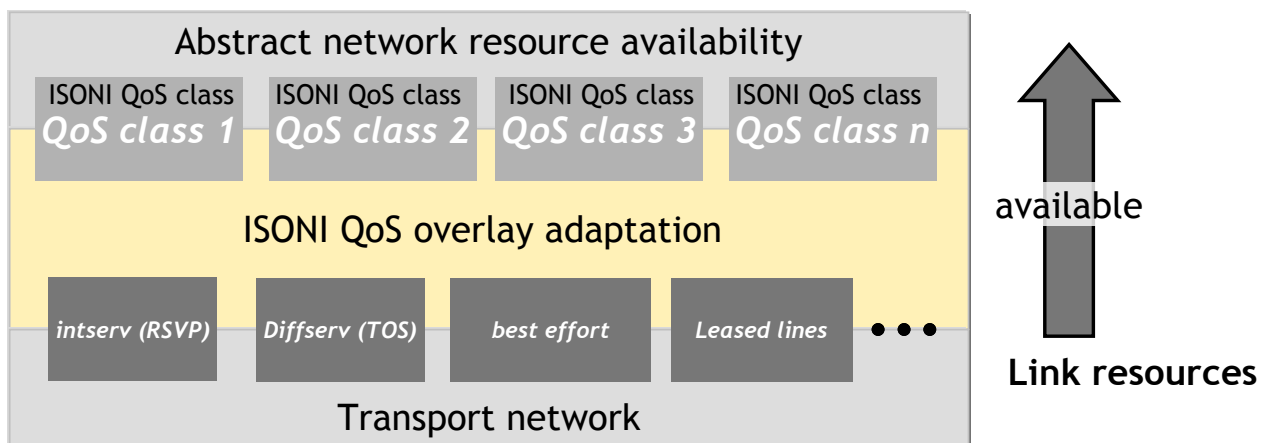


Figure 11 ISONI QoS Overlay Adaptation (IQOA)

### 5.1. Transport network QoS adaptation

The ISONI QoS Overlay Adaptation (IQOA) layer evens out the different transport network capabilities. As said, the abstraction is required for a generalized reporting of network resource availabilities in the Path Manager architecture and in an opposite manner, the translation and realization of a deployment's QoS constraints on the network virtualization layer. This chapter describes the adaptation between the abstraction and the real interfaces of certain types of transport networks.

In general the transport networks can be categorized into main types:

- Leased lines (e.g. ATM virtual circuit, SDH)
- Transport network not providing any QoS mechanisms (e.g. Internet)
- Transport network providing soft QoS (e.g. DiffServ)
- Transport network providing hard QoS (e.g. IntServ, MPLS-TE based, ...)

There are also some approaches mixing e.g. IntServ with DiffServ, which can be adapted by IQOA as well.

#### 5.1.1. Adaptation for leased lines

Leased line adaptation does not require any special adaptation by the IQOA layer. The tunnel itself provides the needed separation of VMU traffic if several VLs with different ISONI QoS classes share the same leased lines. Leased lines represent the usual and simplest way for providing real-time QoS and/or granted bandwidth.

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### 5.1.2. Adaptation for best effort network like Internet

Best-effort network adaptation does not require any special mechanism by the IQOA layer. It is quite obvious that for such interfaces just an ISONI best-effort QoS class can be assigned. Although network access interfaces run at a specified capacity, the traffic transmitted across a best-effort may spontaneously face network congestion at various points in the network backbone. The availability of an ISONI best-effort transition across a wide area network may be chosen according to the access capabilities, knowing that it can only operate at a best-effort quality across the shared public network.

### 5.1.3. Adaptation for networks providing soft QoS

For transport networks providing statistical QoS, DiffServ-designed networks deserve a particular notion here. Differentiated Services classification uses the ToS Byte of the IP protocol as shown in Table 1. IQOA maps an ISONI QoS class to a compatible DSCP or to one of the DSCP reserved for local use.

**Table 1 History of the IP ToS Byte**

7	6	5	4	3	2	1	0	Description				
precedence	D	T	R	0	0	0	0	RFC 791 Internet Protocol precedence: (7) NW control, (6) Internw control, (6) CRITIC/ECP, (4) Flash override, (3) Flash, (2) Immediate, (1) Priority, (0) Routine				
precedence	D	T	R	M	0	0	0	RFC 1349 Type of Service in the Internet Protocol Suite <i>outdated as per RFC3260</i>				
class selector	0	0	0	CU	0	0	0	RFC2474 Differentiated Services Field (6+2bit „currently unused“)				
local/future use	1	0	1					1	1	1	1	1) Class Selector + 3bit Zero / compatibility to precedence RFC791
local use	1	0	1					1	1	1	1	2) local / experimental use (maybe assigned in future)
0	0	0	0					0	0	0	0	3) local / experimental use
DiffServ PHB	0	0	0					0	0	0	0	4) Default PerHopBehaviour all zero
								5) DiffServ PHB + 1bit zero				
DSCP						ECT	CE	Explicit Congestion Notification				
						ECN		RFC2481 ECT (ECN-capable transport) + CE (congestion experienced) RFC3168 (0) Non-ECN capable, (1) ECT-1, (2) ECT-0, (3) Cong. Exp.				
Assured Forw. class 1-4	drop precedence	0	0	0	0	0	0	ECN	DiffServ PHB: RFC2597 Assured Forwarding 4 classes (3bit), 3 drop precedence levels (2bit)			
1	0	1	1	1	0	0	0	ECN	DiffServ PHB: RFC2598/RFC3246 Expedited Forwarding			

The exact usage of the ToS Byte depends on the capabilities and the SLA contract of the utilized transport network. The IQOA marks the ToS Byte of outgoing VMU traffic for the individual transport networks according to the ISONI QoS classes. The mapping rules are specified along with the interface apportionment for the different ISONI QoS classes.

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### 5.1.4. Adaptation for networks providing hard QoS

Among transport networks for hard QoS provision, shared networks with explicit signalling for the establishment of connections with guaranteed transmission QoS, such as IntServ, deserve a particular notion here. Within ISONI, each VL is realized as an individual tunnel among the IXB<sub>NS</sub>. For each newly deployed VL the QoS is requested by the IntServ capable network by using the RSVP [16] protocol. Availability reporting uses the contractual maximum of resources that can be requested from an IntServ-enabled path. The QoS-segmentation and the available capacities that may be requested from the transport provider are contained in the static SLA contract between the ISONI Provider and the ISP.

Since an ISONI VL tunnel already aggregates application connections between the components of VMUs, the RSVP request procedure is necessary at the deployment time only, which mitigates the scalability problem of IntServ transport networks.

## 5.2. QoS class partitioning of transport interfaces

The allowed amount of traffic for each adapted transport network interface in correlation with the ISONI QoS classes is specified by Operation and Maintenance (OAM). The segmentation depends on the QoS capabilities provided by connected transport network. Figure 12 shows some examples how the bandwidth of a physical/bonded network interface could be partitioned for ISONI QoS class usage. On the one hand, it specifies which QoS classes a physical/bonded interface is able to carry in general. The assignable QoS classes depend on transport network capabilities settled in the contract with the transport network provider. On the other hand, a maximum usable bandwidth for each QoS class is specified as a fraction of the interface bandwidth to be used for later reservations. The QoS class fractions could be exclusive portions, partly overlapping, shared fractions (unions) or any other constellation. It depends on the chosen QoS treatment strategy of the ISONI Provider and the capability of concurrent classified VL traffic.

Case a) shows the exclusive reservation for each of the four QoS classes. Case b), c) and d) show shared unions for QoS 1+2 and QoS 3+4, i.e. the specified bandwidth portion can be used together by the correlated QoS classes. Case d) also shows that the interface is restricted to the use of QoS class 1 and 2 only. Please note, that these portions specify the limitations on QoS classes and bandwidth for VSN reservations on this transport interface, which is configured by the ISONI Provider when being put into service for virtual traffic.

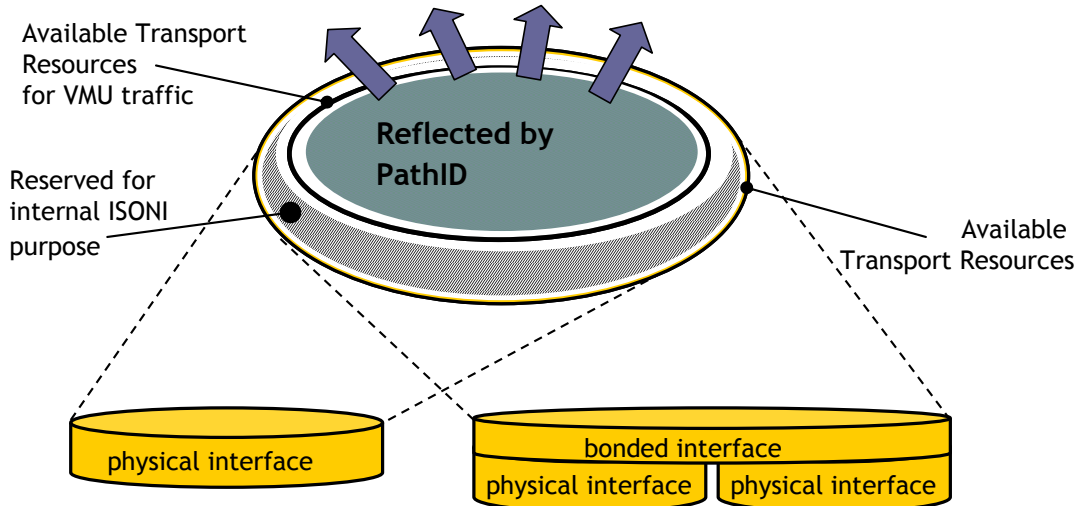
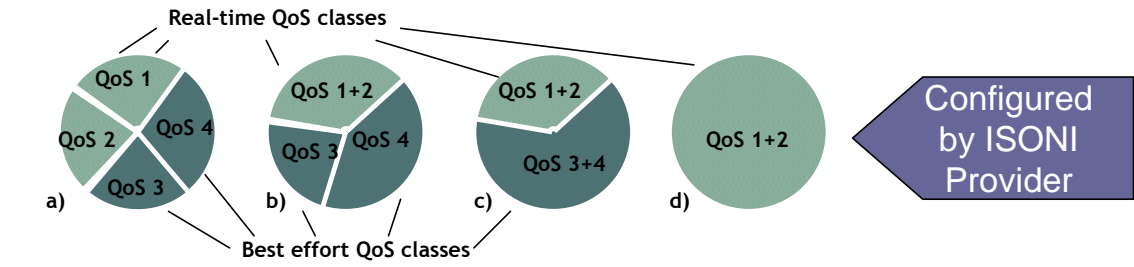


Figure 12 ISONI QoS Overlay Adaptation (IQOA)

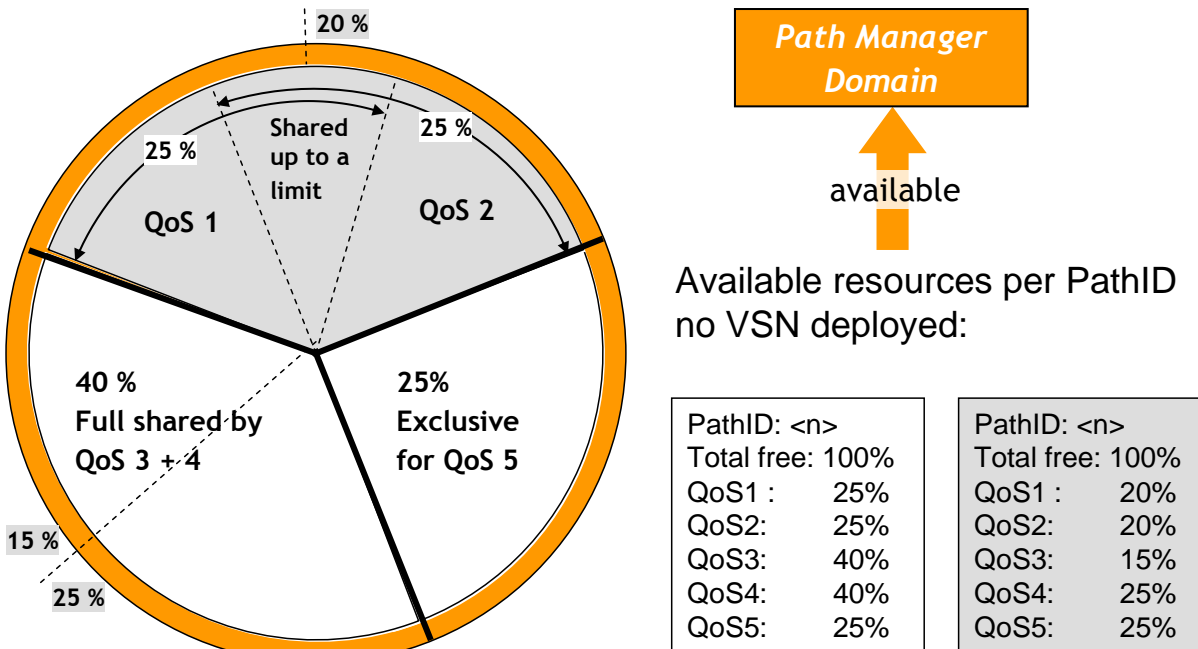


Figure 13 ISONI availability reporting using QoS classes

Figure 13 shows an example for five ISONI QoS classes. QoS class 1 and 2 share bandwidth each up to a certain limit. QoS classes 3 and 4 shares its portion of bandwidth completely and QoS class 5 has an exclusive portion of bandwidth available. Figure 13 just reflects the concept by showing percentages, but the availability report as

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introduced in D7.2.1 [5] contains the absolute values of free network resources. If capacity portions are shared, it may occur that the sum of QoS individual free network resources is higher than the total free available bandwidth. Interface bonding can be either used to extend the capacity of a Path-ID or to improve reliability with implicit seamless redundancy. In the latter case, the ISONI Provider would choose to report just half of the available capacity on the bonded resource to the domain level. The remaining network resources are kept for outage cases of one of the physical interfaces. It is up to the individual ISONI Node, in which way the QoS class related available resources are reported. The figure gives two different examples, how the available network resources are reported. The right hand side (grey box) is more restrictive in reporting QoS class availability unions, since it just reports resources per QoS exclusively per QoS class and do not report any unions of free resources.

### 5.3. Setup of a new network interface

A new network interface is put in operation by defining first the allowed ISONI QoS classes, whose traffic is allowed to be treated over this interface. The mix of allowed ISONI QoS classes determines the total allowed workload and the ratios/partitions of the mix.

If the network interface belongs to an  $IXB_N$  carrying outgoing inter-node VMU traffic, then a domain unique Path-ID must be assigned. Based on this information the total and the available bandwidth for each QoS class are reported to the Path Manager Domain level as indicated in Figure 13. In case of a new Path-ID the correlation table needs to be updated, otherwise the new interface will be not taken into account for any future VSN deployments.

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## 6. Flow Control Architecture

The previous two chapters describe the Flow Control concept, which can be used for controlling different data streams through a network. This chapter describes the ISONI overall architecture and the locations at which it deals with the networking QoS aspects of VL traffic. The following section explains the implications of flow control on the Operation and Maintenance tasks of the ISONI Domain and the consecutive section denotes the changes in the management functional building blocks of the ISONI middleware.

### 6.1. OAM impact related to QoS

Before a physical link is available to be used for intra-node or inter-node VMU traffic in general OAM actions have to take place specifying the allowed ISONI QoS classes and the ratios for this physical interface.

In the case of an inter-node belonging interface the new available network resource is made visible to the domain level via availability reporting. Therefore an ISONI domain-wide unique Path-ID has to be assigned to it.

In addition the network correlation table has to be updated, which considers the new Path-ID.

#### 6.1.1. Bandwidth management in general

ISONI Nodes may differ in their capabilities handling the network traffic of VMUs. Simple structured ISONI nodes may just use a single intra-node network carrying traffic of both best-effort and real-time QoS classes. In addition, the bandwidth available for the VMUs may be restricted due to ISONI traffic requirements for the execution of ISONI features like management signalling, VMU live migrations, etc. Carrier-grade manufactured nodes use several network planes in parallel for different purposes e.g. for separation of real-time traffic from best-effort traffic, for a dedicated network to ISONI signalling and VMU migration and for redundancy schemes. Therefore, just a recommendation can be given on how to deal with the available bandwidth restrictions within a node. For forming a node a lot of factors and load measurements has to be considered to find the set of characteristic system values that defines the bandwidth budgeting of a node. Figure 14 visualises some general dependencies that needs to consider for dimensioning the node network resources. The IXB as well as network switching elements inside a node must operate within a load region that does not jeopardise any quality commitments of VL traversing those network parts. Any overload causes an unduly uncontrolled growing of loss rate, delay and jitter.

An “application data throughput” (e.g. based on TCP) strongly decreases with growing delay and loss rate. For real-time connectionless traffic, like voice transmission, the Mean Opinion Score (MOS) [22] value - quality metric for voice connection - decreases with growing delay and loss rate. Isochronous traffic is also affected by growing jitter which affects as additional delay, because it can only be countered by delaying the

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application reassembly (jitter buffer). To let the node-internal network meet the required qualities of the VSN's traffic, the load of the network elements (i.e. IXB) needs to be limited. Those capacity limits represent the decision basis for a  $PM_N$  to decide upon, whether a reservation request can be satisfied or not.

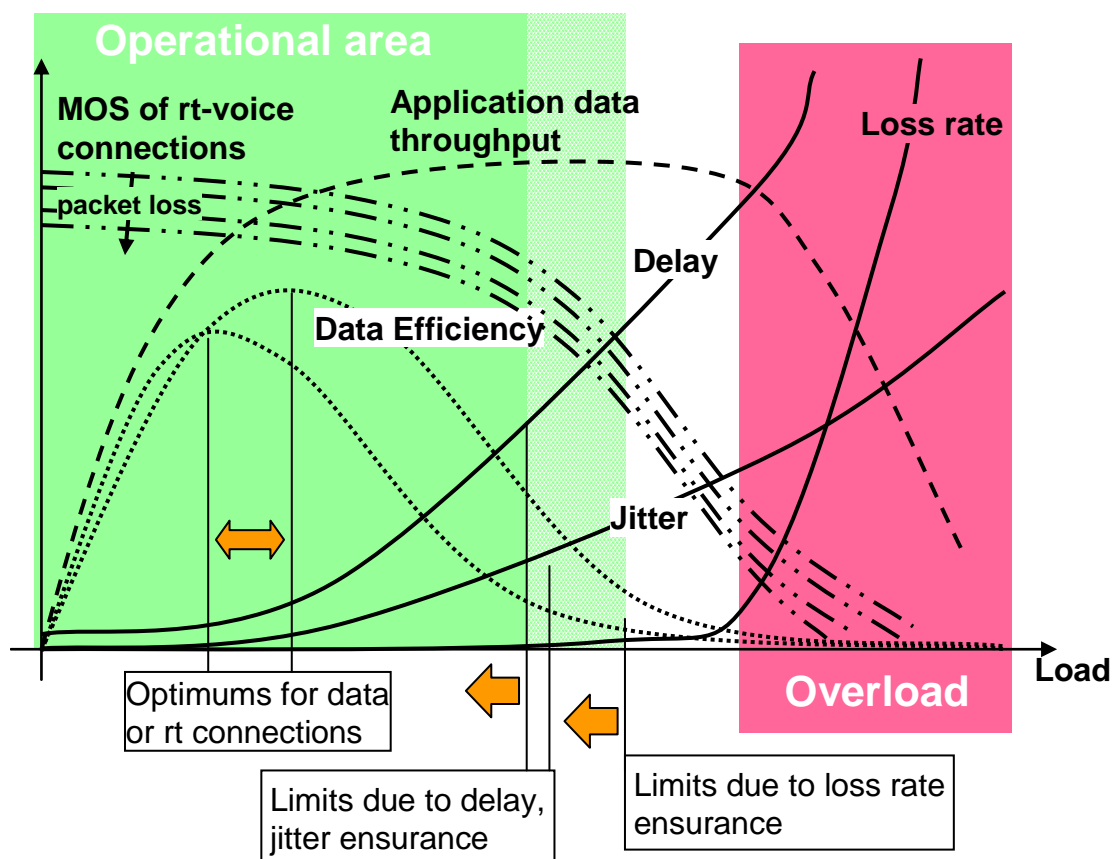


Figure 14 General dimensioning considerations (unqualified)

The order of threshold limits for delay, jitter and loss rate in switched networks depends on hardware capability and is mainly influenced by limited buffer sizes. In theory, a network element with unlimited buffer size would never cause any packet loss, but instead it would cause delay. So in this case the maximum delay determines the limiting factor of allowed load (operational area). For network elements with small buffers the operational area limit is mainly determined by loss rate.

The Path Manager Node ( $PM_N$ ) has to judge about whether a new reservation request can be satisfied or not. Book keeping of network resource reservations put the  $PM_N$  in a position to correlate against the capacities of inter-node ISONI network paths as well as of intra-node ones. The available network resources are reported to domain level as described in D7.2.1.

Figure 15 depicts a general figure of network resource limitations that a  $PM_N$  has to deal with. IXBs and network elements (like routers, switches) are dimensioned to carry a certain VL related network way through. Depending on the mixture of QoS classes a partitioning of network capacities may happen as described in section 5.2. Figure 15 as an example assumes a simple node, which carries best effort and real-time traffic over

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one common intra-node network. Usually cheaper Ethernet switches oversubscribe the backplane, i.e., full wire speed cannot be achieved on all ports simultaneously. This is reflected by way through limitations for the intra-node network elements, which has to be taken also into account for a reservation request.

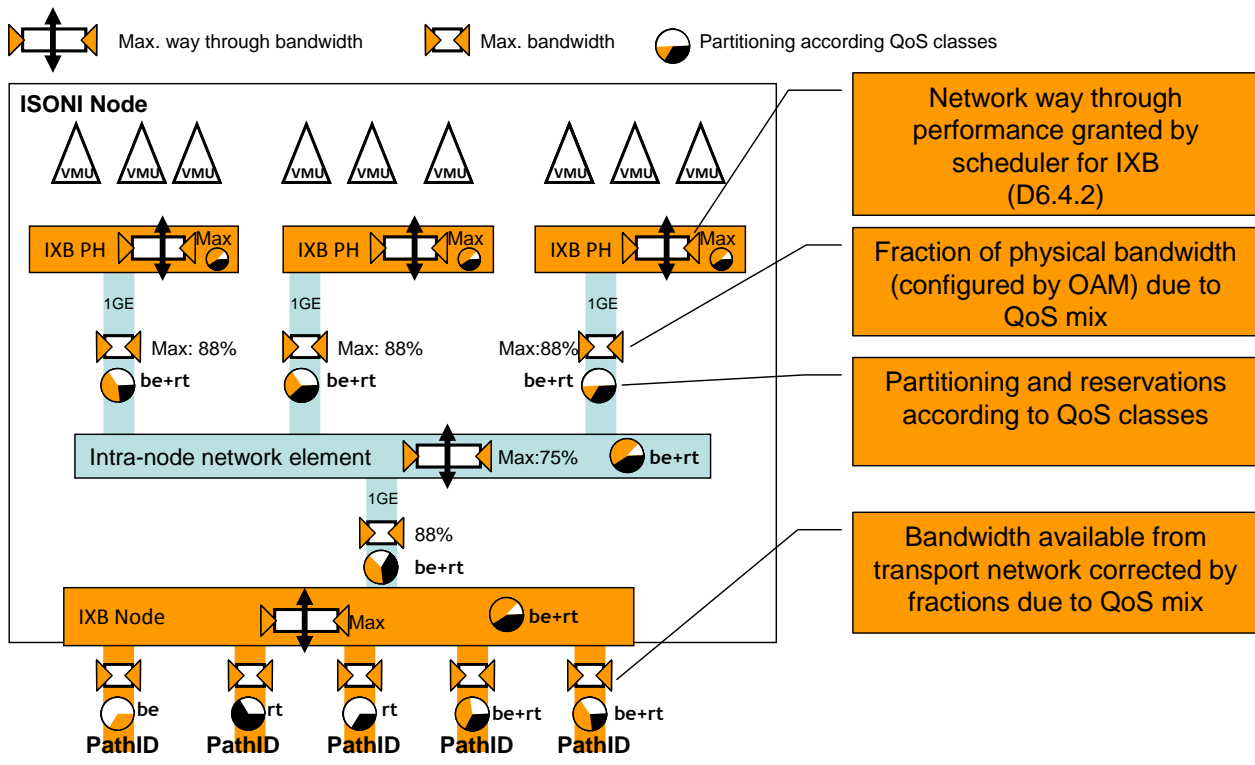
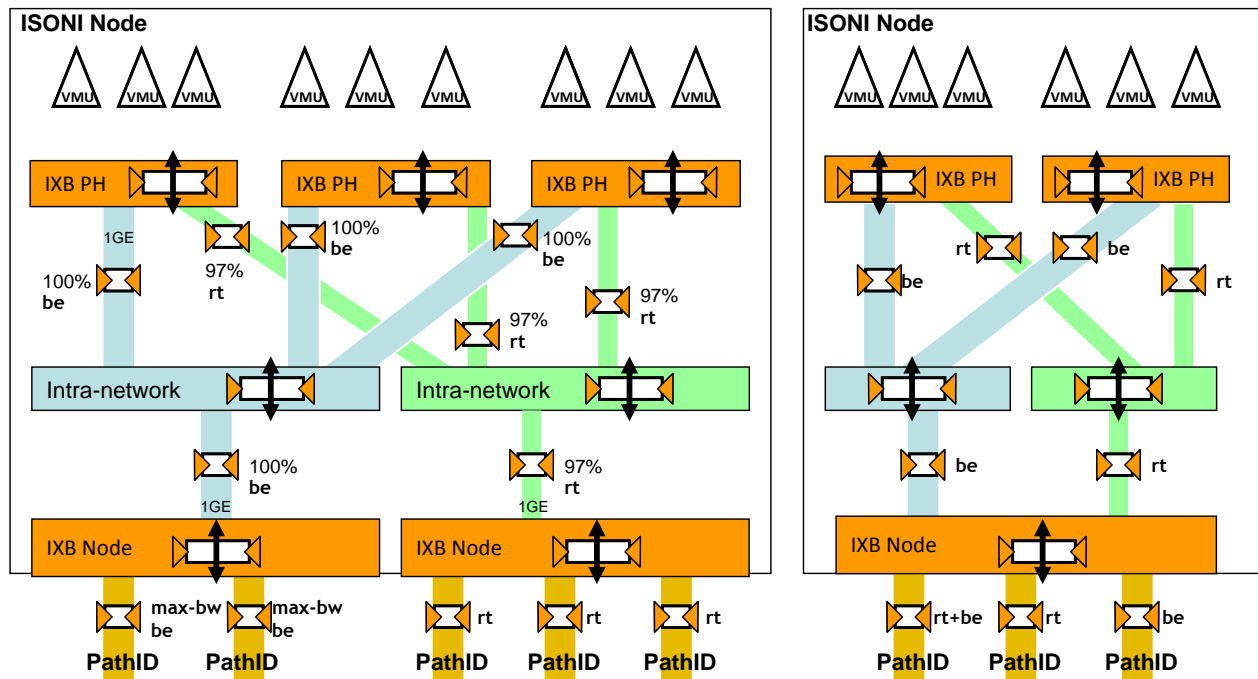


Figure 15 Bandwidth management (simple node)

As a pre-condition, the intra-node as well as the inter-node interfaces are partitioned via OAM actions. Depending on the traffic mix allowed for a certain interface, the total VL traffic maximum is specified in order to keep the QoS commitments. The manufacturer of a node is responsible to generate a rule set assisting in this OAM task determining the correct values. The inner-node network structure could be multifarious.

Figure 16 depicts two additional examples of nodes which lead the real-time and best effort traffic over independent intra-node networks. The difference between the left and the right hand node is the usage of dedicated IXB<sub>N</sub>s (left side) or a common IXB<sub>N</sub> (right side). An adequate structure is dimensioned by the node manufacturer. Especially carrier grade systems like ATCA have various options constructing network resources inside a node (e.g. redundant planes, star or fully meshed, separate management planes ...)

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**Figure 16 Bandwidth management (complex node)**

The decision for a reservation request impacts two main aspects, the intra-node network resource reservation and the inter-node network resource reservation.

As a result, the  $PM_N$  takes book keeping over all reservation by paying attention to the limits of bandwidth of IXBs and network elements inside a node and on the external interfaces of the node as shown in simplified way in Figure 17. For simplification, few VL connections are depicted traversing the  $IXB_{PHS}$  and  $IXB_N$ . The modelling of interior network elements depends on whether it imposes a bottleneck to the infrastructure topology. A network element, which provides full network bandwidth to all ports at the same time does not embody a bottleneck and is therefore transparent for bandwidth management considerations. The example in Figure 17 only shows IXBs and flows without considering the number physical network interface cards or the underlying layer 1 topology. In more complex nodes, these have to be considered separately for the determination of the node-internal traffic admission model.

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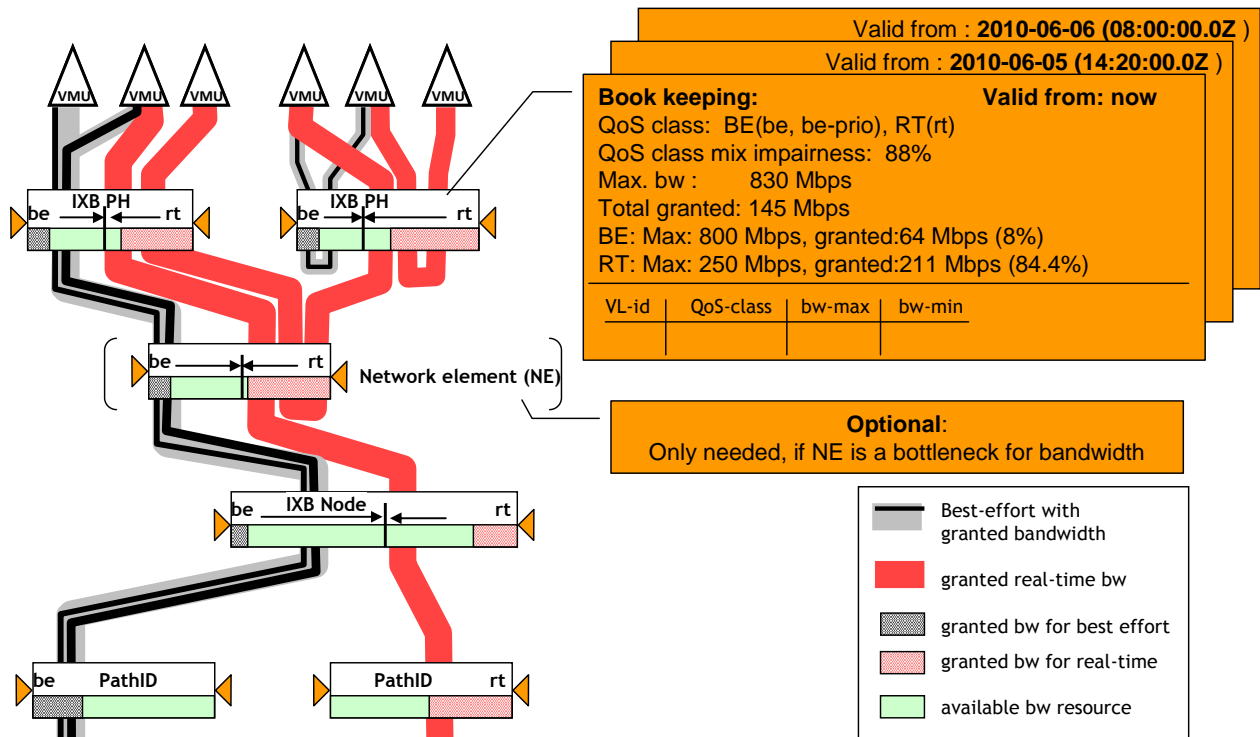


Figure 17  $PM_N$  book keeping example

### 6.1.2. Intra-node bandwidth management

First of all the  $RM_N$  allocates a provisional deployment on dedicated PHs. This information is taken by  $PM_N$  to determine, whether the intra-node resources are really available. Therefore the  $PM_N$  checks on the inner node network resources, whether any maximum allowed bandwidth budgets on the inner node path is not exceeded. If enough bandwidth is available the  $PM_N$  reserves the respective intra-node resources.

### 6.1.3. Inter-node bandwidth management

The proposed network resources are already determined by the domain level through the Path-IDs. The  $PM_N$  is just responsible to validate this proposal by checking whether the bandwidths budgets for the specified QoS class allows a reservation on IXB Node interfaces towards the transport networks.

### 6.1.4. Additional bandwidth management aspects

The minimum bandwidth constraint for granted best effort and real-time virtual links ensures certain connectivity among the VMUs. Plain best effort without minimum bandwidth requirements does not receive this guarantee. If an ISONI operator wants to preserve a small minimum bandwidth rate, this could be incorporated by an ISONI framework considering the amount of best effort link and the maximum bandwidth as shown in Figure 18.

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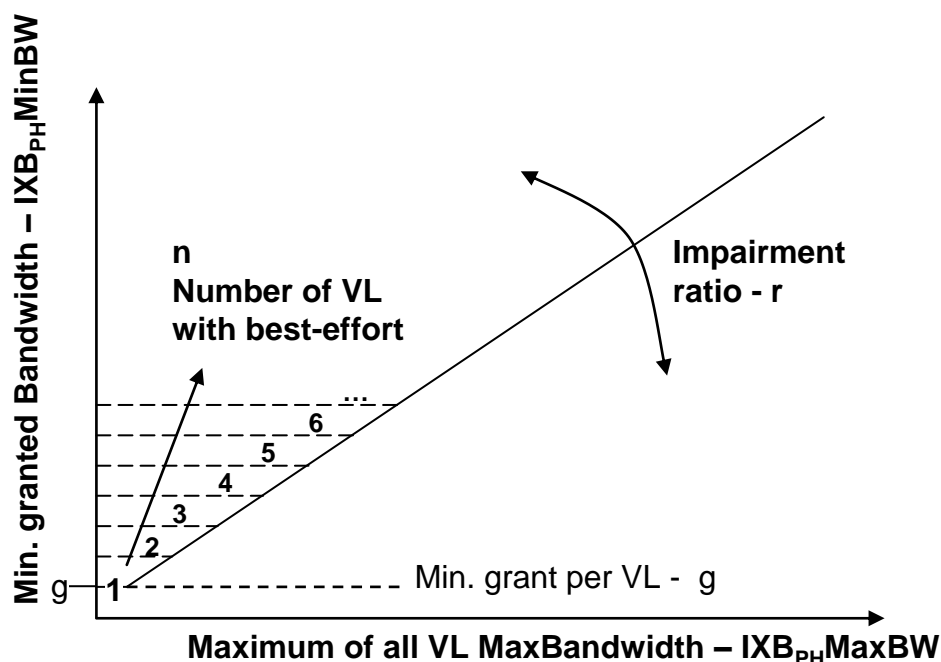


Figure 18 Sustainable bandwidth for best effort VLs ( $IXB_{PH}$ )

The sustainable minimum granted bandwidth of  $IXB_{PH}$  can be calculated with the following formula:

$$IXB_{PH}MaxBW = \max \{ vMaxBW \text{ of all VLs} \}$$

$$IXB_{PH}MinBW = \max \{ n * g , r * IXB_{PH}MaxBW \}$$

The number of VL, which needs to be taken into account, is specified by  $n$ . The minimum grant given for all VLs is specified by  $g$ . First of all each PH determines the maximum of the MaximumBandwidth (MaxBW) as specified in the VSND of each deployed VL on that PH, The  $IXB_{PH}MinBW$  is calculated using the above formulas and is considered for upcoming deployment as reserved. Figure 18 shows the representation of  $IXB_{PH}MinBW$ .

It is up to the ISONI operator to specify the minimum grant per VL ( $g$ ) and the ratio ( $r$ ).

The next multiplexing stage on  $IXB_N$  may follow a similar calculation.

$$IXB_NMinBW = \max \{ n * g , r * \max \{ IXB_{PH}MinBW \text{ of all } IXB_{PH} \} \}$$

The sustainable minimum granted bandwidth for pure best-effort traffic is just for a better consumer experience. It is optional i.e. it is up to the decision of an ISONI Provider. A minimum sustainable bandwidth can be disabled by specifying  $g = 0$  and  $r = 0$ .

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## 6.2. Management impact related to QoS

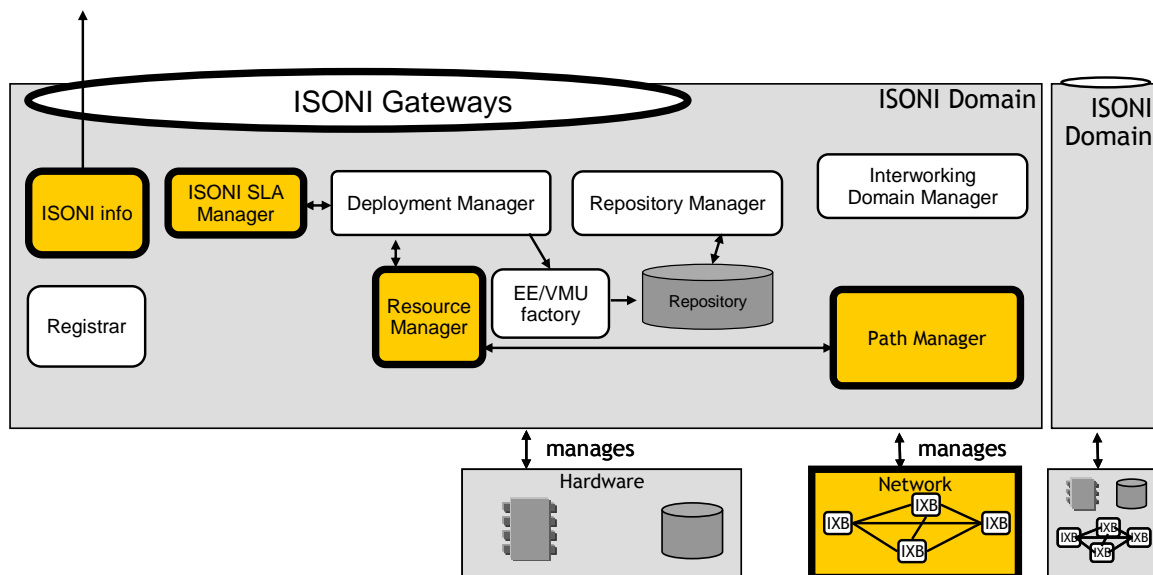


Figure 19 ISONI functional building blocks

Figure 19 shows the involved ISONI Functional Building Blocks dealing with networking QoS aspects. D7.2.1 [5] describes the deployment scenarios in detail. This chapter highlights just the deltas in relation to QoS.

### 6.2.1. ISONI Info System

The T-SLA template (described in D7.2.1 [5]) provided by ISONI Info System contains the allowable QoS related low-level parameters, which can be used by IRMOS FS mapping service to specify a virtual link's QoS constraints within the VSN description as described in D6.1.1 [9].

### 6.2.2. ISONI SLA Manager

After receiving a VSN description (VSND) the ISONI SLA Manager maps the low-level parameter to the corresponding ISONI Provider specific QoS classes. Different ISONI Providers may have different QoS classes depending on their business model and infrastructure. How such definitions of QoS classes may look like is described in chapter 4.1.

### 6.2.3. ISONI Resource Manager Domain

The Resource Manager Domain proposes different locations of deployment of the SCs also regarding the distance between the SC deployment locations to estimate the least delay among them.

A pragmatic possibility is the determination of air distances based on the geographical location of the ISONI Nodes (GPS information) multiplied by a factor of 1.25. (According to ITU-T G.826 [19], the physical-to-actual-distance ratio is 1.25) There is no much

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difference between fibre and electrical propagation delay. So in general about 5 $\mu$ sec/km is assumed in general as propagation delay for optical and electrical transmission systems.

Another possibility is to determine the real delay values between ISONI Nodes based on measurements. How this can be done is further described in D7.4.1 [7].

#### **6.2.4. ISONI Path Manager Domain**

The Path Manager Domain ( $PM_D$ ) validates the proposed SC location mapping of the Resource Manager Domain ( $RM_D$ ) and ensures that there are enough inter-node network resources left to deploy the VSN across the Domain. The validation includes the assignment of a chain of consecutive Path-IDs for each VL.  $PM_D$  considers the available reported network resource availability of applicable ISONI QoS classes. The resulting ISONI network path (reflected by Path-ID chain) ensures that the selected Node's interfaces are capable of carrying the required ISONI QoS classes.

#### **6.2.5. ISONI Path Manager Node**

The Path Manager Node ( $PM_N$ ) constitutes the master control of network resources i.e.  $PM_N$  makes the final decision accepting the deployment request in respect to networking. If the network resource reservation at the  $PM_N$  succeeds in a deployment booking, the  $PM_N$  configures the flow control mechanisms at the involved IXBs on time. The  $PM_N$  incorporates the minimum sustainable reserved bandwidth for VLs as described in chapter 6.1 as well.

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## 6.3. IXB impact related to QoS

### 6.3.1. Intra-Node Flow Control

A VMU may generate different kind of traffic, for which different ISONI QoS classes have been assigned during the deployment process. During VSN runtime the ISONI traffic control must distinguish among the different network traffic types generated by a VMU. The differentiation is based on additional information, which could be:

- Traffic is characterized by dedicated source or destination information like local source port, remote source port or IP address, ...
- The application is able to set the ToS byte in IP traffic
- Using different interfaces for dedicated traffic resolved by routing
- The application is realised as virtual hosts using multiple IP addresses for originating different type of traffic (e.g. a VMU consisting of a SIP B2BUA and a media gateway – transmitting both, best-effort signalling and real-time multimedia traffic over separate IP address interfaces)

In most cases just one VL is specified between VMUs, which makes the identification superfluous. By default the QoS class with the lowest priority is used. Dedicated mapping needs to be specified in the VLD, if needed.

Initiated by the  $PM_N$  the  $IXB_{PH}$  will be configured in respect to Flow Control. First  $IXB_{PH}$  setups the routing and tunnel encapsulation and configures the policer and shaper (if required).

### 6.3.2. Domain-wide Flow Control

Virtual link traffic that flows across ISONI Nodes is led via an  $IXB_N$ . Therefore the  $PM_N$  configures an  $IXB_N$  so that the traffic of the node-spanning VL is led via the transport interface denoted by the Path-ID. The  $IXB_N$  terminates the external link virtualization and therefore hides the Node internal topology similar to a router and protects the Node from unwanted traffic. The  $IXB_N$  only forwards the prepared VMU traffic like a firewall implementing pin holing for virtual links.

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### 6.3.3. Multi-Domain Flow Control

As introduced in D7.1.1 [4] two cases for VSN spanning multiple ISONI Domains exist.

- VSN segmentation
- Resource collaboration

In the case of VSN segmentation the VSN segments are treated by each of the ISONI Domains as normal VSN deployments. Each ISONI Domain assigns its own QoS classes to the VLs.

In the case of resource collaboration the ISONI Inter Domain Manager manages dedicated inter-domain network paths that maintain the QoS requirements between ISONI Domains. By contract among the ISONI Domain provided it has to be ensured, that the assigned QoS classes are compatible on both sides. Each Domain can still have its own QoS classes. Compatible means that e.g. both domains must support matching sets of real-time constraints in respect to bandwidth, delay and jitter.

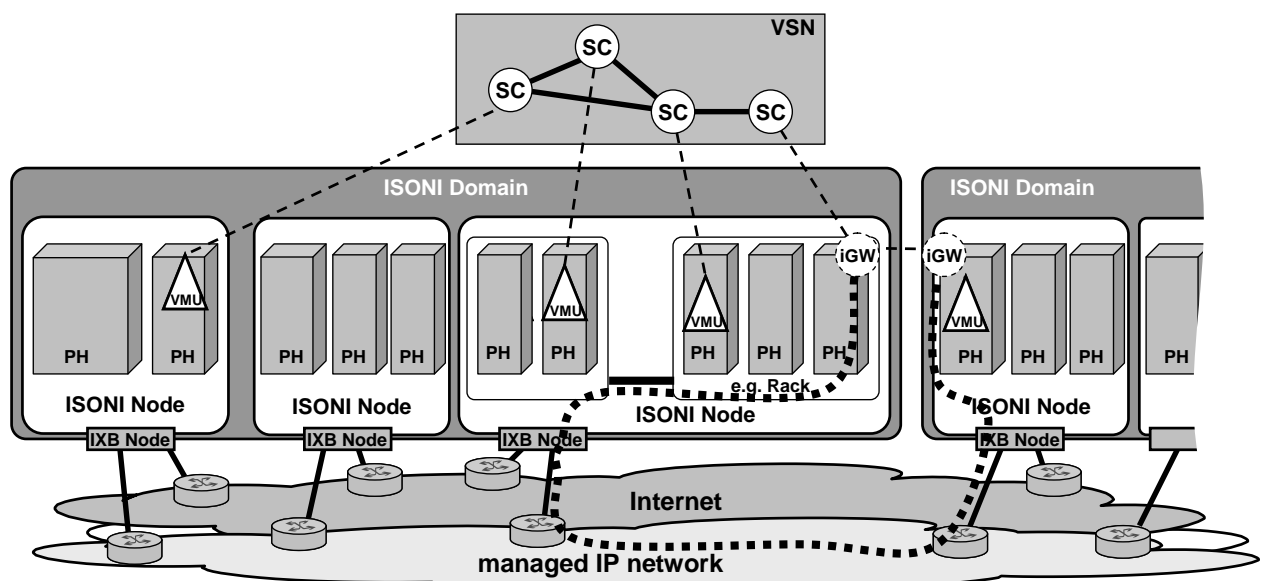


Figure 20 Resource collaboration (D7.1.1 [4])

Flow control on  $IXB_N$  is in both cases the same. Especially the policing of domain incoming traffic is very important here to protect the own domain against overloading or any other interference endanger the QoS capability of the ISONI Domain. An implementation of multi-domain scenario in the IRMOS prototype is not foreseen.

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## 7. Conclusion

This document at hand has presented the ISONI flow control concept and proven it as an essential aspect of the IRMOS IaaS approach for providing QoS attributes in relation to networking infrastructure resources. Research has been undertaken to find a scalable way of mapping the individual network requirements to the infrastructure resource. It was necessary that a possible approach would fit in the heterogeneous landscape of existing transport networks respecting different levels in respect to QoS capabilities. A solution has been found by introducing the ISONI internal QoS classes. This document is focused on flow control complementing the ISONI QoS class approach by policing running ISONI services, i.e, following the instantiation of an IRMOS service on ISONI, the link-interfaces utilization of the service is policed by the ISONI Flow Control in correlation with the QoS classes, so as to prevent service traffic from interfering with one another, e.g. in case of a misbehaving Service Component and ensuring certain networking QoS.

Bandwidth management of networking resources is in addition an inevitable precondition for ensuring any QoS - especially real-time - capabilities in respect to networking preventing overloading of the network resource premises.

Flow Control is an essential part of an IaaS approach offering networking resources with certain QoS attributes as a service. Special attention has been given to the question of QoS parameters breaking down to QoS classes.

The results of this document will be transferred and integrated in the Final ISONI Prototype to be delivered in July 2010.

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