



Interactive Realtime Multimedia Applications on Service Oriented Infrastructures

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D7.3.1 Initial version of Flow Control Architecture

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Authors

Thomas Voith, Manuel Stein, Karsten Oberle (ALUD); Sören Berger (USTUTT); Ralf Einhorn (DTO), Tor Neple (SINTEF)

Internal Reviewers

Patrick Mandic (USTUTT); Eduardo Oliveros (TID); Consolidating Reviewer: Fabio Checconi (SSSA)

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Glossary of Acronyms

Acronym	Definition (Context)
ASC	Application Service Component (IRMOS)
ATM PVC	Asynchronous Transfer Mode Permanent Virtual Circuit
be	Best-effort (QoS class)
bep	Best-effort with minimum throughput (QoS class)
CBR	Constant bitrate
CC	Client Component (IRMOS)
DiffServ	Differentiated Services
DSCP	Differentiated Services Code Point
eSC	External Service Component
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 _N	IXB Node
IXB _{PH}	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 _D	Path Manager Domain
PM _N	Path Manager Node
PoP	Point of Presence
QoS	Quality of Service
RM	Resource Manager (ISONI)
RM _D	Resource Manager Domain
RM _N	Resource Manager Node
RSVP	Resource Reservation Protocol
rt	Real-time (QoS class)
SaaS	Software as a Service
SC	Service Component
SDH	Synchronous Digital Hierarchy
SLA	Service level agreement
SOA	Service-oriented architecture
SONET	Synchronous optical networking

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Acronym	Definition (Context)
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
WFQ	Weighted Fair Queuing

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1. Executive Summary

As presented in ISONI whitepaper [7] the ISONI consists of a modular management middleware layer hierarchical structured in domain and node level.

As presented in D7.1.1 [4] the transparently namespace information of each executed application is described as a so-called Virtual Service Network (VSN). It provides connectivity between Service Components, realized by so-called 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 by having the scalability as in the case of the Differentiated Services (DiffServ) approach. 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 initial version of the Flow Control architecture. The Flow Control is part of the overall IRMOS Intelligent Service Oriented Network Infrastructure (ISONI) Path Manager functional entity as being described in more detail in D7.2.1 [5] and ISONI Whitepaper [7]. The deliverable at hand which is the initial version of the Flow Control architecture is serving as input to the first IRMOS proof of concept demonstrator at the end of project year 2. The outcome of this deliverable will be consumed first inside the WP on Intelligent Networking and delivered as part of the integrated ISONI proof of concept with limited functionality at project month 22 for integration into the IRMOS proof of concept demonstrator. A follow up deliverable of the Flow Control architecture is scheduled for project month 25 which will enhance the architecture in terms of functionality and level of detail and make use of results and feedback achieved from the first prototype tests.

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 especially on QoS (Quality of Service) related concepts and other related issues such as traffic classification, traffic policing, flow shaping methods and the Flow Control concept. One target of the ISONI Flow Control Architecture was to base it upon existing network architectures. This means that it should be deployed in today's networks and use its advantage, such as e.g. MPLS (Multiprotocol Label Switching) and focus the effort on our research topics and challenges.

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

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the IRMOS Framework Services. It has been decided that ISONI manages link resources that are classified in several ISONI-internal QoS classes. The classifications remain ISONI-internal and their definition will not be made public. The purpose of this classification is to optimize the usage of the link resources owned by the ISONI. Within the VSN description a service creator describes the required properties of the links by giving parameter sets comprising bandwidth, delay, jitter, etc. An ISONI will map those parameters onto an ISONI-internal QoS class that provides the required links with at least the QoS properties as requested by the VSN description. There are two main reasons for hiding the definition of QoS classes and to force service creators to describe the links 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 then 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.

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 the real-time networking real-time aspects are addressed and ensured within an 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 VSN Description (VSND) according to D6.1.1 [8] and the transport network resources available for the interconnection of the 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. Firstly, 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 that can be distinctly 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, 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.

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 single network infrastructure. Hence, the ISONI Flow Control Architecture is expected to

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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 intuitively 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 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 Service Oriented Network Infrastructure (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 VSN description (VSND) [8] 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].

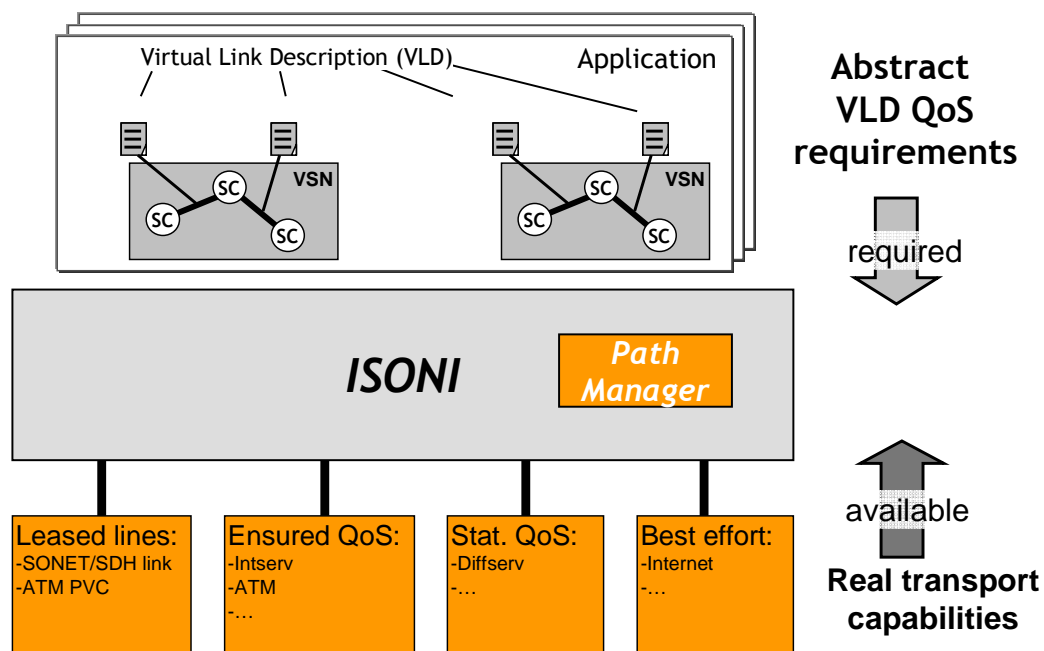


Figure 1 Mapping of VLD QoS requirements

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 as indicated in Figure 1. The transport network resources managed by ISONI can be subdivided in four categories in respect to 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 to which resources are utilized by a virtual link, both network resources between and within ISONI Nodes without impacting each other. Hence, resource admission control is carried out

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following the ISONI two-level architecture as introduced in [7]. 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 particular processing tasks. With network-based application paradigms, such as SOA-enabled SaaS [22], 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 human computer interface and Application Service Components (ASC), which reside in the network 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 [9].

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 for the network Quality of Service (QoS).

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

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- 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 distinct 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 [8] 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 know, they just use 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.

3.2. Transport QoS adaptation

The ISONI concept follows the principle of managed resources, which postulates the planning of network resources. As introduced in D7.2.1 [5], the ISONI Path Manager Architecture subsumes all network-related tasks of a managed network infrastructure

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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 abstract availability of transport network resources has to be reported to Path Manager Domain (PM_D) 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 simple algorithms. 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.

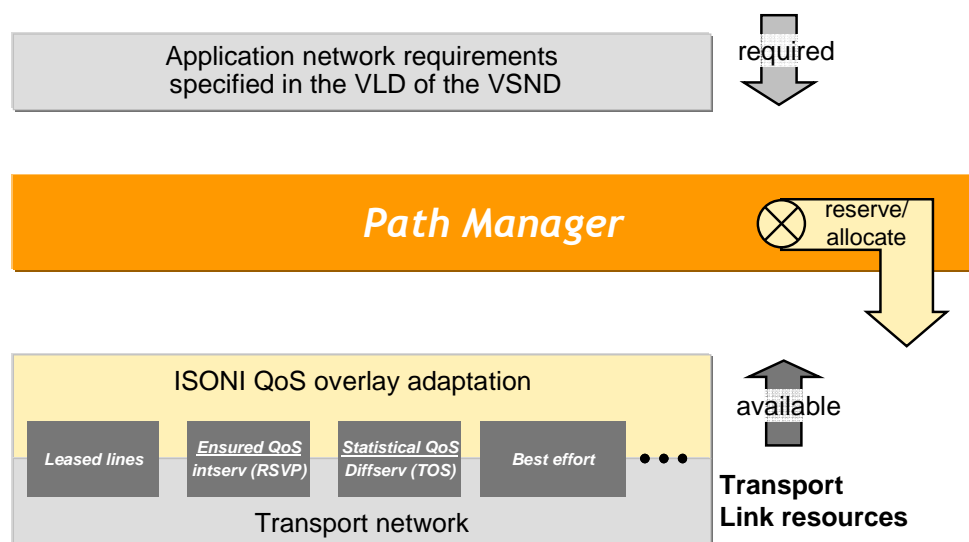


Figure 2 Network resource reservation (abstract view)

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). The responsibility of the Path Manager is to find and to reserve/allocate adequate networking resources.

This document elaborates 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. ISONI intention 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. 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. ACC, EASC), 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

IRMOS project competes against best-effort networks like the Internet providing some kind of real-time guarantees. The Internet just provides best-effort service, which does not provide any guarantees. Two oppositional approaches have been made by 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 [16], which limits the demand per network connection and reserves the resources to meet the QoS. Intserv provides end-to-end QoS that requires keeping states per connection and an individual reservation per connection, which can ensure QoS in respect to delay, jitter and throughput, but it does not scale due to the needed context for each connection. In addition the reservation per connection requires a reservation protocol (RSERV) [15], 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 [12], 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 for having both the scalability and absolute QoS guarantees.

The solution shall be

- Scalable by dealing with aggregated traffic and not individual connections
- Ensuring QoS by doing reservations
- But just easy to use avoiding an application overhead for 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 count on a certain throughput i.e. a data transfer task could be finished by a given specified time limit. This is a deterministic behaviour which characterizes real-time systems. A system providing best-effort with an ensured minimum bandwidth can be already denoted as networking real-time capable system. The problem is that normally with the term real-time other values are implicated in addition - delay and jitter, which belongs usually to audio and video streams. In ISONI we just follow the usual terms for real-time which belongs to the audio and video streams. But remember 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.

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. In ISONI it has been decided to specify the jitter, which goes along with a certain loss rate. The highest priority traffic receives automatically the lowest jitter and lowest packet loss.

Delay is mainly designed by an appropriate placement of the VMUs, which is done in a first stage by Resource Manager Domain - RM_D (D6.1.2 [9]) and then confirmed by Path Manager Domain - PM_D . The entire scenario is described in chapter 6.

Dedicated jitter and loss rate guarantees causes prioritisation of concurrent VL network traffic. The problem is that each later deployment of another VSN changes the made assumptions made during the previous deployment. So it is impossible to treat the QoS requirements individually. ISONI reserves for certain categories of VL QoS certain link capacities and scheduling behaviours in advance. This ISONI solution goes along with the introduction of ISONI QoS classes, which is described in next chapter.

4.1.2. ISONI QoS classes

QoS classes are already used in 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 the abstract behaviour that persists across ISONI Node borders. The ISONI QoS class classification avoids the burden dealing with the QoS low level parameter individually and enables to have enough space for later concurrent deployments.

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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 PathIDs. 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 leases lines e.g. especially for real-time traffic whereas the best effort traffic is leaded e.g. via 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.

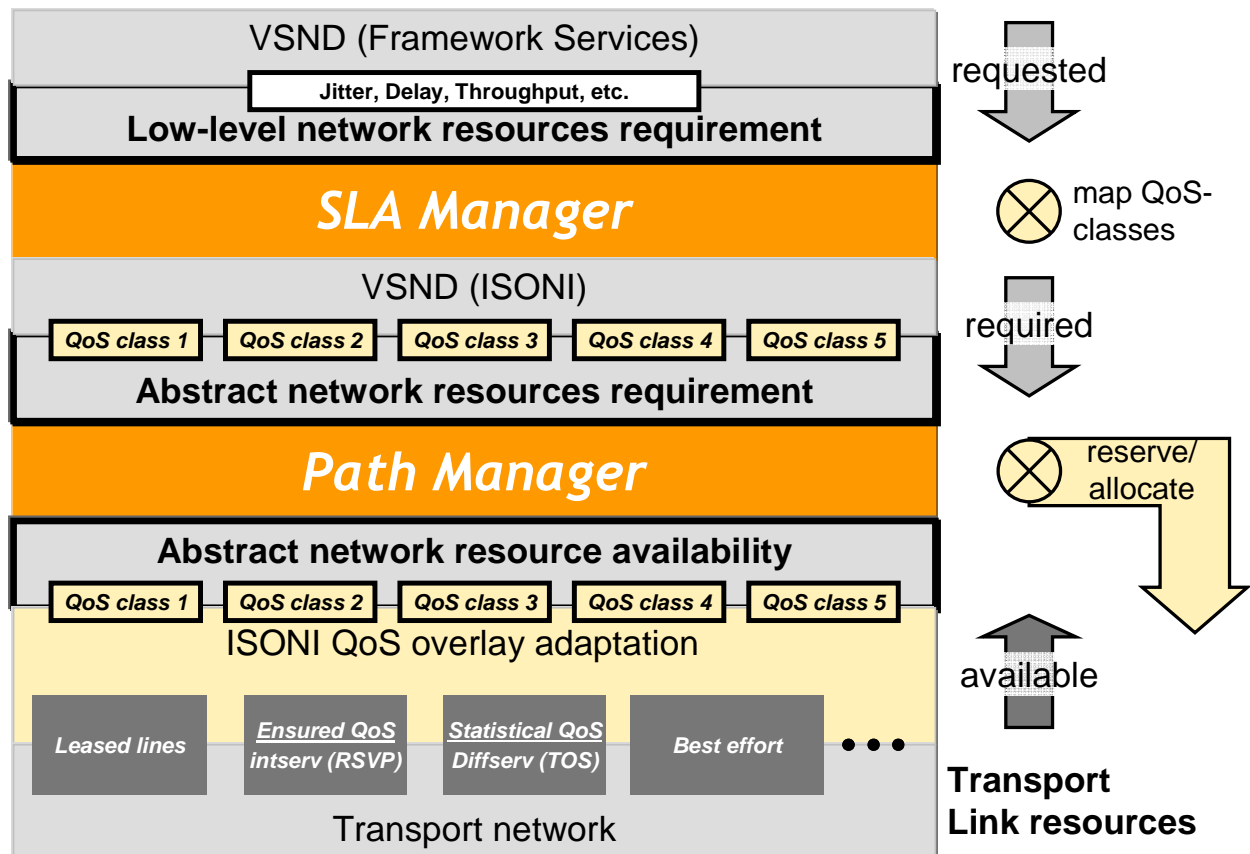


Figure 3 ISONI QoS classification

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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 big set of ISONI QoS classes:

- Best-effort (be)
- Best-effort with granted bandwidth (bep)
- Real-time streaming audio (rtsa)
- Real-time streaming video (rtsv)
- Real-time interactive audio (rtia)
- Real-time interactive video (rtiv)

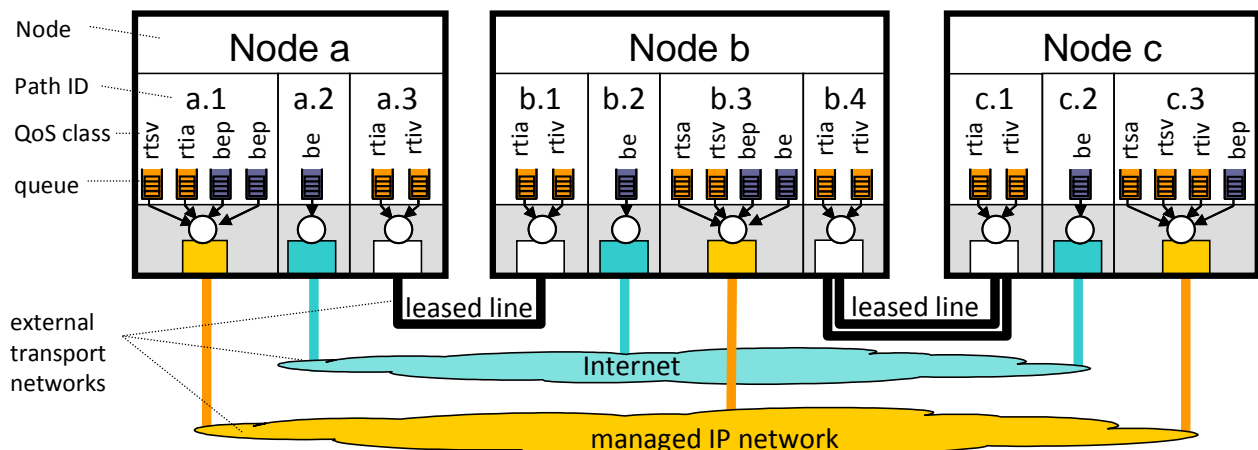


Figure 4 Example: QoS class concept fine-grained ISONI

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
- Real-time interactive

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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)

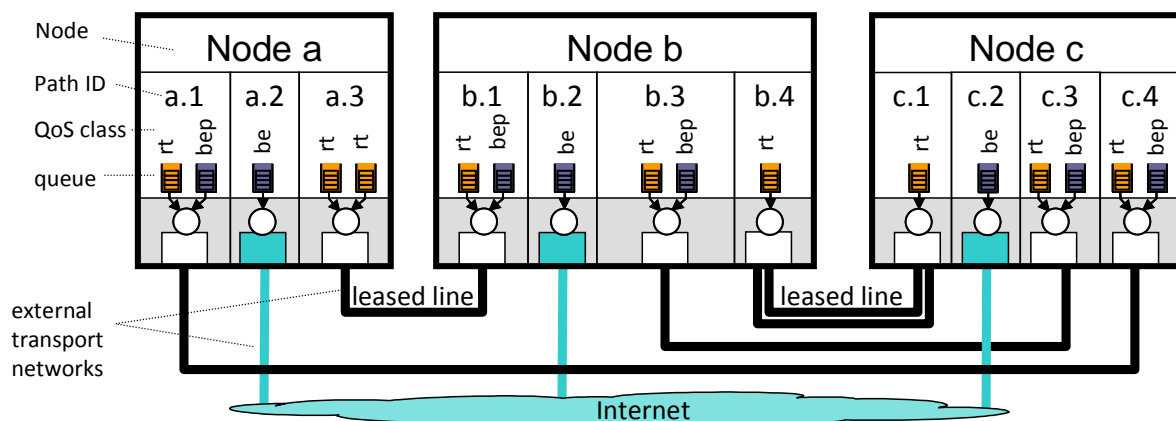


Figure 5 Example: QoS class concept coarse-grained ISONI

But this 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 operator 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. For the latter possibly an extension of the VSND is needed.

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4.2. QoS class scheduling

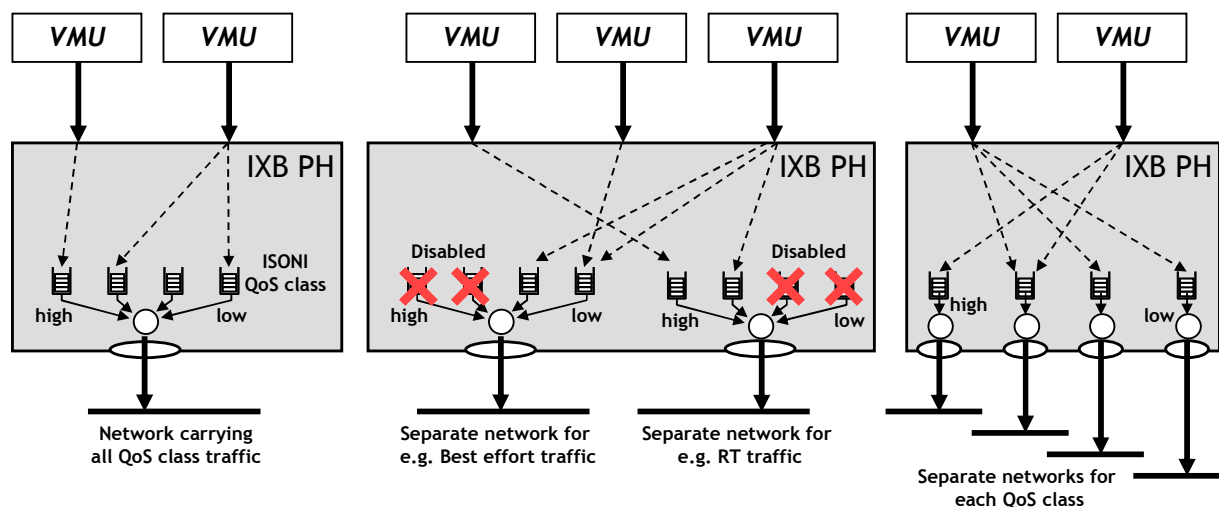


Figure 6 Network scheduling - IXB_{PH} outgoing/egress - 4 QoS classes

Network scheduling is needed to get a 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 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.

This is just needed in case of multiplexing egress traffic of different QoS levels per interface. Figure 6 shows three scheduling examples of outgoing egress¹ traffic in the case of using 4 QoS classes. The ISONI Node internal realization of QoS traffic treatment may be diverse. 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, since the workload depends strongly upon 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.

Same applies also to the IXB Node (IXB_N) level as shown in Figure 7.

¹ "outgoing/egress" denotes sent traffic (outgoing interfaces) leaving the ISONI Node (egress)

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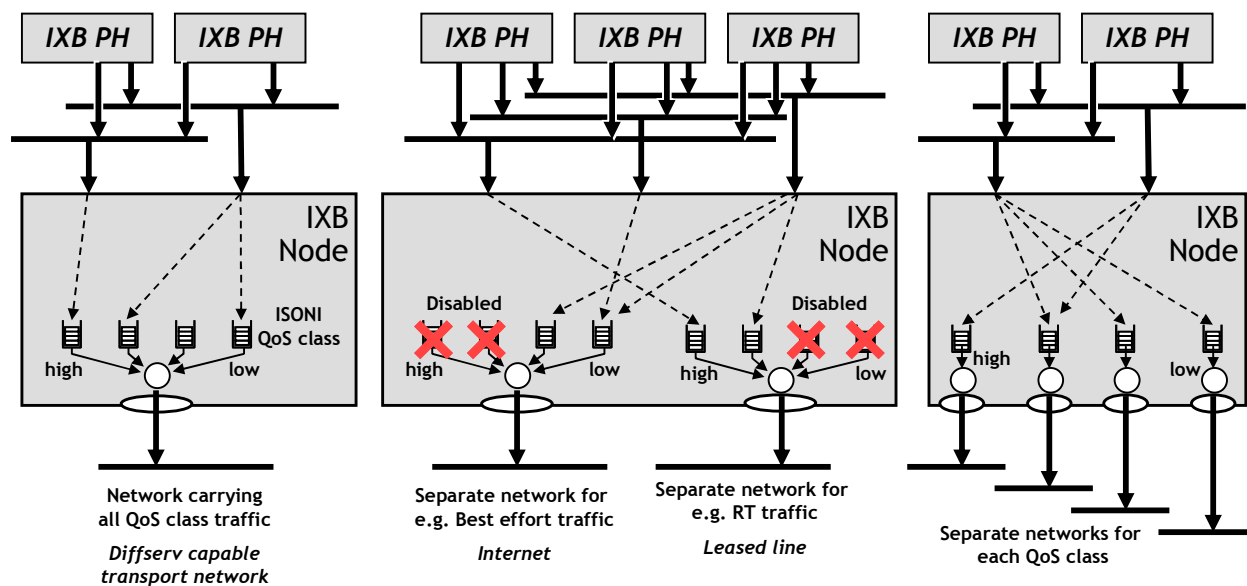


Figure 7 Network scheduling - IXB_N outgoing/egress - 4 QoS classes

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 [21] the mix of audio, video and data traffic for 10Base-T, 100Base-T amongst others:

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 (anew 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_D to select a network path for a virtual link as a chain of

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two or more PathIDs, 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 PH and IXB node level commonly (aggregated). The VL realized by tunnels 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_{PH} and IXB_N 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 that ISONI can 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)

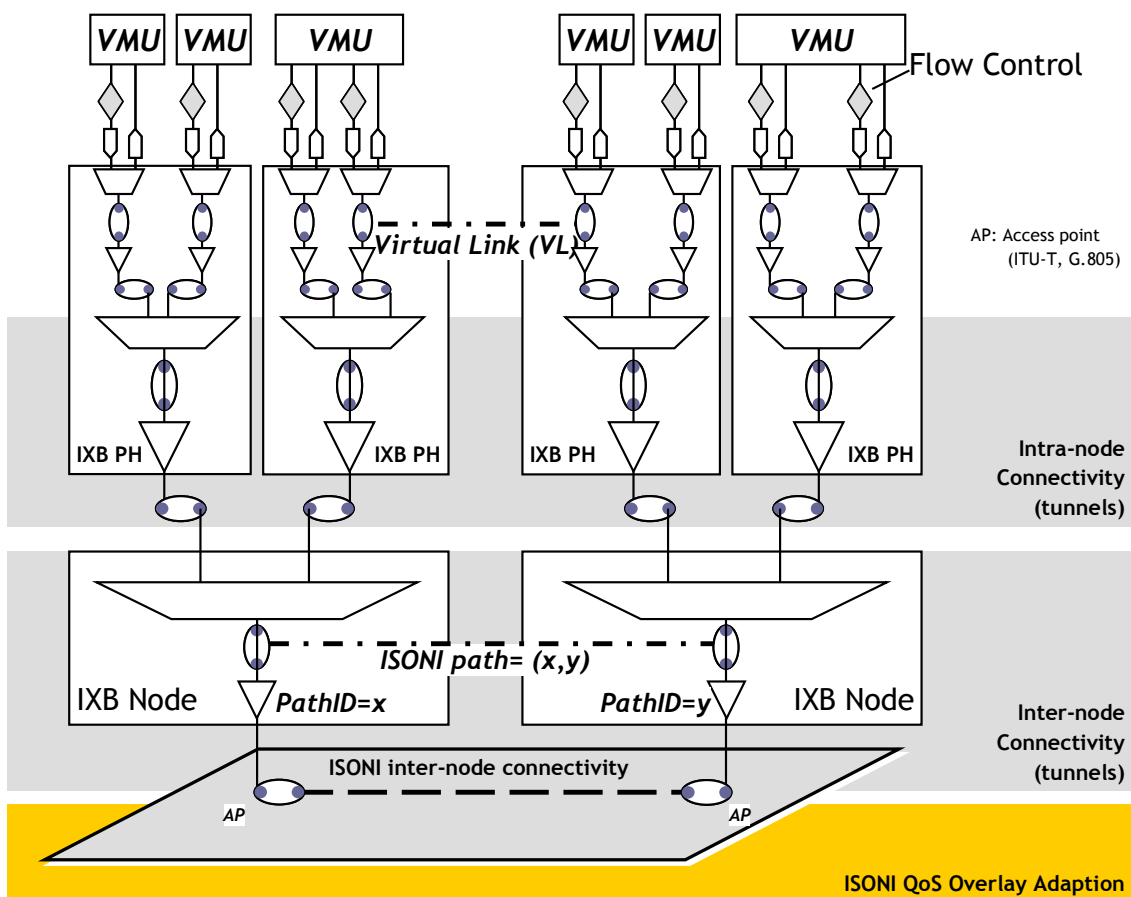


Figure 8 Flow Control within ISONI

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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 [19].

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.

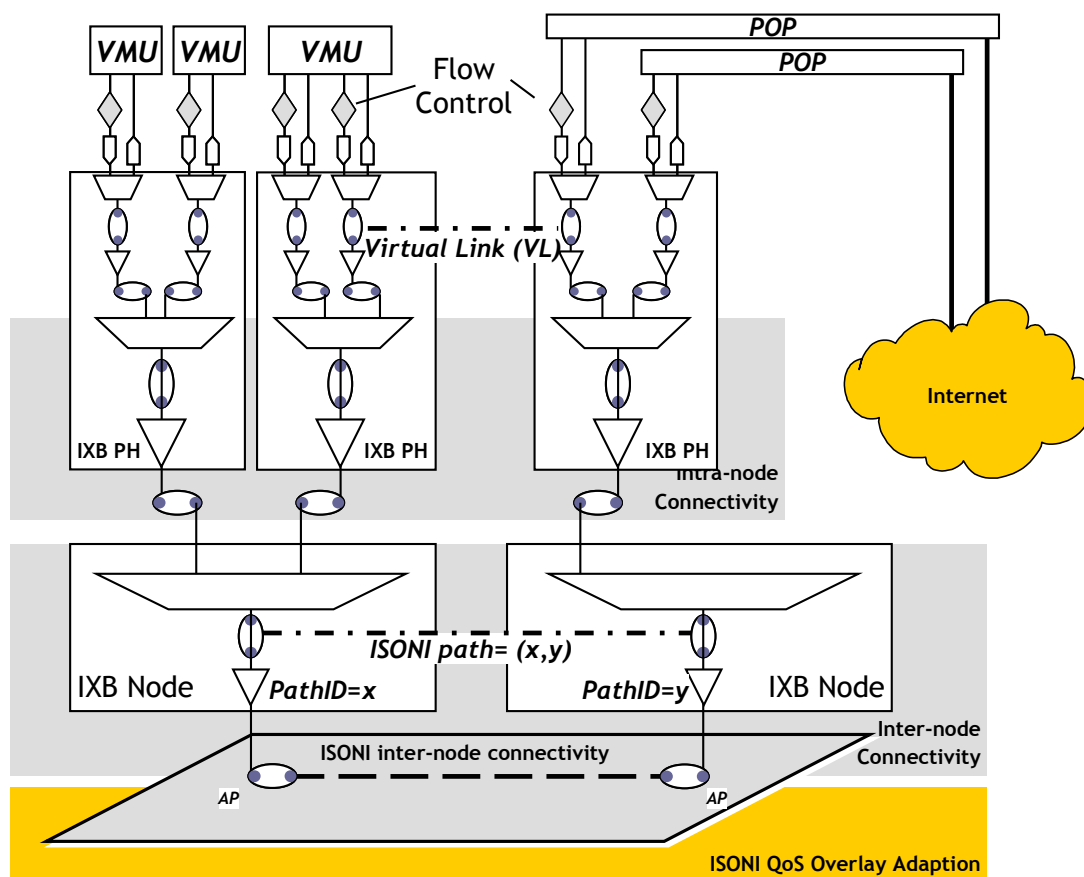


Figure 9 Flow Control for public IP traffic

4.4. Flow shaping

Shaping is additional mechanisms 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

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multiplex sections, if the buffers of multiplexer are overloaded. Bursty traffic is characterized by 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.

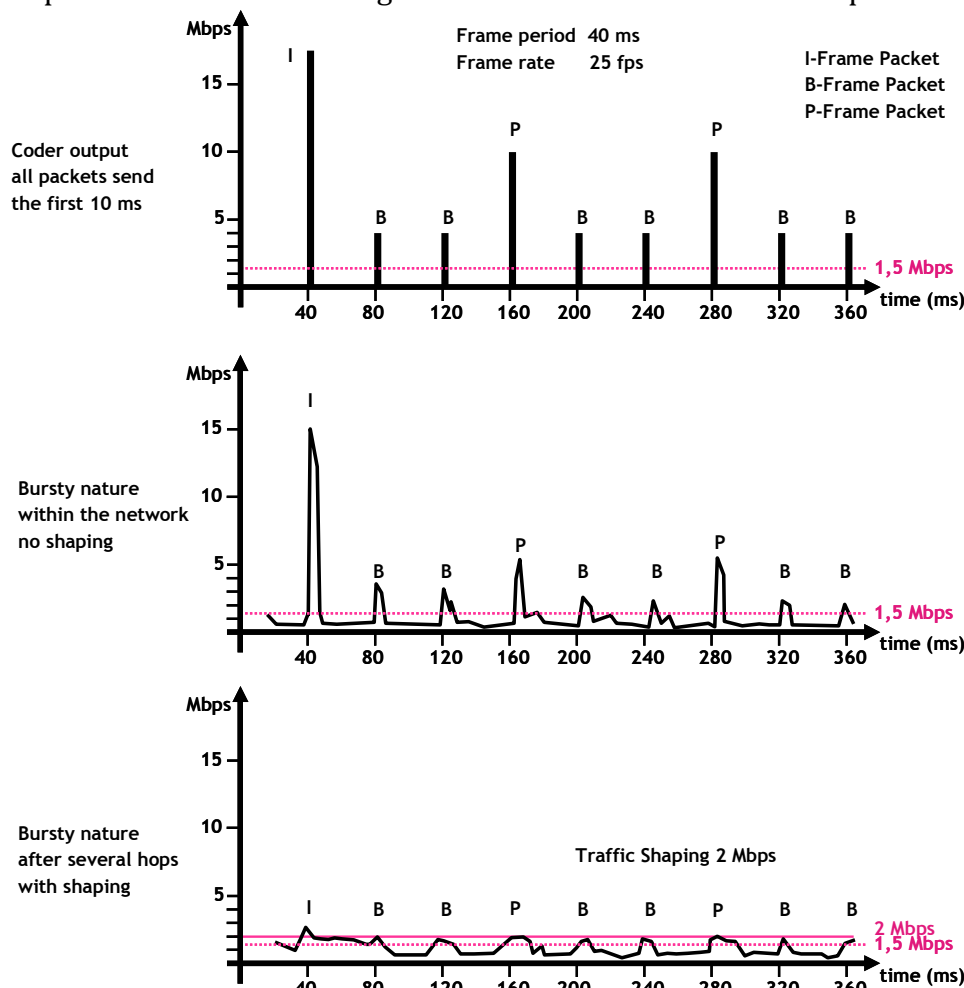


Figure 10 Shaping example of one video flow (MPEG2-1,5 Mbps)

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 bitrate 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)

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4.5. Virtual isolation for QoS

The traffic is carried isolated as described in D7.1.1 [4], which provides just isolation in sense of connectivity. The isolation (encapsulated) traffic of 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 by means that concurrent traffic of later deployed VNSs do 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 requirement 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 represent the general treatment of network with respect to QoS. The transport network abstraction is explained now more in detail.

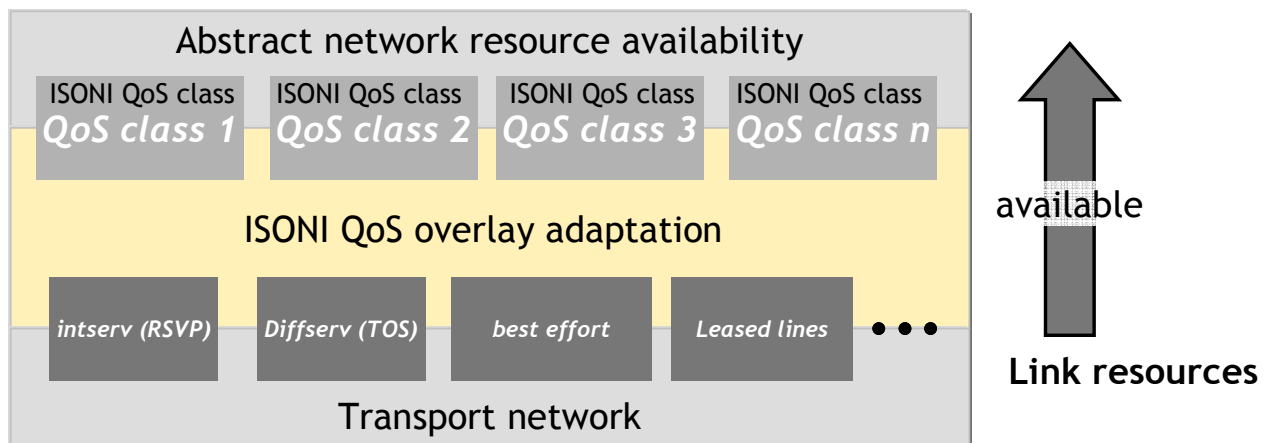


Figure 11 ISONI QoS Overlay Adaptation (IQOA)

5.1. Transport network QoS adaptation

The ISONI introduces a QoS Overlay Adaptation (IQOA) layer that evens out the different transport network capabilities. The availability of link resources is reported in a certain abstraction level, which expresses the planned usage in conjunction with the ISONI QoS classes. This chapter describes the relations between the adaptation and the real interfaces towards transport network.

In general the networks can be categorized into main categories:

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

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.

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	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	RFC 1394 Typ of Service in the Internet Protocol Suite <i>all outdated as per RFC3260</i>	
class selector		0	0	0	CU		0	RFC2474 Differentiated Services Field (6+2bit „currently unused“) 1) Class Selector + 3bit Zero / compatibility to precedence RFC791 2) local / experimental use (maybe assigned in future) 3) local / experimental use 4) Default PerHopBehaviour all zero 5) DiffServ PHB + 1bit zero	
local/future use		1		0					
local use		1		1					
0	0	0	0	0					0
DiffServ PHB				0					
DSCP						ECT	CE	Explicit Congestion Notification RFC2481 ECT (ECN-capable transport) + CE (congestion experienced) RFC3168 (0) Non-ECN capable, (1) ECT-1, (2) ECT-0, (3) Cong. Exp.	
						ECN			
Assured Forw. class 1-4		drop precedence		0		ECN		DiffServ PHB: RFC2597 Assured Forwarding 4 classes (3bit), 3 drop precedence levels (2bit)	
1	0	1	1	1	0		ECN	DiffServ PHB: RFC2598/RFC3246 Expedited Forwarding	

The exact usage of TOS Byte depends on the capabilities and the SLA contract of the correlated transport network. The IQOA marks the TOS Bytes of outgoing VMU traffic for the individual transport networks according to the ISONI QoS classes. The mapping rules are already 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, IntServ-designed networks deserve a particular notion here. Each VL is realized as an individual tunnel among the IXB_{NS}. For each newly deployed VL the QoS is requested by the IntServ capable network by using the RSVP [15] protocol.

A VL tunnel already contains aggregated VMU traffic, which mitigates the scalability problem of IntServ approaches.

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. Some examples will be given later on. 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 and d shows shared unions for QoS 1+2 and QoS 3+4. It means that the specified bandwidth portion can be used together by the related QoS classes. Case d specifies that this interface foreseen just for QoS class 1 and 2 traffic shared. 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.

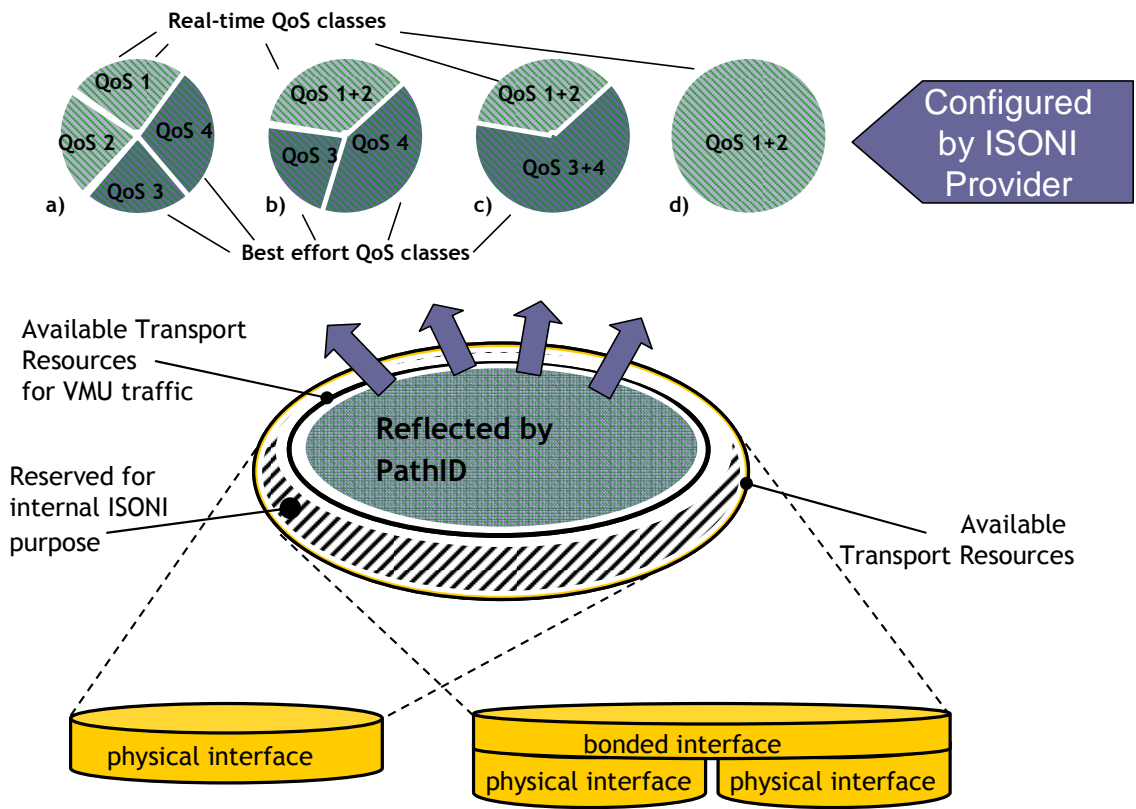


Figure 12 ISONI QoS Overlay Adaptation (IQOA)

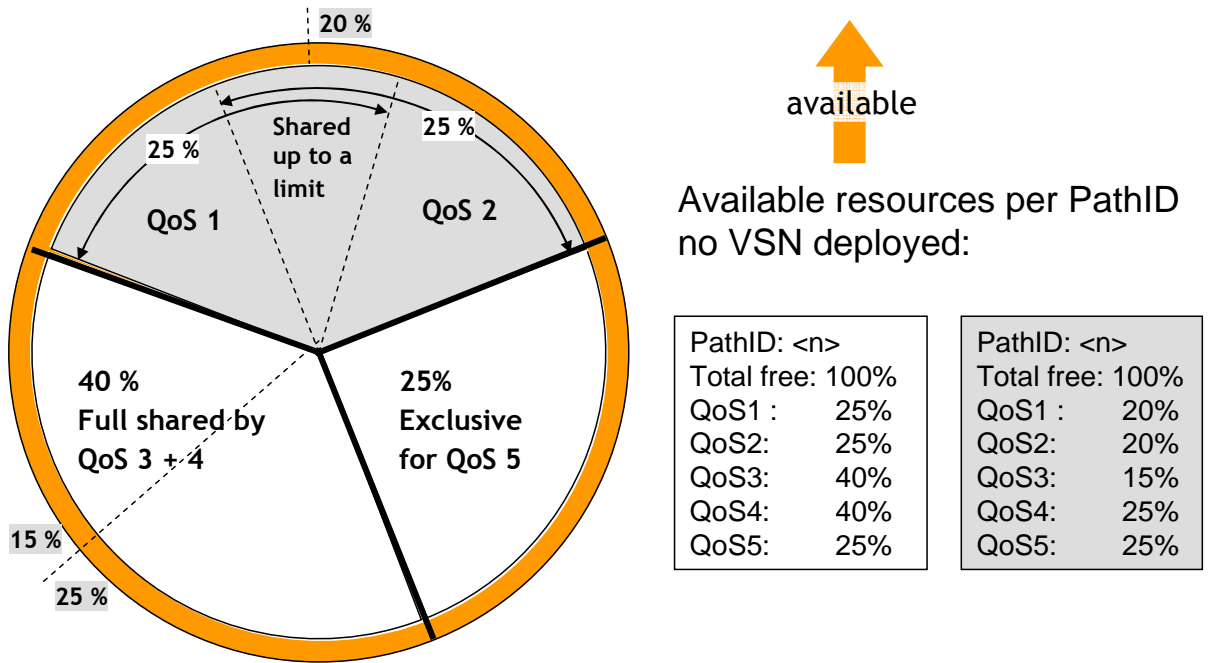


Figure 13 ISONI availability reporting using QoS classes

Figure 13 shows an example for five ISONI QoS classes. QoS class 1 and 2 shares 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 just reflects the concept by showing percentages, but the availability report as introduced in

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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.

5.3. Setup 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 deployment.

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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 describe the ISONI overall architecture and the locations at which it deals with the networking QoS aspects of VL traffic.

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.

6.2. Management impact related to QoS

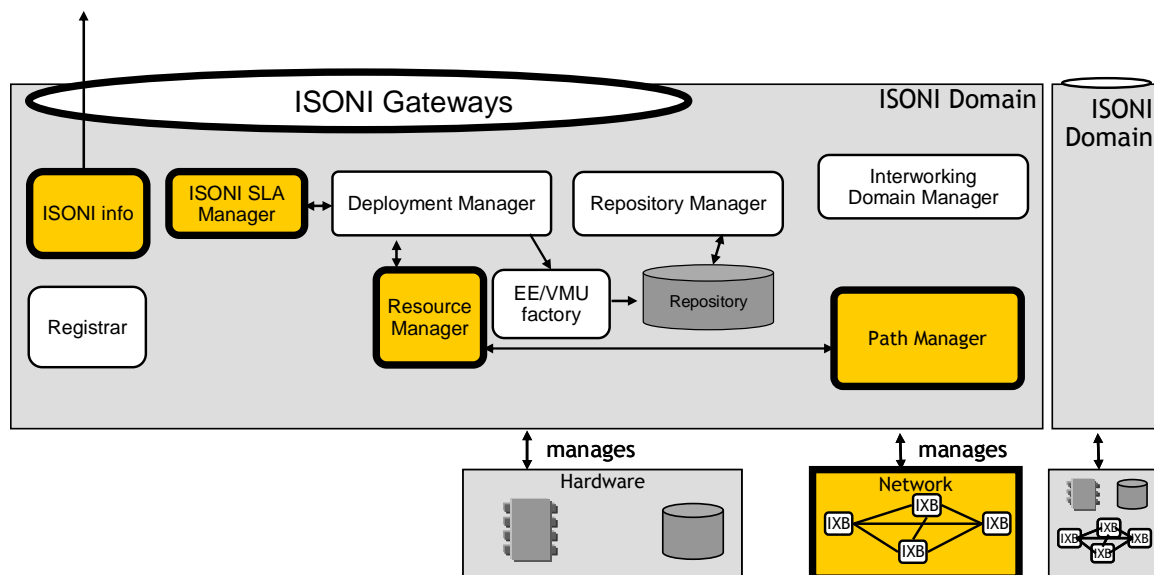


Figure 14 ISONI functional building blocks

Figure 14 shows the involved ISONI Functional Building Blocks dealing with networking QoS aspects. D7.2.1 [5] already describes the deployment scenarios in detail. This chapter highlights just the deltas in relation to QoS.

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6.2.1. ISONI Info System

The T-SLA template provided by ISONI Info System contains the QoS related virtual link parameters, which can be specified by IRMOS FS mapping service obtaining certain QoS guarantees for any VSN deployments as described in D6.1.1 [8].

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 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 SCs so minimize the delay between 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 [17], the physical-to-actual-distance ratio is 1.25) There is no much difference between fibre and electrical propagation delay. So in general about 5µsec/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 [6].

6.2.4. ISONI Path Manager Domain

The Path Manager Domain (PM_D) validates the proposed location of the Resource Manager Domain (RM_D) and ensures that there are enough resources left to deploy the VSN by adding the Path ID pair for each VL to the proposal. PM_D considers the available reported network resources broken down to ISONI QoS classes. The selected ISONI network path (reflected by PathID pairs) on domain level ensures that the selected interfaces (by PathID) in general are capable 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 booking of the PM_N allows the deployment request to be ensured, the PM_N configures the Flow Control on the related IXBs in time.

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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 has 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 TOS bits in a certain way
- 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 - generating best-effort traffic and a media gateway – generating real-time traffic. Media gateway uses a different IP address for media streams.)

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

In the case of inter-node VLs the encapsulated traffic is led via the IXB_N . Therefore the PM_N configures the IXB_N so that the encapsulated traffic of each VL is led via the transport interface denoted by the PathID. The IXB_N hides the Node internals and protects the Node from outside world. The IXB_N acts therefore like a NAT for encapsulated VMU traffic, which is a firewall implementing pin holing for encapsulated VL traffic.

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 segmented parts of the VSN 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

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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 real-time QoS in respect to delay and jitter.

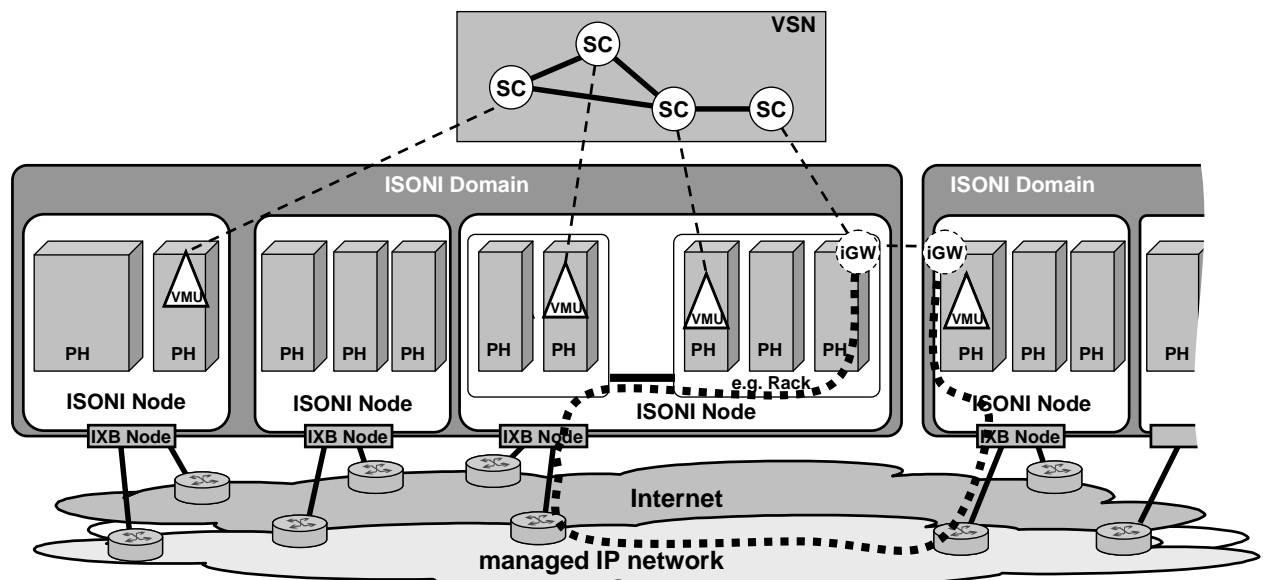


Figure 15 Resource collaboration (D7.1.1)

The 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.

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