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Abstract: This draft Recommendation specifies the functional architecture and procedure for latency guarantee in large scale networks including IMT-2020 and beyond.

Summary

With the base text TD037/WP1 (03-2022), this TD was created during Q.6/13 4-15 July 2022 SG13 Plenary meeting. The meeting agreed to accept proposals made by C75 with the editor’s note that states the mapping the logical architecture into IMT-2020 is necessary and the associated modification is required.

Draft Recommendation ITU-T Y.IMT2020-fa-lg-lsn

Functional Architecture for latency guarantee in large scale networks including IMT-2020 and beyond

Summary

Latency sensitive applications across multi-domain large scale networks emerge, such as autonomous driving, augmented reality, virtual reality, tactile internet, and smart industry. ITU-T Y.3113 describes the requirements and framework for latency guarantee in large scale networks. ITU-T Y.3113 combines the FA-based queuing and scheduling architecture and the regulators at the aggregation domain (AD) boundaries. Because of its novel framework, Y.3113 requires its own procedures, functional entities, interfaces, and overall architecture. At the network design phase, the boundaries of ADs should be decided. The size of an AD is a key network design parameter. It affects the number of FAs, number of flows in an FA, the number of regulators, and the end-to-end (E2E) latency bound itself. In the call setup phase, given the traffic specification of a flow, the E2E latency bound must be pre-calculated with the cooperation among ADs. An FA may have flows join/leave dynamically, therefore it is necessary to re-negotiate the E2E latency bounds with the sources of flows in the FA. This is called the dynamic QoS negotiation.

In the Internet or the IMT-2020 network there are inevitably multiple network domains, with possibly different QoS frameworks. For example, in the IMT-2020 networks access networks ~~(ANs)~~, core networks ~~(CNs)~~, and the network slices ranging across core networks ~~CNs~~ have different QoS provisioning architecture. The fronthaul network of the IMT-2020 may have Ethernet based architecture with the IEEE 802.1 TSN profile that requires class-based strict priority scheduling, token bucket type flow metering, and frame pre-emption, while core networks may be based on MPLS and DiffServ architecture with metering functions at the edge and class-based schedulers. It is necessary to cope with such different types of edge networks.

Further, with network slicing technology emphasized in IMT-2020 and beyond, the link and buffer resource should be strictly and dynamically divided and allocated to virtual networks according to the slicing requests. Resource allocation negotiations among different networks should be plausible.

In this Recommendation it is described the architecture, the functional entities, the interfaces, and the procedures including the cooperation among heterogeneous QoS network domains.

Keywords

Latency guarantee, large scale network, flow aggregate, quality of service, regulator

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Functional Architecture for latency guarantee in large scale networks including IMT-2020 and beyond

1 Scope

This Recommendation specifies the architecture and procedures for latency guarantee in large scale networks, based on the requirements and framework specified in ITU-T Y.3113, as follows:

- Architecture
- Functional entities and their interfaces
- Operational pProcedures for the aggregation domain design, the call setup, the dynamic QoS negotiation, etc.

Detail protocols, routing and upper layer functions are out of scope of this Recommendation. If necessary, the document will, instead, reference the existing works appropriately.

2 References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-R M.1645] Recommendation ITU-R M.1645 (06/2003), *Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000*.

[ITU-R M.2083] Recommendation ITU-R M.2083-0 (09/2015), *IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond*.

[ITU-T E.800] Recommendation ITU-T E.800 (09/2008), *Definitions of terms related to quality of service*.

[ITU-T Y.2111] Recommendation ITU-T Y.2111 (2006), *Resource and admission control functions in Next Generation Networks*.

[ITU-T Y.2121] Recommendation ITU-T Y.2121 (2008), *Requirements for the support of flow-state-aware transport technology in NGN*.

[ITU-T Y.2122] Recommendation ITU-T Y.2122 (2009), *Flow aggregate information exchange functions in NGN*.

[ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network.*

[ITU-T Y.3113] Recommendation ITU-T Y.3113 (2021), *Requirements and framework for latency guarantee in large scale networks including IMT-2020 network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IMT-2020 [ITU-R M.2083]: Systems, system components, and related technologies that provide far more enhanced capabilities than those described in [ITU-R M.1645].

NOTE – [ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network.

3.1.2 customer premises equipment [ITU-T E.800]**:** Telecommunications equipment located at the customer installation on the customer side of the network interface.

3.1.3 service provider [ITU-T E.800]**:** An organization that provides services to users and customers.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 aggregation domain: A maximal set of the interfaces of the consecutive relay nodes in the path, travelled by a flow, in which the 'flow membership' of the flow aggregate the flow belongs to is unaltered. An aggregation domain is defined per a flow.

3.2.2 domain: A set of relay nodes and end-hosts under a single administrative control or within a closed group of administrative control; these include campus wide networks, private WANs, and IMT-2020 networks.

NOTE – This definition references the description in Introduction clause of [b-IETF RFC 8655].

3.2.3 large scale network: A network or a set of interconnected networks, with diameter of 16 or larger, in which the numbers of flows and nodes are proportional to the diameter of the network.

3.2.4 relay node: A node supporting relay functionality that acts as an intermediary node, through which other nodes can pass their traffic (e.g. router, switch, gateway, etc.).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

~~5QI 5G QoS Identifier~~

AD Aggregation Domain

~~AN Access Network~~

ATS Asynchronous Traffic Shaping

~~CN Core Network~~

CPE Customer Premises Equipment

DiffServ Differentiated Services

~~DL Downlink~~

~~DN Data Network~~

E2E End-To-End

FA	Flow Aggregate
FIFO	First-In First-Out
~~GBR~~	~~Guaranteed Bit Rate~~
~~GFBR~~	~~Guaranteed Flow Bit Rate~~
IntServ	Integrated Services
IR	Interleaved Regulator
PD-FE	Policy Decision Functional Entity
PE-FE	policy Enforcement Functional Entity
PFAR	Port-based Flow Aggregate Regulator
~~MDBV~~	~~Maximum Data Burst Value~~
~~MFBR~~	~~Maximum Flow Bit Rate~~
~~NGBR~~	~~Non-GBR~~
~~PDB~~	~~Packet Delay Budget~~
~~PDU~~	~~Protocol Data Unit~~
~~QFI~~	~~QoS Flow ID~~
QoS	Quality of Service
RACF	Resource and Admission Control Function
RSpec	Request Specification
RSVP	Resource reSerVation Protocol
TRC-FE	Transport Resource Control Functional Entity
TRE-FE	Transport Resource Enforcement Functional Entity
~~SDF~~	~~Service Data Flow~~
~~SMF~~	~~Session Management Function~~
~~TDM~~	~~Time Division Multiplexing~~
TSN	Time Sensitive Network
TSpec	Traffic Specification
~~UE~~	~~User Equipment~~
~~UL~~	~~Uplink~~
~~UPF~~	~~User Plane Function~~
~~uRLLC~~	~~Ultra-Reliable Low Latency Communications~~

5 Conventions

~~None.~~The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6. Introduction

[Editor's Note: any contributions to further improve or fill any missing gaps are invited.]

Latency sensitive applications across multi-domain large scale networks emerge, such as autonomous driving, augmented reality, virtual reality, tactile internet, and smart industry. ITU-T Y.3113 describes the requirements and framework for latency guarantee in large scale networks.

ITU-T Y.3113 combines the FA-based queuing and scheduling architecture and the regulators at the aggregation domain (AD) boundaries. The framework requires its own procedures, functional entities, interfaces, and overall architecture to be specified. At the network design phase, the boundaries of ADs should be decided. The size of an AD is a key network design parameter. It affects the number of FAs, number of flows in an FA, the number of regulators, and the end-to-end (E2E) latency bound itself. FA granularity should be also be decided. In the call setup phase, given the traffic specification of a flow, the E2E latency bound must be pre-calculated with the cooperation among ADs. An FA may have flows join/leave dynamically, therefore it is necessary to re-negotiate the E2E latency bounds with the sources of flows in the FA. This is called the dynamic QoS negotiation.

In the Internet or the IMT-2020 network there are inevitably multiple network domains, with possibly different QoS frameworks. For example, in the IMT-2020 networks access networks (ANs), core networks (CNs), and the network slices ranging across CNs core networks have different QoS provisioning architecture.

Further, with network slicing technology emphasized in IMT-2020 and beyond, the link and buffer resource should be strictly and dynamically divided and allocated to virtual networks according to the slicing requests. Resource allocation negotiations among different networks should be plausible.

In this Recommendation it is also described the cooperation among heterogeneous QoS network domains in the framework.

7 High level functional architecture

7.1 Aggregation domain (AD)

An aggregation domain is defined per a flow. As it is defined in clause 3.2.1, an AD is a maximal set of the interfaces of the consecutive relay nodes in the path, travelled by a flow, in which the 'flow membership' of the flow aggregate the flow belongs to is unaltered. There should be one or more non-overlapping aggregation domains (ADs) in an end-to-end path of a flow. Based on the FA, the queuing, scheduling, and regulation are executed. An important consequence of such treatment based on FA is that the first-in first-out (FIFO) characteristic of the FA is maintained within an AD. Requirement 7 in ITU-T Y.3113 specifies that it is required that networks be able to handle FAs as control elements. This requirement mandates that the network relay nodes should be able to queue and schedule a packet according to FA. However, in an extreme case in which flows are treated based on their class, such as in DiffServ, an AD is limited to a single interface of a node. In this case, the membership of an FA is unaltered only for a single hop. Note that this case still meets the requirement 7 in ITU-T Y.3113.

For example, flows with an identical path may have different ADs. An AD may have a regulation function at its segregation point. Figure 1 a scenario in which the flows with the same path (flow 1 and 2) are put into different FAs thus have different ADs.

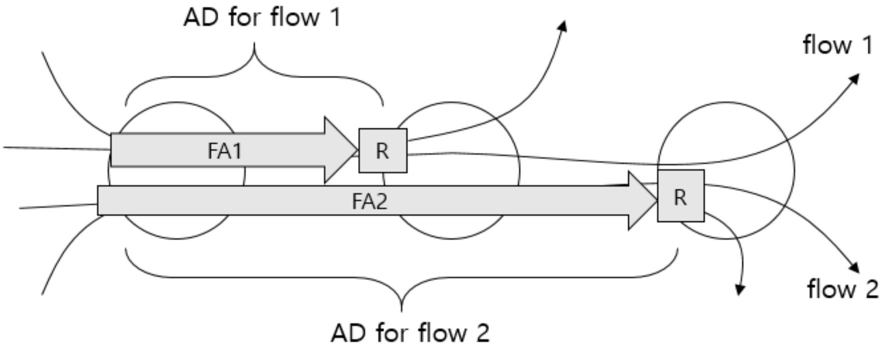

Figure 1 – Aggregation domain for each flow

In reality, the flows with the same path and similar traffic specifications are likely to belong to a single FA and have an identical AD.

7.2 Aggregation point of an AD

An aggregation point of an AD is defined to be a functional entity, at which the flow is aggregated into an FA. An aggregation point is defined per flow. An exemplary location of an aggregation point is an output port of a relay node. An aggregation point is part of an AD.

7.3 Segregation point of an AD

A segregation point of an AD is defined to be a functional entity, at which the FA is segregated. The flows are separated into different output paths. A segregation point is defined per flow. An exemplary location for a segregation point is an input port (or a switch fabric) of a relay node. A segregation point is part of an AD.

7.3 Location of regulation functions

A regulation function is recommended to be collocated with the segregation point of an AD. By placing a regulation function with the FA segregation, the FIFO characteristic of the AD for the flows can be kept before the regulation. However, the regulation function may be omitted for an AD; or the regulation functions may be placed anywhere in an AD.

7.5 Relay node capability

The relay nodes may have incomplete transport functionality. For example, a legacy node does not have the FA based scheduling or the regulation function. The FA based scheduling function is required to guarantee both 1) the FIFO characteristic among the packets within an FA and 2) the isolation of an FA with a separated queue. A simple FIFO scheduler with a single queue, as well as a weighted fair queuing scheduler with separated queues, would guarantee the FIFO characteristic for any FA. However, a FIFO scheduler can accumulate the maximum burst of FAs sharing the queue. If a cycle is formed by relay nodes with such FIFO schedulers, one cannot guarantee a latency bound. As such, it is required that the FA based scheduling supports the FA isolation.

Based on the supporting functions, relay nodes are categorized as the following:

- CAT 0: A relay node without the FA based scheduling or the regulation function.
- CAT 1: A relay node with the FA based scheduling but without the regulation function.

- CAT 2: A relay node with the regulation function but without the FA based scheduling
- CAT 2-1: A relay node dedicated for the regulation function. This type of relay nodes does not have the switching capability.
- CAT 3: A relay node with both the FA based scheduling and the regulation function.

7.6 Regulation function capability of a node

The regulation refers to a function of keeping packets in a buffer according to a predetermined rule even if packet transmission is possible. It resides in relay nodes, or is placed in separated physical devices. It may be available only in some relay nodes. It is preferable that a regulation function is collocated with the segregation point of an AD. The location information of the regulation functions is preferable to be gathered prior to an AD design. This information is gathered through a dedicated interface with an automated procedure or manually. The regulation function, however, is independent of flow aggregation/segregation functions. The regulation functions may also be placed at the middle of an AD.

7.7 Regulation function taxonomy

A regulation function is categorized based on its queue management scheme and the regulation target entity. The per flow regulation function has queues per flow and regulates based on a flow-level regulation rule. The interleaved regulator (IR) has a single queue for a set of flows but is based on a flow-level regulation rule. An IR examines the packet at the head of the queue, checks the flow it belongs to, and determines when to transmit the packet. The per FA based regulator has a single queue for the FA, and the regulation target is the FA itself. The regulation rule is based on the FA's parameters such as the sum of flows' arrival rates, which belongs to the FA. An example of FA-based regulators is described in Clause 9.1 and Appendix I.

8 Mechanisms and operation procedures

~~[Editor's Note: This clause is currently a rough draft. Further refinement is necessary]~~

8.1 AD decision

The ADs have to be determined with considerations of many aspects. The size of an AD decides the number of the boundary ports of the AD, therefore the number of input-output ports pairs of the AD, and the number of FAs within the AD. Smaller the AD, fewer FAs, fewer queues necessary, thus simpler the network schedulers. On the other hand, smaller AD means more ADs in the path, larger the latency bound. The balanced point in between has to be determined in the network design phase. As the network state dynamically changes, AD merge and division should also be possible.

8.2 AD alteration

Aggregation domains may be merged or divided anytime. The ADs have to be determined with considerations of many aspects. The size of an AD decides the number of the boundary ports of the AD, therefore the number of input-output ports pairs of the AD, and the number of FAs within the AD. Simply put, smaller the AD, fewer FAs, fewer queues necessary, thus simpler the network schedulers. On the other hand, smaller AD means more ADs in the path, larger the latency bound. The balanced point in between has to be determined in the network design phase or during the runtime. As the network state dynamically changes, AD merge and division is recommended to be possible.

8.3 FA granularity decision

[Editor's Note: One of the requirements for the framework is that the flows with different in/out port pairs should belong to different FAs. Flows with the same in/out port pairs may or may not belong to athe same FA. More criteria, such as latency bound requirements or maximum burst size may be considered for FA granularity. Finer granularity means better performance but more complexity.]

- FA granularity negotiation among ADs should be possible.

8.4 Call setup

[Editor's Note: The call setup mechanism includes the admission control and resource reservation. They are covered in numerous standards such as IETF resource reservation protocol (RSVP) [b-IETF RSVP] and ITU-T Y.2111 (resource and admission control function, RACF). RSVP has the path-coupled (in-band) control mechanism, while RACF has specific interfaces between control function entities (out--of-band). It should be considered in the framework that the AD and the administrative domain may not be identical.]

- Network may provide to the flow multiple latency bounds to choose. The flow may select one of them.
- The TSpec may include token bucket parameters (a burst size and an input rate), a peak rate (p), and a maximum datagram size (M). If a packet is larger than M, then it may not receive the same service with the conforming packets.
- Upon the flow admission request, the end-to-end path should be decided; and the guaranteed performance level should be calculated and notified to the flow.
- Existing best-effort service traffic should not affect the latency bound of the high priority flows. Networks should be aware of the best-effort service traffic and take it into consideration.
- For another example, the QoS provisioning is based on the network allowance. This means that an individual flow does not specify their latency bound requirement (RSpec in IntServ). Rather, as a flow specifiesy traffic specification (for example the burst size and the input rate), then based on the best end-to-end path among those can be provided, the feasible latency bound is calculated and notified to the flow. The flow decides whether to accept or not.
- Interactions among supporting domains (or "Transport network" in the following figure) should be possible. There are two scenarios for passing the QoS information for a given service over an end-to-end path. [Y.2111 RACF]

1) In scenario 1, the QoS requirements and information for a given flow's service can be passed over the end-to-end path through application layer signalling or through the Ri reference point between RACF.

2) In scenario 2, the QoS requirements for a given service can be passed over the end-to-end path through path-coupled QoS signalling (e.g., RSVP-like).

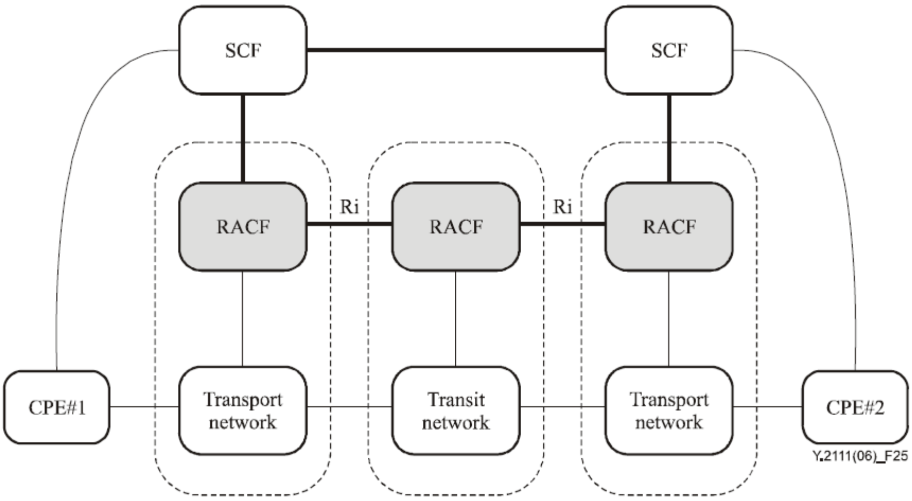

Figure 25/Y.2111 – Inter-operator RACF communications

Figure 2. Overall NGN architecture with RACF [Ed. note: The caption embedded in the figure will be removed]

8.5 Dynamic QoS negotiation

~~[Editor's Note: ~~The IntServ's admission control is static. It guarantees a fixed service rate to a flow during its lifetime. It is simple but may under-utilize the network. It is required in the framework of the dynamic QoS negotiation. The network or the end-host may initiate the re-negotiation. A single flow's renegotiation may result in all the other flows' renegotiation. As such this process must be executed with care.~~]~~

- The service level negotiation can be a two-way handshake, or a more complex process.
- The simplest negotiation is that of the IntServ. Flow specifies its Request-spec and Traffic-spec. Network decides whether it is met. If not, it den~~ies~~ies ~~the ~~admission.
- Latency budget negotiation should be possible.
- Dynamic admission control information exchange should be possible. (Current flow's latency guarantee status)
- If the first negotiation failed, the flow may restart with a new TSpec.

8.6 Flow treatment in data plane

After the call setup process (the admission and resource reservation process), an admitted flow shall be aggregated into an FA at the entrance of an AD according to the aggregation criteria applicable to the flow.

An FA should be queued, scheduled, and regulated according to the requirements defined in Y.3113. In Y.3113 it is required that the FIFO characteristics of a flow should be preserved within an AD. A simple FIFO scheduler that accommodates all the FAs in a single queue, or separate queues per FA can fulfil the requirements. In order to minimize the E2E latency, it is recommended to have separate queues per FA and a fair scheduler for the queues at the output ports. A FIFO queue that accommodates all the FA in the same priority can be allowed, for relatively simple networks, in which a burst accumulation is not problematic.

Y.3113 also requires interleaved regulators per FA be placed at the boundary of an AD.

An FA within an AD is treated as a single control entity, i.e., the flow inside an FA is not a control target. However, whenever a flow joins/leaves, the schedulers and regulators should take these changes into account. The schedulers shall update the fair rates that should be allocated to the FA. The regulators shall update the proper sustainable rate and maximum burst of the FA to be regulated.

9 Architecture

[Editor's Note: This clause is currently a rough draft. Further refinement is necessary]

[Editor's note: mapping the logical architecture of lg-lsn into IMT-2020 may be necessary and associated contributions are invited. Scope, summary and introduction clauses may be revisited for the same purpose.]

Based on the framework defined in Recommendation Y.3113, a network can have arbitrary aggregation domains and regulators in between. A switching node in a network can be a part of an AD. Even only a part of a switching node can be included in an AD. An example network of the framework is depicted in Figure 3, in which non-overlapping ADs partition the network, and regulators are implemented between the ADs. Note that different types of regulation functions, described in 7.7, are allowed. Assume the network in Figure 3 is perfectly symmetrical. A flow travels

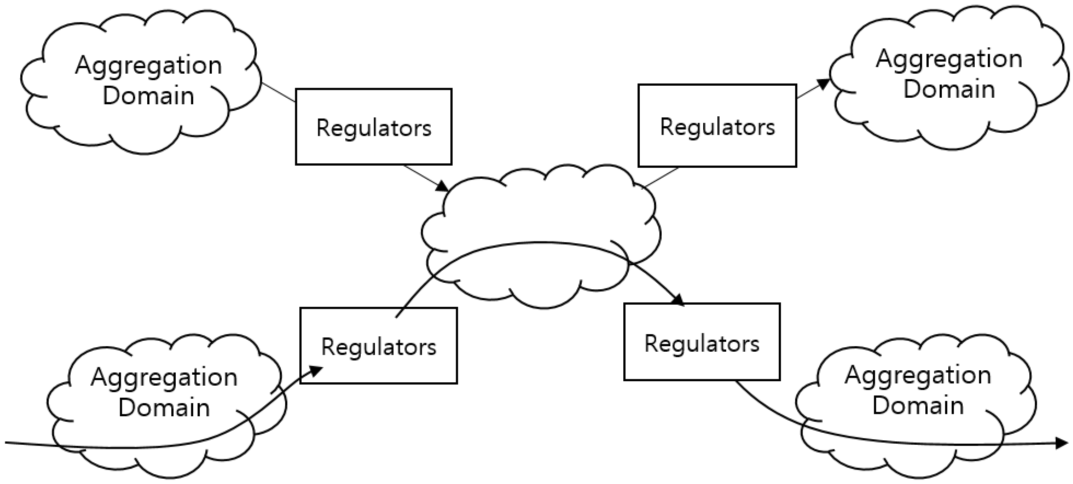

Figure 3 – An example network architecture of the framework.

d domainsADs, with identicallly *h* hops in an domainAD, which further makes the total number of hops the flow travels is $E=hd$. The critical design choice in this architecture would be the value of *h* (and thus *d*), given *E*.

9.1 Architectures of networks with single node ADs

The aggregation domain in Figure 3 can be a single hop, i.e. is restricted within a relay node or spans over a single link. In this case a flow aggregate within the AD can then be configured to be a set of flows sharing the same input and output ports of the node. As such, some of existing QoS frameworks become a specific architectural example of the general framework described in this Recommendation. For example, IEEE TSN ATS can be modelled with a strict priority scheduling node as a single hop AD and the minimal IR as a regulator. Another example is to model a strict priority scheduling node as a single hop AD and a regulator per FA, which is based on input/output port pairs of a flow. Such a regulator is called Port-based Flow Aggregate Regulator (PFAR). The details of PFAR architecture is described in Appendix I.

9.2 Architectures of networks with multiple node ADs

The aggregation domain in Figure 3 can also be a multiple hop. The flow aggregates in such an AD is defined according to the ingress and egress ports of the AD. One possible configuration for an FA is to put all the flows with the same {ingress, egress ports} pair into a single FA. Finer FA can also be configured, for example according to the performance requirements. The critical design choice in the ADs with multiple hop is ~~that~~ whether to allocate a separate queue in each node for an FA.

If so, then the scheduler for the queues of the FAs with the same priority should provide fair sharing, preferably be one of the fair-queuing schedulers, such as the deficit round robin scheduler.

If not, i.e. multiple FAs are put into a single queue, then the burst accumulations among the FAs occur and possibly the burst explosion happens as well because of the cyclic dependency. As such,~~ a~~ careful planning to avoid the cyclic dependency is necessary. One way of avoiding such a problem is to place regulators inside the AD, to cut the cycles formed by FAs inside the AD.

10 Functional Entities

10.1 ~~Overview~~ Functional entities defined in~~of~~ Y.2111 RACF

This recommendation follows the overall framework defined in Y.2111. The main focus in this document is on the transport functions below the RACF, as depicted in Figure 4.

In Y.2111, it is described that the policy decision functional entity (PD-FE) handles the QoS resource requests received from the SCF via the Rs reference point or from the policy enforcement functional entity (PE-FE) via the Rw reference point. The PD-FE decides the admission of a flow. It monitors the available resources, maps the service request to the network resource, and decides the policy regarding the resource allocation to the flows.

The t~~T~~ransport resource control functional entity (TRC-FE) collects and maintains the network information and resource status information. It is also responsible for the technology dependent information maintenance~~s~~.

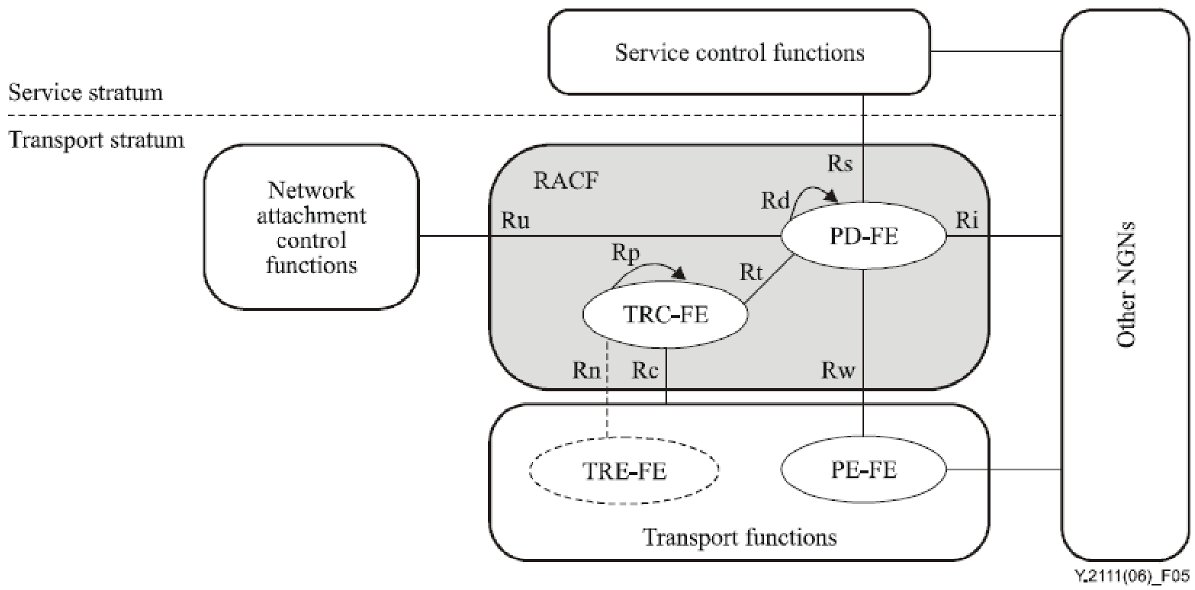

Figure 5/Y.2111 – Generic resource and admission control functional architecture in NGN

Figure 4 – Generic RACF architecture in NGN [Ed. note: The caption embedded in the figure will be removed]

The ~~policy enforcement functional entity (~~PE-FE~~)~~ in the transport functions enforces the network policy rules instructed by the policy decision functional entity (PD-FE) on a per-subscriber and per-IP flow basis. The PE-FE includes functions such as rate limiting, bandwidth allocation, packet filtering, traffic classification and marking, traffic policing and shaping, as well as collecting and reporting resource usage information.

The transport resource enforcement functional entity (TRE-FE) enforces the transport resource policy rules instructed by the transport resource control functional entity (TRC-FE) at the technology-dependent aggregate level (e.g., VLAN, VPN and MPLS). It should be able to perform the functions based only on transport link information (e.g., VLAN/VPN ID, and LSP Label). For example, a TRE-FE may be used to modify the bandwidth associated with an LSP, or to set ATM traffic management parameters such as cell rate or burst size.

10.2 Additional functionalities required to RACF

The TRC-FE, while responsible for the technology dependent network control, should be able to handle the AD decision and alteration. It should be able to decide the granularity and the resource allocated to the FA.

The TRE-FE should be able to enforce the actual amount of the resources allocated to FAs such that the latency bound in an AD for the FA is adjustable. The regulators and schedulers are under direct control of the PE-FE.

The PE-FE should be able to perform the regulation and scheduling functions.

A single set of the TRE-FE and PE-FE can be allocated to a single AD, or multiple ADs. If the network has the capability of merging and dividing ADs as described in 8.2, then s single TRE-FE and PE-FE pair should be able to handle multiple ADs. This relationship is depicted in Figure 5. Note that the interface Rx is newly defined in this Recommendation.

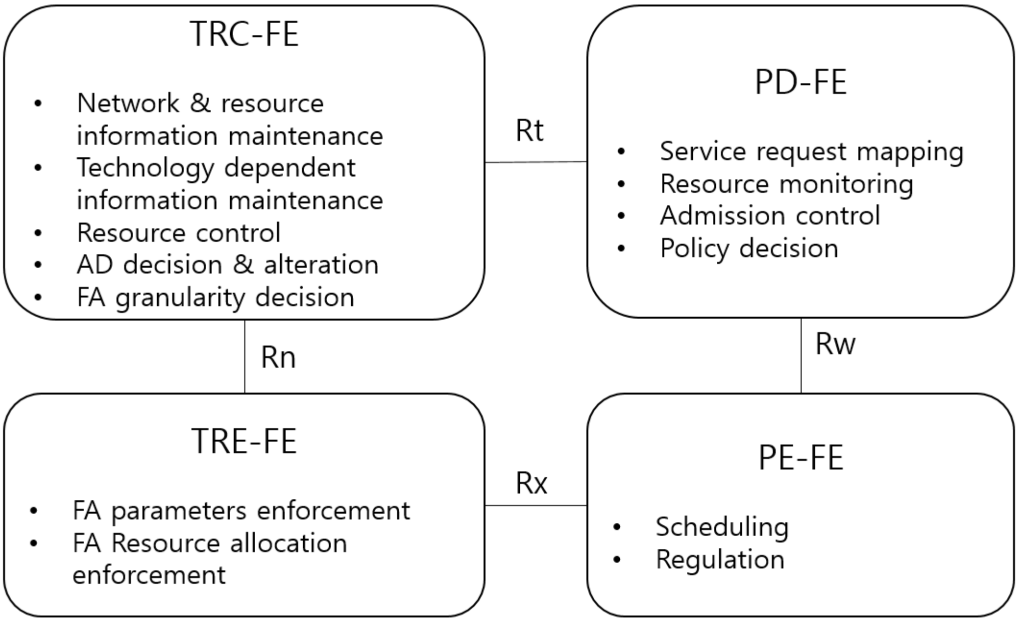

Figure 5 – Functional architecture for latency bound guarantee

11 Reference points

12. Security Considerations

The QoS management of IMT-2020 network includes ~~UE~~user equipments, ~~ANs~~access networks, and ~~CN~~ core networks that are subject to security and privacy measures. Sensitive information should be protected as a high priority in order to avoid leaking and unauthorized access. Security and privacy concerns should be aligned with the requirements specified in [b-ITU-T Y.2701] and [b-ITU-T Y.3101].

Appendix I

Architectural example: Port-based FA Regulator (PFAR)

(This appendix does not form an integral part of this Recommendation.)

A port-based flow aggregate (PFA) is defined to be a set of flows with thea same priority sharing the input and output port in a relay node such as a switch or a router. If there are N ports in a switch, and *C* classes, then there can be at most N^2C PFAs in the switch. There can be *NC* such PFAs in a single output port module, ignoring the fact that there is no flow having an output port that is the same with the input port. In this architecture a regulator may be placed for each high priority PFA in an output port module, just before the class-based queueing/scheduling system of the output port module. We call this regulator the Port-based flow aggregate regulator, PFAR. A PFAR sees a PFA a single flow with the parameter {the sum of initial arrival rates; the sum of initial maximum bursts} of the flows in the PFA, and regulates the PFA to meet the parameters. By the initial parameter of a flow, we mean the parameter of a flow at the source as it generates the flow according to the traffic specification (i.e. TSPEC defined in DiffServ framework). The PFARs can be placed at the output port of a switch for the regulation of high priority traffic. Figure I.1 depicts an example architecture of the data-plane of a switch having the PFARs within the output modules.

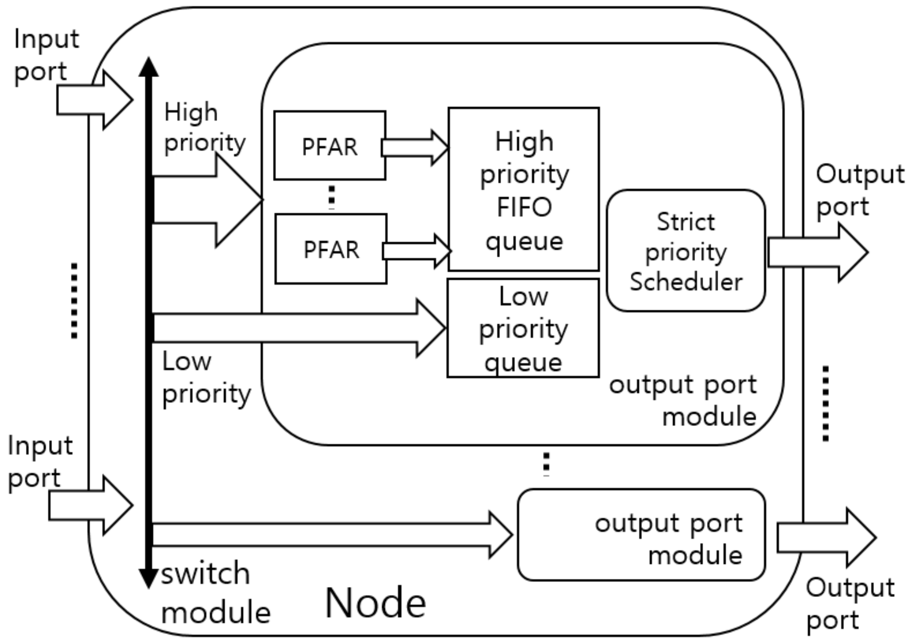

Figure I.1 – Example architecture of a node with PFARs at the output port modules

A network with switches with PFAR is an extreme example of the general architecture in Figure 3. Here the AD is from the scheduler to the next node's output module and the regulator is a set of PFARs in an output module of a switch, as depicted in Figure I.2. The AD encompasses submodules in two nodes, but the FA can be defined based on the seconds node’s input and output ports.

Similarly, as another example, IEEE TSN ATS can be modelled with a strict priority scheduling node as a single hop AD and the minimal IR as a regulator.

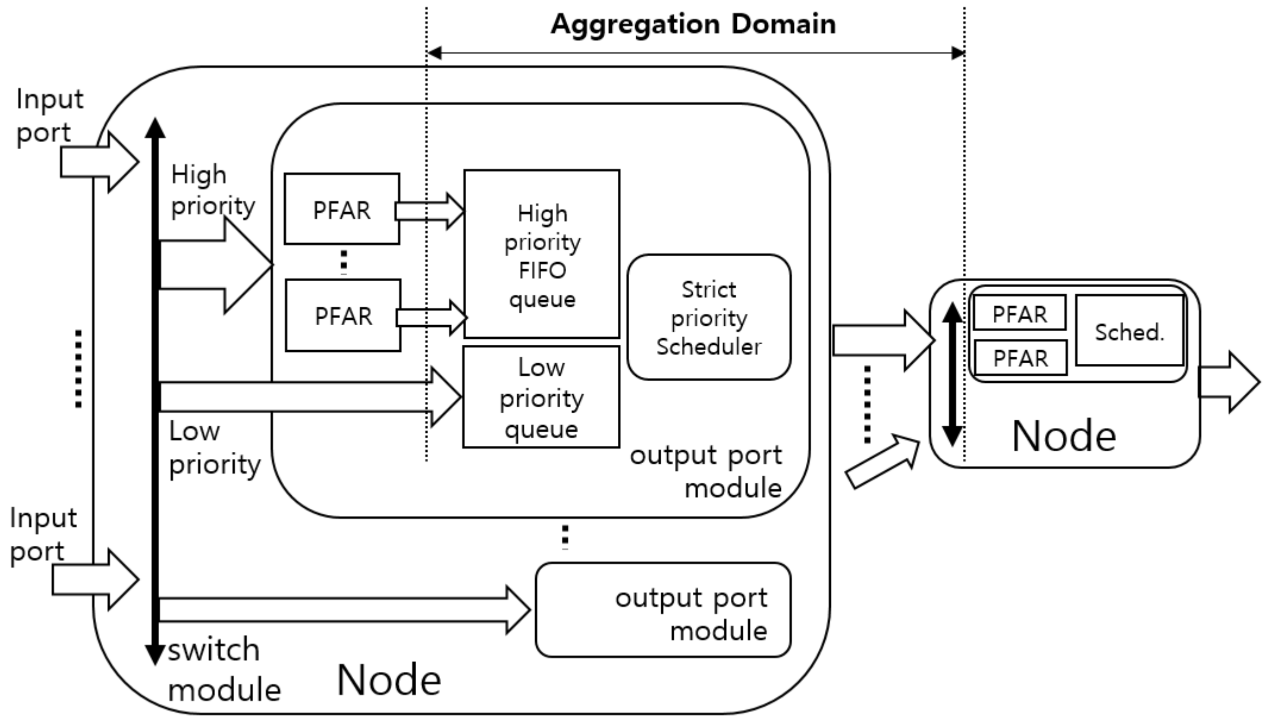

Figure I.2 – Mapping between the general architecture and PFARs at the output port

By PFAR, the complexity of regulation is reduced therefore the architecture becomes scalable. In ATS, two factors contribute to the implementation difficulty. First, it has to ~~be~~ identify~~ied~~ the flow that the packet at the head of the queue (HOQ) belongs to. The current flow state, thus the eligible time of the flow can then be obtained. Second, the individual flow state has to be maintained in order to be able to decide the eligible time of a packet. While the latter is the complexity within a control plane, the former impacts the real-time data-plane packet processing. With the PFAR, the HOQ flow identification process is unnecessary, and only hundreds of PFAs' states, instead of millions of flows' states, are maintained at a switch.

It is well known that a network with cycles suffers from the cyclic dependency problem. A carefully deployed PFAR, as well as an IR or a per-flow regulator, can break any cycle in a network. The delay bound of a network with PFAR is comparable to that of a network with ATS IRs. For detailed knowledge on the performance of PFAR, see [b-Joung-2022].

Bibliography

[b-ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

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