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Abstract: This document is the output of draft Recommendation ITU-T Y.det-qos-reqts-lan "QoS requirements and framework for supporting deterministic communication services in local area network for IMT-2020", resulting from discussion of Q6/13 meeting on 4-15 July 2022.

This document is the output of draft Recommendation ITU-T Y.det-qos-reqts-lan "QoS requirements and framework for supporting deterministic communication services in local area network for IMT-2020", resulting from discussion of Q6/13 meeting on 4-15 July 2022.

This document is based on this meeting's discussion and results on the following contribution:

No.	Title	Source	Main discussion and results
SG13-C155	ITU-T Y.det-qos-reqts-lan	China Unicom, Zhejiang Lab,	1. The scope is updated in order to

	"Frameworks and QoS requirements for supporting deterministic communication services in local area network for IMT-2020": proposal for updating clause 1,3,4,7,8 and 9	University of Science and Technology Beijing	reflect the soul of the main body which are the QoS requirements and framework of deterministic communication services of heterogeneous network technologies in the local area network is the focus of this Recommendation. A new editor's note for appendix is added. 2. the term, "gateway" is replaced with "interworking module". The whole document is aligned with the new term "interworking module". The term "station" is adopted to replace of "terminal" of the document. 3. in clause 3.2, definition for "local area network" is updated; based on the meeting's discussion, a new definition for technology domain is added. 4. 5G is replaced with 5G NPN to exactly match the context of local area network. And a new reference for 5G NPN is added in the bibliography. 5. a new editor's note is added for figures of clause 7.2, 7.3 and 7.4. 6. based on the meeting's discussion, a new clause 7.5 "Basic process for Deterministic communication services in local area network is added". 7.clause 8 is updated based on the contribution and the meeting's discussion. 8. clause 9 is updated based on the contribution and the meeting's discussion. 9. a new references for "periodic control applications" is added in the bibliography.

Table of Contents

Draft new Recommendation ITU-T Y.det-qos-reqts-lan

QoS requirements and framework for supporting deterministic communication services in local area network for IMT-2020

Summary

Keywords

Inter technology domain~~Inter-domain~~, deterministic communication services, local area network, framework, QoS requirements, IMT-2020

Introduction

<Optional – This clause should appear only if it contains information different from that in Scope and Summary>

1 Scope

Deterministic communication services supported by local area network may benefit verticals. Deterministic applications enabled by deterministic communication services can be supported by local area network both with isomorphic network technology and with heterogeneous network technologies.The QoS requirements and framework of deterministic communication services of heterogeneous network technologies in the local area network is the focus of this Recommendation.

~~-~~To analysis ~~end-to-end~~ deterministic communication services in the local area network, three scenarios are identified. Then ~~to support the three identified scenarios,~~the QoS requirements for deterministic communication services are specified. Based on the identified QoS requirements, ~~a~~a framework ~~for the deterministic communication services in the local area network~~ is abstracted~~.~~ ~~Based on the abstracted framework, the QoS requirements are specified~~.

The scope of the Recommendation includes:

- Introduction on the deterministic communication services in local area network
- Scenarios of deterministic communication services in local area network
- QoS requirements of deterministic communication services in local area network
- Framework of deterministic communication services in local area network

Appendix: to be added. ~~*Contributor*~~[Editor's note: a use case to be added in order to give sample(s) of deterministic communication services being used in local area network (e.g. in industry park, factory, etc.) to link the related technologies described in this draft Recommendation with specific LAN technologies.]

~~[Editor's note: clarification of the scope of this draft Recommendation needs to be provided. For example, interworking of technology domains is a main focus.]~~

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

TBD

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IMT-2020 [ITU-T Y.3100]: (Based on [ITU-R M.2083]) Systems, system components, and related technologies that provide far more enhanced capabilities than those described in [ITU-R M.1645].

3.1.2 Bearer service [b-ITU-T I.112]: A type of telecommunication service that provides the capability for the transmission of signals between user-network interfaces.

3.1.3 Teleservice [b-ITU-T I.112]: A type of telecommunication service that provides the complete capability, including terminal equipment functions, for communication between users according to protocols established by agreement between Administrations and/or recognized operating agencies (ROAs).

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 local area network: A shared or switched medium peer-to-peer communications network that broadcasts information for ~~stations terminals~~ stations directly or via an interworking module~~a gateway~~ to receive within a moderate-sized geographic area, such as a single office building~~ or~~ , a campus, a workshop, a factory or an industrial park. ~~The network is generally owned, used and operated by a single organization.~~ It provides services including those of the physical layer, the MAC layer, and the transport layer. [b-ITU-T H.322]

NOTE 1 – In a single local area network, multiple network technologies (TSN, real-time Ethernet, WiFi, 5G NPN [b-3GPP NPN]as examples) may co-exist and be connected with each other via interworking modules. ~~Technology domains in the local area network are divided according to these network technologies.~~

~~[Editor's note: the term 5G needs more clarification.]~~

~~– Multiple network technologies, such as TSN, real-time Ethernet, WiFi, 5G etc,. may be used in a single local area network.~~

NOTE 2 – the interworking module~~gateway (s) is used to connect the~~ provides necessary functionalities, e.g., network interconnection, protocols translation, and broadcasting ~~-~~support, for interworking of heterogeneous network technology domains~~ies~~ in the local area network.

~~[editor's note: technology domain definition is needed.]~~

3.2.2 technology domain: A local area network with the same network technology, i.e., the same physical layer and data link layer schemes, with which the stations can send and receive information

without interworking module. ~~*[Editor's note]: the definition for local area network need to be further improved to reflect the scope and the study objects of the draft Recommendation.*~~

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

5G 5th Generation Mobile Communication Technology

CM Control and Management

HD High Definition

IM Interworking Module

NPN Non-public network

OT operational technology

TD technology domain

TSN time sensitive network

WiFi Wireless Fidelity

TD Technology domain

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document 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**" and "**may**" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are 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 on the deterministic communication services in local area network

~~*[Editor' note]: this section will provide introduction on deterministic communication services and the value of deterministic communication services in the local area network.*~~

It's getting clearer that the verticals need deterministic communication services to support their services or products development. Deterministic communication services are a set of data transmission capabilities provided for vertical industries through local area network. These services can provide data transmission with characteristics of bounded delay, bandwidth, jitter and packet loss rate.

Verticals can get benefits from deterministic communication services. Smart grid is an example. Based on [b-ITU-T Smart Grid], [b-IEEE], [b-Niwas Maskey], [b-Carlos H. Barriquello] and other academic papers, the deterministic communication services may provide the smart grid with more reliable QoS guarantee for network communication, not only in metro and core but also in local area.

Smart manufacturing is another example. Deterministic communication services are needed by levels of automation [b- Rasmus Suhr Mogensen]. Especially time-sensitive applications, high reliability applications in the local area can benefit from deterministic communication services.

To fulfil the requirements for deterministic communication services from the verticals, deterministic related network technologies (TSN, real-time Ethernet, WiFi, 5G NPN as examples), are evolving.

In practice, in the scenarios of a single local area network (the LAN used in a building, a factory, or an industrial park as examples), multiple network technologies are usually used. For example, in a factory, TSN may be used for the machine control of the production-line; WiFi may be used for cameras; 5G NPN may be used for connecting the TSN system with the cameras.

Though each network technology is evolving on its own, it is necessary to study the coordination mechanisms of these technologies so that they can connect with each other as different technology domains (TDs) in the local area network, so as to guarantee the required QoS. ~~cross network technologies (i.e., heterogeneous network technologies) in order to ensure end-to-end QoS guarantee in the local area network.~~

7 Scenarios of deterministic communication services in local area network

~~*[Editor' note]: this section will consider the following two scenarios (it will be pointed that the technologies on intra-domain scenarios are out of the scope):*~~

- ~~*Service scenarios for deterministic communication in local area networks*~~
  - ~~*Intra-domain deterministic communication services*~~
  - ~~*Inter-Domain deterministic communication services*~~

7.1 Deterministic communication services in local area network

~~*Domain: in a single local area network, multiple network technologies (TSN, real-time Ethernet, WiFi, 5G as examples) may co-exist and be connected with each other via IMSgateways. Domains are divided according to these network technologies.*~~

In local area network, deterministic applications can be enabled by deterministic communication services supported by heterogeneous network technologies.

NOTE – in local area network, deterministic application can ~~also~~ be supported by local area network both with isomorphic network technology and with heterogeneous network technologies. ~~But t~~The heterogeneous network technologies for support of deterministic communication services in local area network is the focus of this Recommendation.

Basic communication services include bearer services and teleservices [b-ITU-T Q.1743 (09/2016)].

~~According to~~Based on [b-ITU-T I.112], deterministic communication services is a type of teleservices with additional capabilities which can ensure deterministic communication performances. Compared with best-effort communication, the performances of deterministic communication have narrower performance ranges which means that the differences between the best performance and the worst performance in these ranges are small.

In this Recommendation, in order to study QoS requirements and framework of deterministic communication services that adopt heterogeneous network technologies in the local area network, the technology domains (TDs) are defined. A local area network can be composed by several TDs. As shown in Figure 1, the deterministic communication service in the local area network can support the deployment of deterministic applications in different TDS, i.e., inter technology domain deterministic communication services. For example, the deterministic communication service can

support communication for deterministic application 1 in TD1 (5G NPN is the network technology adopted by TD1) and deterministic application n in TD n (TSN or WiFi is the network technology adopted by TD n).~~the technology domains (TDs) are divided according to different network technologies. For example, as shown in figure 1, devices (including terminal devices and network devices) supporting TSN 5G together with the TSN 5G network linkages among these devices are divided as the TD 1; devices (including terminal devices and network devices) supporting 5G TSN or WiFi together with the TSN5G or WiFi network linkages among these devices are divided as the TD 2.~~

In the~~a single~~ local area network, ~~gateway(s)~~ IM(s) (interworking module(s)) ~~-~~is used in order to support of deterministic communication service across multiple ~~domains~~TDs, as shown in figure 1.

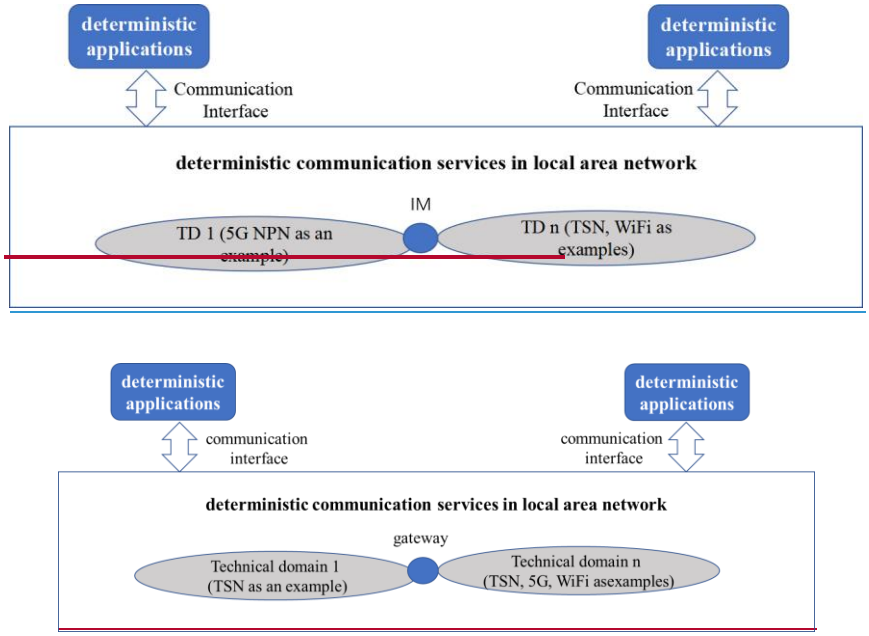


Figure 1 Concept of inter technology domain~~inter-domain~~ deterministic communication services in local area network

7.2 Deterministic communication service scenarios in local area network for support of periodic control applications

Small packets, low jitter and high reliability for both upstream and downstream are the requirements from the periodic control applications [b-periodic control] for inter technology domain~~inter-domain~~ deterministic communication services.

Deterministic communication services can provide periodic control applications with deterministic network performance, including but not limited to bounded latency, low jitter, and low packet loss.

Figure 2 is an example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of periodic control application.

As shown in figure 2, sensors and actuators are deployed in TD A. OT [b-OT] network may be the instance of TD A. Network technologies adopted by OT network include but not limited to TSN [b-IEEE TSN], Profinet [b-Profinet], Real-time Ethernet [b- Real-time Ethernet], and 5G NPN.

[Editor's note: some terms (sensor, actuator, controller as examples) used in figures of clause 7.2, 7.3 and 7.4 may need to be changed to ~~have more general meanings~~logical terms which is independent from implementation.]

Controllers are deployed in TD B. Industrial park network may be the instance of TD B. Network technologies adopted by industrial park network include but not limited to 5G NPN, WiFi and Real-time Ethernet [b- Real-time Ethernet].

NOTE 1 – sensors and actuators may be alternatively deployed in different TDs.

NOTE 2 –Although there are common choices of network technologies for TD A and TD B, but the case that these two TDs using different network technology is the focus.

NOTE 3 - the sensors, actuators, controllers and ~~gateway~~IM(s) are logical functionalities.

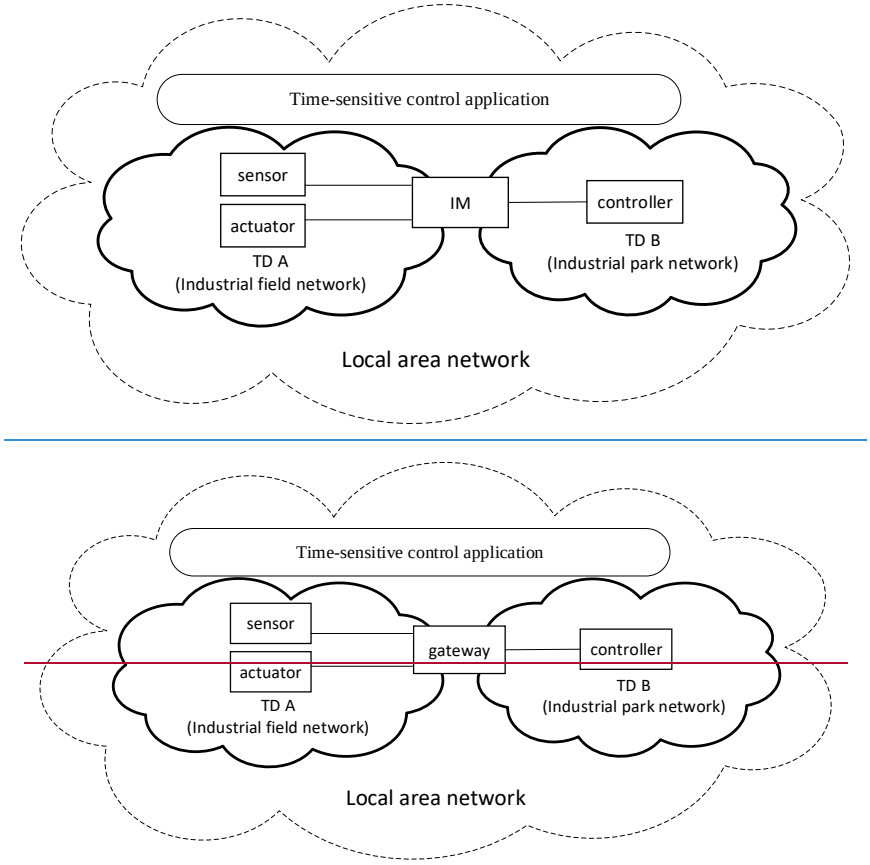


Figure 2 Example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of periodic control application

7.3 Deterministic communication services in local area network for support of high-bandwidth applications

Large packets, low packet loss and high reliability for both upstream and downstream are the requirements from the high-bandwidth applications for deterministic communication services.

Deterministic communication services can provide high-bandwidth applications with deterministic network performance, including but not limited to high reliability, low packet loss and guaranteed high-bandwidth.

Figure 3 is an example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of high-bandwidth application. HD video monitoring, AR assisted operation and machine vision of production inspection may be the instance of Figure 3.

As shown in figure 3, cameras are deployed in TD A. OT network may be the instance of TD A. Servers are deployed in TD B. Industrial park network may be the instance of TD B. Network technologies adopted by OT network and Industrial park network include but not limited to 5G NPN, WiFi , PON,TSN[b-IEEE TSN] and Real-time Ethernet [b- Real-time Ethernet]. NOTE - Although there are common choices of network technologies for TD A and TD B, but the case that the two domains use different network technology is the focus.

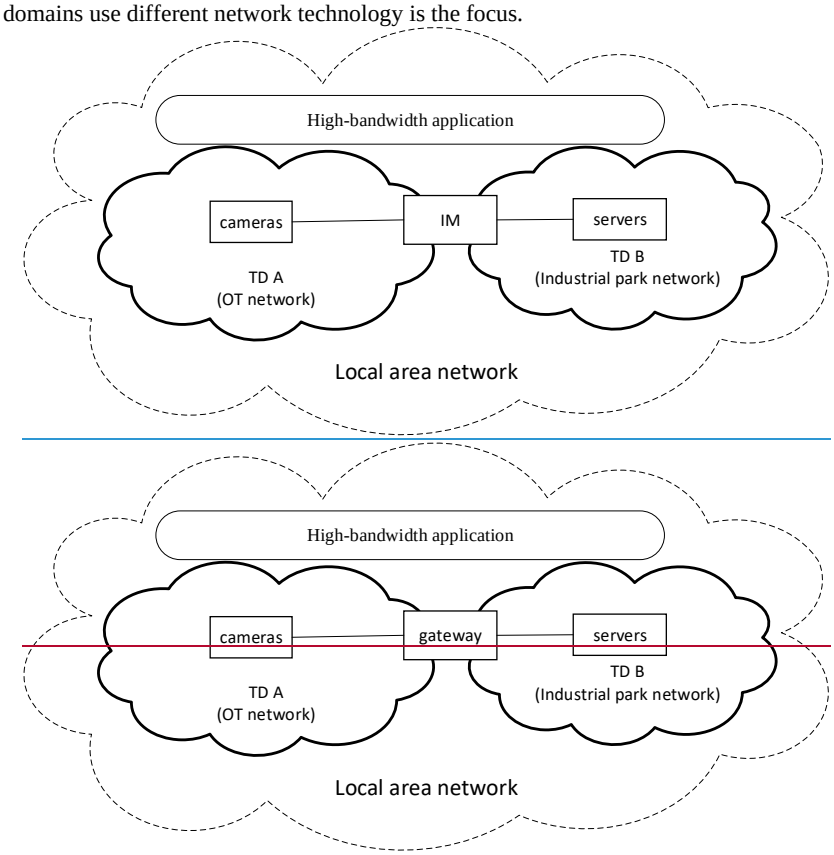


Figure 3 Example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of high-bandwidth application

7.4 Deterministic communication services in local area network for support of time-sensitive and high-bandwidth mixed applications

Large packets, low packet loss for upstream video traffic plus low latency, high reliability for downstream actuator-control traffic are the requirements from the HD video based remote control applications for deterministic communication services.

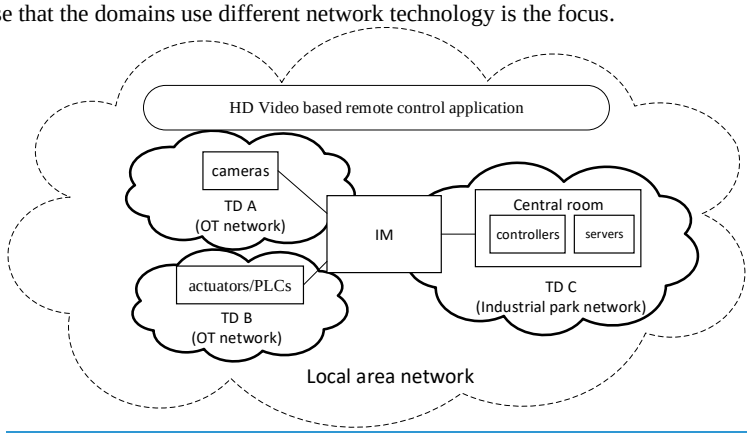
Deterministic communication services can provide video based remote control applications with deterministic network performance, guarantee the network requirements of both video stream and control stream at the same time, including but not limited to bounded latency, low jitter, high reliability, high-bandwidth upstream and low packet loss.

Figure 4 is an example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of video based remote control application, which can be widely used in smart ports, steel industry, mining industry, factories etc. For example, crane remote control, unmanned driving and coking four carts cooperative remote control in steel industry, remote control of the crane implemented to realize grasping and handling containers in smart ports.

As shown in figure 4, cameras and actuators/PLC may be deployed in different domain of the field. Cameras may belong to the network of domain A and actuators/PLC may belong to the network of TD B. OT network may be the instance of TD A and TD B using different network technologies. Controllers and servers are deployed in central room of TD C. Industrial park network may be the instance of TD C. Network technologies adopted by OT network and Industrial park network include but not limited to 5G NPN, WiFi , PON,TSN[b-IEEE TSN] and Real-time Ethernet [b-Real-time Ethernet].

NOTE 1 – cameras and actuators/PLCs may be alternatively deployed in the same TD.

NOTE 2 –Although there are common choices of network technologies for TD A, TD B and TD C, but the case that the domains use different network technology is the focus.



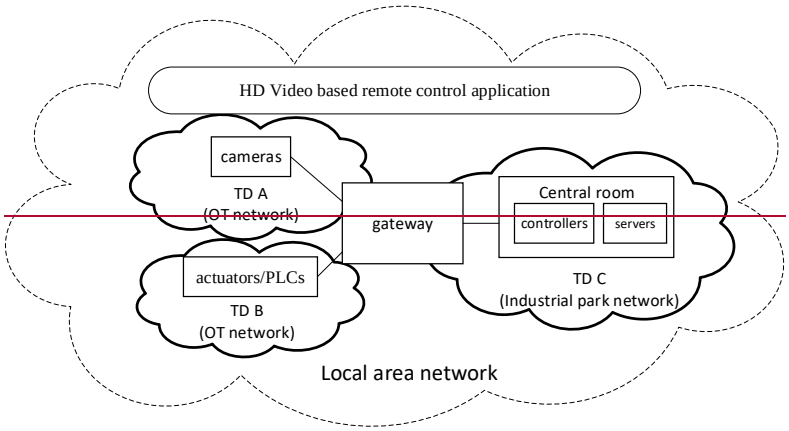


Figure 4 Example of deterministic communication service scenarios supported by heterogeneous network technologies in local area network for support of video based remote control application

7.5 Basic process for Deterministic communication services in local area network

Basic process for deterministic communication services is applicable for the above three scenarios, as shown in figure 5.

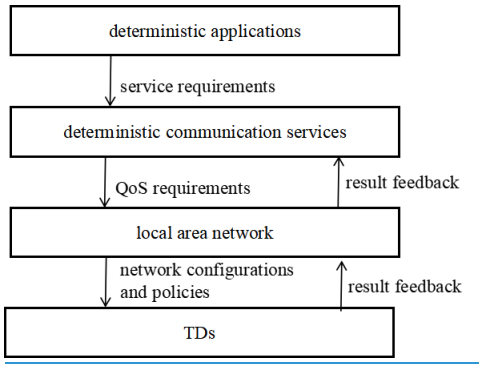


Figure 5 Basic process for deterministic communication services

- Deterministic applications send service requirements to deterministic communication services;
- Deterministic communication services transfer these service requirements to QoS requirements then send these QoS requirements to the local area network;
- The local area network maps these QoS requirements into network configurations and policies, then send them to TDs;
- TDs implement these network configurations and policies;
- QoS guarantee results are feedback from TDs to deterministic communication services via local area network;

- Based on the received QoS guarantee results and service requirements of the deterministic applications, the deterministic network services dynamically adjust their QoS requirements;
- The TDs constantly update their network configuration according to the received QoS requirements from the local area network to dynamically response to the service requirements of deterministic applications and QoS guarantee results.

8 QoS requirements for deterministic communication services in local area network

In local area network, there are three QoS metrics groups, as shown in figure ~~5~~6.

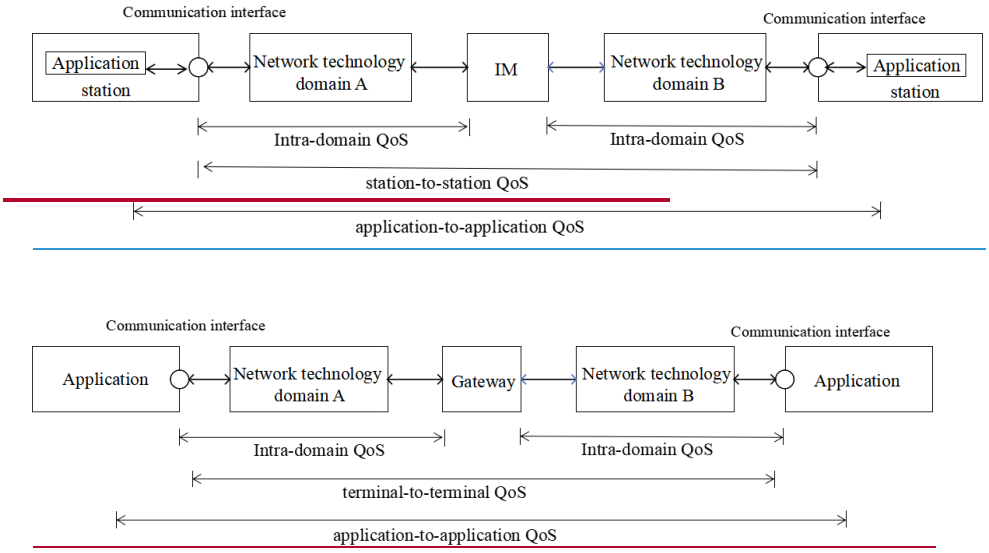


Figure ~~5~~6 Three QoS groups

Application-to-application QoS metrics are a set of QoS metrics which indicate both the network and application processing performance between the source application and the destination application. NOTE – The source application and the destination application are deployed in two ~~terminal~~stations connected by a LAN.

~~Terminal~~Station-to-~~terminal~~station QoS metrics are a set of QoS metrics which indicate the network performance between the communication interface of source application and the communication interface of destination application.

~~Intra-domain~~Intra technology domain metrics are a set of QoS metrics which indicate the network performance inside a single TD.

It is recommended to use deterministic network technologies include but not limited to 5G ~~URLLC~~NPN, TSN, -real time Ethernet, network slicing and Flex E to guarantee ~~Intra-domain~~intra technology domain QOS.

It is required to ~~realize~~support the collaboration of different network technologies across TDS to guarantee station~~terminal~~-to-station~~terminal~~ QoS.

It is required to ~~realize~~support the collaboration of communication network and Application to guarantee Application-to-application QoS.

~~*[Editor's note]: requirements need further elaboration.*~~

It is recommended to provide required application-to-application QoS metrics (e.g., application-to-application latency, application-to-application Jitter, application-to-application network bandwidth) to the deterministic communication services in local area network.

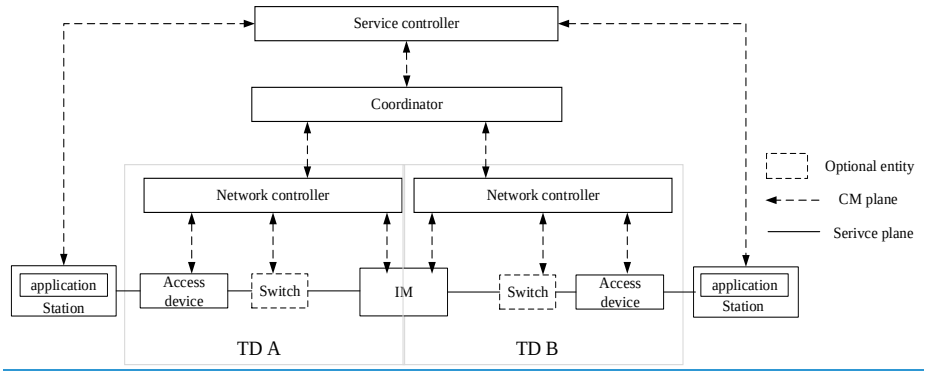
1. It is required to be able to resolve application-to-application QoS metrics provided by applications and to be able to deduce the station~~terminal~~-to-station~~terminal~~ QoS metrics based on the received application-to-application QoS metrics.
2. In case QoS metrics, provided by the source application and the destination application, are contradictory, deterministic communication services in LAN is required to adopt appropriate methods to solve these conflicts in order to meet both applications. In case the service controller can't meet all the required QoS metrics, deterministic communication services in LAN is required to feedback the related applications that their requests are failure.
3. It is required to be able to provide the deduced station~~terminal~~-to-station~~terminal~~ QoS metrics to deterministic communication services in LAN.
4. It is required to be able to resolve the station~~terminal~~-to-~~terminal~~station QoS metrics and to be able to transfer the station~~terminal~~-to-station~~terminal~~ QoS metrics into intra technology domain~~intra-domain~~ metrics for related TDs.
5. In the case that industrial applications are sensitive to low latency and jitter, application-to-application QoS metrics are required to be guaranteed for deterministic communication services.
6. In the case that industrial applications are sensitive to jitter but less sensitive to low latency, station~~terminal~~-to-station~~terminal~~ QoS metrics are required to be guaranteed for deterministic communication services.
7. In the case that both source and destination industrial applications are deployed within a single TD, intra technology domain~~intra-domain~~ QoS metrics are required to be guaranteed for deterministic communication services.

~~4.~~

9 framework of deterministic communication services in local area network

~~*[Editor' note]: The order of section 8 and section 9 is an open point for further consideration.*~~

In figure 7~~6~~, there are two network domain, i.e., TD A and TD B, which use different network technologies inside a LAN.



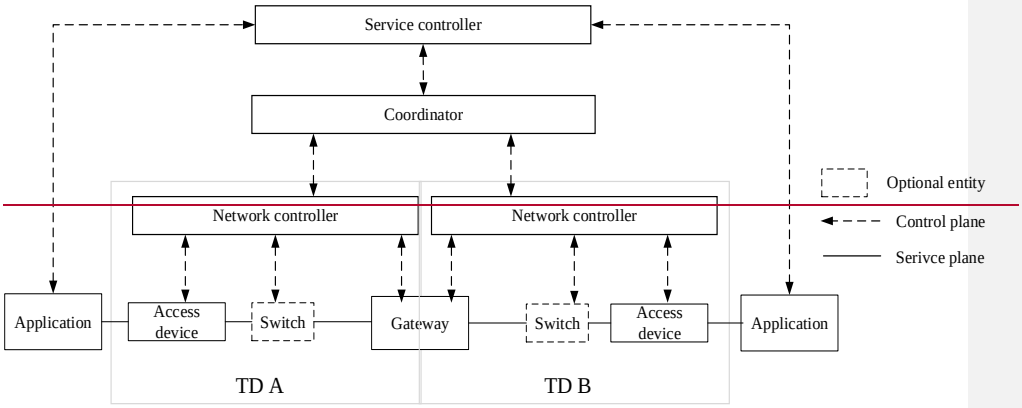


Figure 7~~5~~ Framework of deterministic communication services supported by heterogeneous network technologies in local area network

- Stations are equipments that host user applications, owned and operated by users.
- Applications, hosted by stations, may be industrial automation applications, AR/VR applications, audio and video applications, etc. and can be enabled by deterministic communication services.
- Access device is a network adapter that is used to connect the application to the network，and is the endpoint of deterministic communication network.
- IM~~Gateway~~ connects multiple networks adopting different deterministic communication technologies and converts the format of the packet between TD A's protocol and TD B's protocol to guarantee the applications' deterministic requirements cross domains.
- Switch is a multi-port bridge and a data link layer device, which is optional in the TD.

NOTE - switch can be used to support more devices to connect with each other inside a TD.

- Service controller, which mainly has two functionalities:

–To receive and process the service request from applications

–To act as an interpreter between application and network, and deliver the service request and related QoS requirements to the intra technology domain~~inter-domain~~ coordinator.

- coordinator, which mainly has three functionalities:

–To collect network information and monitor the status of heterogeneous networks, such as buffer state, transmission rate, latency, packet loss rate and so on.

–To take responsibility for cross-TD policing and controlling, such as transmission path selection and making decision on strategies based on service requests and conditions of heterogeneous networks including but not limited to admission control, resource allocation and reservation.

–To configure the network controller(s) in different domains according to decisions of cross-TD policing and controlling.

- Network controller, which mainly has three functionalities:

~~*[Editor's note]: it may be combined with the physical development. Elaboration for further consideration is needed.*~~

–To collect network information from heterogeneous networks.

–To take responsibility for resource management, schedule multiple applications according to available network resources (e.g., time slot, buffer and queuing, power, etc.) and decisions from coordinator, which acts as constraints for scheduling.

–To configure the network devices according to received information from coordinator and itself's resource management.

NOTE –In figure 7~~5~~, service controller~~,~~ –, coordinator~~,~~ –, network controller are defined in terms of functionality not specific entities. In practice, they can exist independently or combine together in the specific entity, supporting centralized and distributed deployment.

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