

Recommendation

ITU-T G.7716/Y.1707 (11/2022)

SERIES G: Transmission systems and media, digital systems and networks

Data over Transport – Generic aspects – Transport network control aspects

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet protocol aspects – Operation, administration and maintenance

Architecture of management and control operations

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Recommendation ITU-T G.7716/Y.1707

Architecture of management and control operations

Summary

Recommendation ITU-T G.7716/Y.1707 addresses the architecture of management and control operations. This Recommendation provides guidance for service providers on the transport network plan, initialization, performing typical operations and maintenance in the network.

History

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Recommendation ITU-T G.7716/Y.1707

Architecture of control plane operations

1 Scope

This Recommendation provides guidance for service providers on:

- how to plan a transport network with management-control (MC) systems;
- how to initialize the transport network with MC systems;
- how to operate and maintain the transport network with MC systems.

This Recommendation also provides guidance to MC function and protocol designers on the sort of operations MC protocols and implementations they need to be able to support.

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 G.7701] Recommendation ITU-T G.7701 (2022), *Common control aspects*.
- [ITU-T G.7702] Recommendation ITU-T G.7702 (2022), *Architecture for SDN control of transport networks*.
- [ITU-T G.7703] Recommendation ITU-T G.7703 (2021), *Architecture for the automatically switched optical network*.
- [ITU-T G.7710] Recommendation ITU-T G.7710 /Y.1701 (2020), *Common equipment management function requirements*.
- [ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2008), *Architecture and specification of data communication network*.
- [ITU-T G.7714] Recommendation ITU-T G.7714/Y.1705 (2005), *Generalized automatic discovery for transport entities*.
- [ITU-T G.7715] Recommendation ITU-T G.7715/Y.1706 (2002), *Architecture and requirements for routing in the automatically switched optical networks*.
- [ITU-T G.7715.1] Recommendation ITU-T G.7715.1/Y.1706.1 (2004), *ASON routing architecture and requirements for link state protocols*.
- [ITU-T G.7718] Recommendation ITU-T G.7718/Y.1709 (2020), *Framework for the management of management-control components and functions*.
- [ITU-T G.7719] Recommendation ITU-T G.7719 (2021), *Management information model for management-control components and functions*.
- [ITU-T M.3010] Recommendation ITU-T M.3010 (2000), *Principles for a telecommunications management network*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 platform [b-ITU-T X.638]: An implementation of an identified platform specification.

3.1.2 platform specification [b-ITU-T X.638]: The functional specification of a formal programmatic interface and a set of supporting local services for an identified stack specification.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 commissioning: The act of specifying parameters necessary to create a control domain instance.

3.2.2 provisioning: The act of specifying the parameters necessary when assigning/deassigning network resources to/from the control domain or to invoke/remove services provided by a control domain instance.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AN	Abstract Node
ASON	Automatically Switched Optical Network
BN	Boundary Node
CC	Connection Controller
CD	Control Domain
CCN	Control Communication Network
DA	Discovery Agent
DCN	Data Communication Network
E-NNI	External Network-Network Interface
FCAPS	Fault management, Configuration management, Accounting management, Performance management, Security management
FP	Forwarding Point
ID	Identifier
I-NNI	Internal Network-Network Interface
LRM	Link Resource Manager
MCS	Management Control System
NCC	Network Call Controller
NE	Network Equipment
OSPF-TE	Open Shortest Path First – Traffic Engineering
PC	Protocol Controller
RA	Routing Area
RC	Routing Controller

RSVP-TE	Resource reservation Protocol – Traffic Engineering
SCN	Signalling Communication Network
SDN	Software Defined Networking
SN	Subnetwork
SNP	Subnetwork Point
SNPP	Subnetwork Point Pool
SLA	Service Level Agreement
TAP	Termination and Adaptation Performer
TMN	Telecommunication Management Network
TRI	Transport Resource Identifier
UNI	User Network Interface
VN	Virtual Network
VPN	Virtual Private Network

5 Conventions

None.

6 Overview of MC deployment

The design of a transport network requires network planning as well as traffic planning. The process of network planning determines the network design given a traffic forecast. Network planning processes could apply to only parts of a network, e.g., subnetworks (SNs). The process of traffic planning determines the way that traffic predicted in the traffic forecast will be routed using existing network resources. The process of capacity install is based on the service request from the customer, and activates the network resource for the assigned traffic.

These two processes are constantly attempting to provide the highest quality service at the least cost to the operator. They separately exist as they operate in two different time scales – the process of building new network resources (i.e., fibre routes, central offices, network equipment (NE) deployment) to deal with new traffic predicted in a network forecast takes months to years while the process of establishing trunks using existing resources may take only minutes to weeks.

Traffic forecasts are periodically developed based on trends, advance information from customers and macro-economic factors. Since these inputs are dynamic, the forecast is also dynamic.

Figure 6-1 shows the three processes in transport network design and operation phases. The result of the traffic planning process is the input to the network planning process, and the network resource is activated by the capacity install process.

Software defined networking (SDN) technology can also provide the functionalities on traffic planning and network planning. The local capacity and traffic demand can be reported from the network to the controller and be optimized in a more dynamic way. After deployment, both the controller and the equipment will need to update the database to sync up with the upgraded network, including the automatically switched optical network (ASON) characteristic sync up for old equipment and SDN controller, and the capability installation on new equipment.

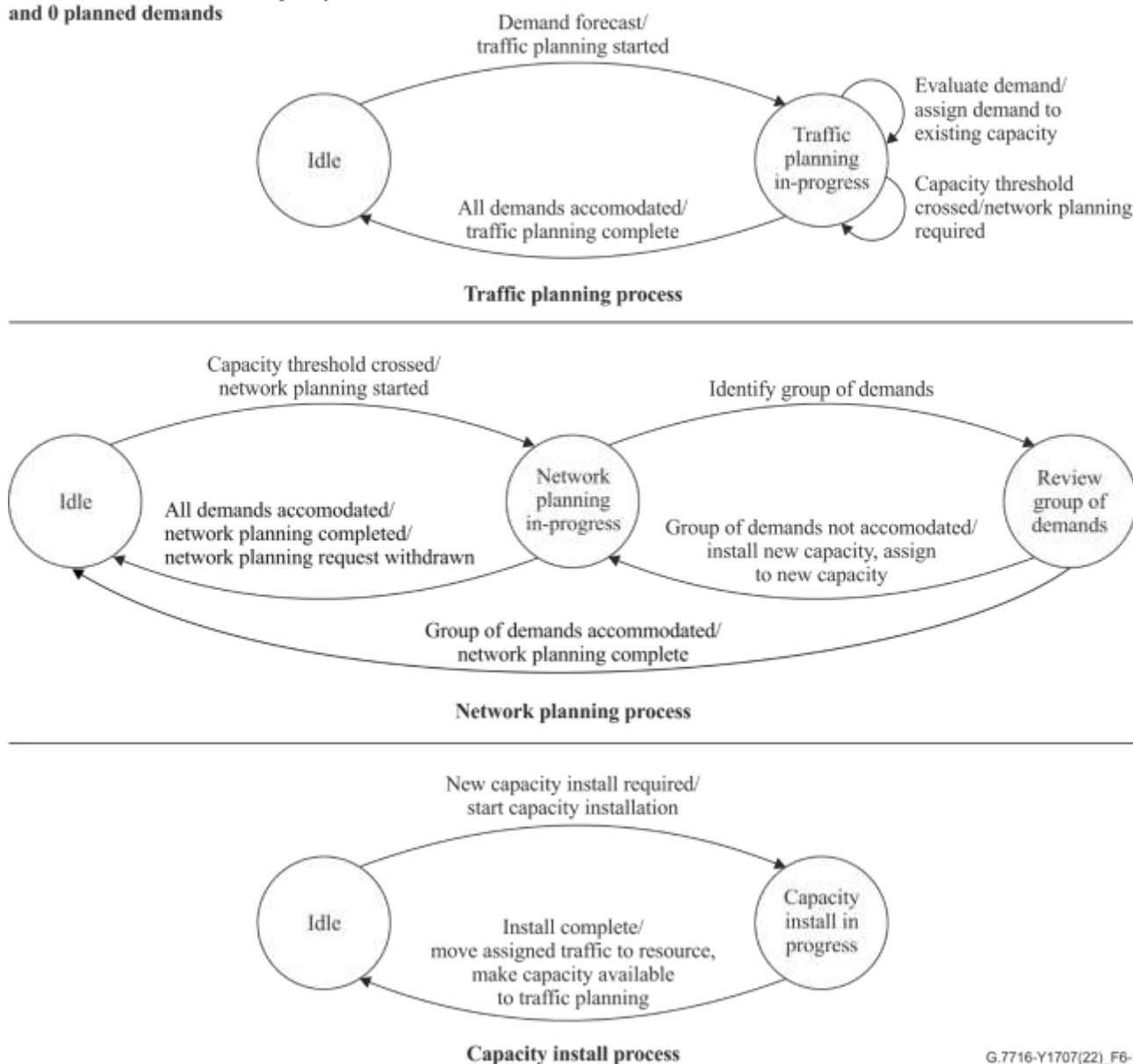
SDN technology and ASON are complementary and interwork with each other in the network. Common aspects are described in [ITU-T G.7701], by taking the mixed architectural approaches into account.

Before the network planning process starts, the operator should collect the traffic demands. These demands may come at different times. The network planning process can be started when one demand comes and reiterated when there are other demands. So the demands are grouped, and the network planning process is periodically executed.

The network initialization is divided into physical and virtual parts. For the physical part it is mainly the capacity install, while for the virtual part it is mainly the set-up of the MC systems to run various of configuration through different protocols.

The network operation and maintenance start after the network is initialized. MC systems are collaborating with each other to guarantee the network running without any problems. Performance on the network is consecutively monitored by the operator to capture the status of the network, and recovery/reconfigurations are needed once there are special events such as faults and alarms.

Initial state: Network has 0 capacity and 0 planned demands



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Figure 6-1 – Three processes in transport network design and operation phases

7 Transport network planning

As a part of the network engineering process, a transport network planning is developed and refined. This planning specifies the fundamental information needed to set up and operate a transport network controlled by a management control system (MCS). Based on [ITU-T G.7701], the MCS instance could be ASON control, SDN controller, NMS and any combinations among them. The information in the transport network plan can be divided into three categories: Transport network resource, MCS infrastructure and control communication network (CCN) infrastructure. It is worth noting that the transport network resource can be either physical and/or virtual from the perspective of MCS, and the planning described in this clause should be applicable to both physical and virtual transport network resources. Detailed characteristics for virtual transport network resource planning are described in clause 10.

When there are multiple MC systems in the network, the network planning is conducted in a joint manner. A global view of the network is needed to be collected to one MC system to plan the network. One of these systems would be designated as the leading system before the planning starts. Other systems are considered as the supporting systems which provides the detailed data to the leading system. Stitching would be needed, in the leading system, in order to form the global view.

7.1 Transport resource planning

The transport network resource planning includes the following information:

- subnetwork/routing area definition (Note 1);
- layer network relationships;
- subnetwork/routing area hierarchy;
- topology abstraction;
- addressing structure (Note 2).

NOTE 1 – Subnetworks and routing areas are functionally identical, with some subtle differences. Clause 6.2 of [ITU-T G.7703] describes these differences.

NOTE 2 – These addresses are for the transport resources and should not be confused with addresses in use in a CCN for ASON.

Due to the dynamic nature of traffic forecasts, the transport network plan needs to be flexible – it must accommodate changes in network engineering, under the coordination from multiple control systems. These may be manifested in changes to the data plane topology as well as to the signalling network, component adjacencies and even functional component distributions. The representation of such changes in ASON control domain and SDN controllers should be correct and consistent.

7.2 MC System infrastructure

MC function (in MC components) may be contained in MC systems of which three types are shown: SDN, ASON and others. Each instance of an MC system has in its scope a set of transport resources over which it supports connection management in a layer network. The common control components for SDN and ASON are specified in [ITU-T G.7701]. The management functions would include the instantiation of an MC system and its components, assignment of transport resources to the scope of an MC system, etc. Management functions recur and a management function instance can manage a set of other management function instances. The management requirements of the MC components and functions are specified in [ITU-T G.7718]. [ITU-T G.7719] provides a protocol-neutral management information model for MC components and functions. The protocol-neutral management information model should be used as the base for defining protocol-specific management information models. This Recommendation uses the ITU-T G.7719 information model when describing operational procedures. How implementations provide the information model and any operations necessary to synchronize the internal operation of the model implementation are out of scope of this Recommendation.

Transport resource management functional areas are identified in [ITU-T M.3010] as: performance management, fault management, configuration management, accounting management and security management. These management functions could be contained in another MC system which could be instantiated as an OSS/NMS/EMS.

For ASON, the network planning information includes:

- protocol selection;
- control component distribution;
- signalling network design;
- control component adjacency design.

For SDN, the network planning information includes:

- network topology design;
- status check for nodes/links;
- connectivity design;
- data communication design;
- control components installation.

Due to the dynamic nature of traffic forecasts, the transport network plan needs to be flexible – it must accommodate changes in network engineering, and the changes may be decided under the coordination of multiple control systems. These may be manifested in changes to the transport network topology as well as to CCN, component adjacencies and even functional component distributions. The representation of such changes in ASON control domain and SDN controllers should be correct and consistent.

7.3 CCN infrastructure

[ITU-T G.7712] defines the architecture requirements for a DCN which may support, among other applications, the distributed management communications related to the telecommunication management network (TMN), distributed signalling communications related to the ASON, distributed control communication related to the SDN and other distributed communications. This Recommendation uses the [ITU-T G.7712] architecture to describe the CCN available to control domains and notes that the control components may be dependent on that CCN infrastructure. Configuring and managing the CCN infrastructure is outside the scope of this Recommendation.

8 Transport network initialization

Initialization is the process of determining what resources exist, that they need to be bound to the appropriate MC functional components, and that the MC functional components need to array themselves into the appropriate confederation. This clause recognizes that certain information needed to accomplish this must be provisioned by the network administrator.

Besides physical resources, a multi-domain or multi-layer network is usually composed by multiple MC systems. The responsibility of initialization in these networks can be decomposed into multiple single-domain or single-layer network. Based on the decomposition, many smaller networks with single MC systems can be initialized respectively.

One leading system would be needed to collect the status of the initialization for each piece in the network. Every other system can be considered as supporting systems to provide the feedback to the leading system once the initialization is done. The leading system will know that the initialization has been completed once every supporting system has completed their own initialization.

8.1 Commissioning

Commissioning is the process of initial configuration used to provide a network element with critical binding information, network-wide naming information and global protocol parameters. These parameters are fundamental to the continued operation of the control domain instance and cannot be changed without significant impact to the control domain instance. Therefore, commissioning is only done during the initialization phase of the control domain lifecycle. Note that commissioning is focused on the commissioning on the control domain component and not the transport resource. Functional components are bound via operations on the management information, introduced in clause 8.1.2 and specified in [ITU-T G.7718].

The information provided to the network element in the commissioning phase consists of the critical parameters identified as a part of network planning. The commissioning phase of a network element could be done automatically by the NE with minimal manual intervention. For example, DHCP could be used by the NE to get appropriate IP address configurations. Other critical parameters for commissioning could be passed to the NE after the communication channel has been set up.

Some configurations must be completed such as the node ID, area hierarchy, and so on, before the control domain starts up through initialization. The procedures of the local initialization include two steps: MC component activation and MC component binding. As initialization is performed, the components shall report transitions in status to the element management function [ITU-T G.7710].

8.1.1 MC component activation

The tasks and processes that support the functions described by the MC components are activated through object creation operations on the management information model. For example, a routing protocol controller is instantiated by creating a routing protocol object. Internal operations within the network element to carry out activation are outside the scope of this Recommendation.

The order of managed object creation must take into account the dependencies that exist between the objects. For example, routing areas must be created first, as subnetwork point pool (SNPP) names include the routing area identifier. Likewise, an adjacency between distributed signalling protocol controllers may depend on the configuration of a link for which it is responsible, and so cannot be created before the link has been created.

8.1.2 MC component binding configuration

The MC components local to a MCS or on peer MCSs must coordinate with each other to fulfil the management and control domain functionality, so these MC components must be associated with each other in either a physical or a logical way. This Recommendation discusses the binding required between MCSs supporting MC functions. The bindings internal to an MCS are a matter of the implementation and are outside the scope of this Recommendation.

The relationship between MC components is illustrated in Figure 6-1 of [ITU-T G.7701]. The bindings of the components need to be established at the initialization stage. These bindings may be software bindings or remote interface bindings, either physical or virtual. They may be static, provisioned or dynamic. Examples of bindings are NCC-CC, CC-RC, RC-LRM, as well as inter-level MC system interaction, etc.

An SNPP is controlled by a specific connection controller (CC), routing controller (RC) and link resource manager (LRM) component. These components must be bound to each other in order to perform the control function. The bindings between CC and RC, RC and LRM as well as CC and LRM may be established before SNPP links have been created between routing areas.

8.1.3 Routing initialization

The prerequisite information for routing object activation includes routing operational style (i.e., centralized/distributed path computation) as this controls routing protocol neighbour adjacencies, addressing (including routing area hierarchy and subnetwork identifiers). The

operational style is predefined by the operator and the other information could be embedded in the equipment by the manufacturer or could be accessed from a configuration store when the equipment is installed. In the context of virtual network (VNs), all the adjacency and identifiers are logical and have a local mapping to physical equipment, and the routing initialization can be done based on this logical information.

The association between routing areas (RAs) (e.g., child RA and parent RA, local RA and remote RA, physical RA and virtual RA) is configured by providing the correct identifiers in the created Routing Area objects.

In order to support the establishment or maintenance of network connections and available network topology, each routing table object should have consistent topology information about the network.

The adjacencies between RC PCs within a routing area must be established to support the advertising and maintenance of the available SNPP link topology. Virtualization can be applicable between RCs to instantiate the SNPP link from one RC to another. The information of the peer RC PCs (such as signalling communication network (SCN) address) can be manually configured or dynamically discovered during the adjacencies set-up process.

In the case of hierarchical routing, adjacencies between lower level RCs and upper level RCs in the corresponding parent routing area are established when the "parent routing area" and "child routing area" parameters are configured on the "routing area" object. This supports the hierarchical routing information collection, maintenance and the hierarchical routing computation. The information of the hierarchical RAs is configured or dynamically discovered during the adjacencies set-up process.

Note that hierarchical routing may result in multi-RCs and multi-PCs. In this situation, the relationship between those RCs and PCs should be properly maintained during routing initialization.

RC PCs are configured when a routing protocol is selected for an adjacency during routing initialization. Per [ITU-T G.7703], the type of routing approach (i.e., step-by-step, source routed, hierarchical) is not restricted. The protocol selected will determine the specific configuration information that is required to initialize the RC PC. This protocol-specific configuration is given as a part of the RC PC creation. [ITU-T G.7719] provides the specific attribute information required when creating an RC PC managed entity.

Per [ITU-T G.7703] and [ITU-T G.7715], there may be several protocol controllers supported for routing information exchange. The routing architecture allows for support of multiple routing protocols. This is achieved by creating different routing protocol objects, which may result in several protocol controllers being instantiated. The architecture does not assume a one-to-one correspondence between routing controller instances and protocol controller instances. During the routing initialization procedure, the relationship between PCs and RCs should be properly configured.

A virtual private network (VPN) is a construct within a single layer network and can be created by:

- 1) explicitly allocating network resources for it;
- 2) sharing common network resources among multiple VPNs.

VN is a more generic term that can not only be used in single layer network but also multi-layer network. Besides the characteristics in VPN, the VN can also be created by combining network resources from multi-layer networks.

8.2 Reconfiguration during commissioning for MC component

During the commissioning state, reconfiguration of commissioning parameters may be performed without impact. This is different than reconfiguration while in the operations and maintenance state as the impact to active services provided by the MC is different. During the commissioning state, the MC components have not been placed into service yet. As a result, changes in the configuration of

critical MC components will not impact the set-up of new calls and connections or the continuation of existing calls and connections.

Some configurations during commissioning may have been done for trialling purposes, so the operator needs to reconfigure some information according to the practical network environments for the MC functions. For example, ASON control domain security functions should be tested, so encrypting open shortest path first – traffic engineering (OSPF-TE) or resource reservation protocol – traffic engineering (RSVP-TE) may be configured to examine the validity. However, according to current practical network environments, there is no need for control domain security, so the configuration should be reconfigured.

Most configurations during commissioning may be configured by a manual process which would be prone to manual errors, so the reconfiguration should also be initiated in the case of a manual mistake. For example, the configured node IDs for some nodes may conflict, so these node IDs need to be reconfigured. For another example, the binding relationships between MC components described in clause 8.1.2 may be configured by mistake, so these binding relationships should also be reconfigured.

Incorrect configuration during the commissioning state should be detected by MC components and reported to the MC. This notification would allow an operator to correct these errors before progressing to the operations and maintenance state.

9 Transport network operation and maintenance

The operation and maintenance for a multi-domain or a multi-layer network is basically repeating the single-domain/layer operation and maintenance with coordination. From the perspective of one operation and/or maintenance functionality, such coordination includes synchronization among systems and workload sharing. One leading system is needed to distribute the workload to multiple supporting systems in the network, to conduct the operation and maintenance. The status of the work are reported to the leading system and the workload may be reallocated for balancing between supporting MC systems.

9.1 Provisioning

Provisioning is the process of incremental configuration performed when service instances are configured on or resource changes are made to a network. The parameters specified by provisioning are specific to a resource or service request, and making changes to those parameters will only affect the specific resource or service request. Provisioning is allowed in the initialization and operations phases of the control domain lifecycle. Resource changes may be the result of assigning an SNPP link to or removing an SNPP link from the control domain, or the modification of an SNPP link property. Modifications made to SNPP link properties include the binding of additional SNP link connections into an SNPP link or the binding of a transport resource identifier (TRI) to an SNPP.

When a link has link connections being used by a call in a network, the link should not be deleted before the services are successfully removed. Note that property modifications to a link that bears services must be made carefully because although some properties of the link may be modified (e.g., the protection capability advertised for a link), some other properties must not be modified (e.g., reducing the link protection provided by the transport resource below the protection level being advertised).

The MC has a full view of the properties of the link, and the control domain only has a partial view of the properties of the link, which may be advertised by routing protocols.