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| Network Function Virtualization | | | |
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# Abstract

This document proposes revised text and figures for the chapter 6.2ff to cover agreed extensions for Network Management, network function virtualization and Network Slicing.

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# Network Reference Model

## **Basic architectural concepts and terms (informative)**

>>> No modification to this section <<<

## Overview of IEEE 802 Network Reference Model

The Network Reference Model (NRM) defines a generic foundation for the description of IEEE 802 access networks, which may include multiple network interfaces, multiple network access technologies, and multiple network subscriptions, aimed at unifying the support of different interface technologies, enabling shared network control and use of software-defined networking (SDN) principles.

### Schematic Overview

Within the bigger picture of an end-to-end network model for providing access to IP services, the NRM deals in particular with the link layer communication infrastructure between the network layer in the terminal and the access router in the core network as depicted in Figure 5.

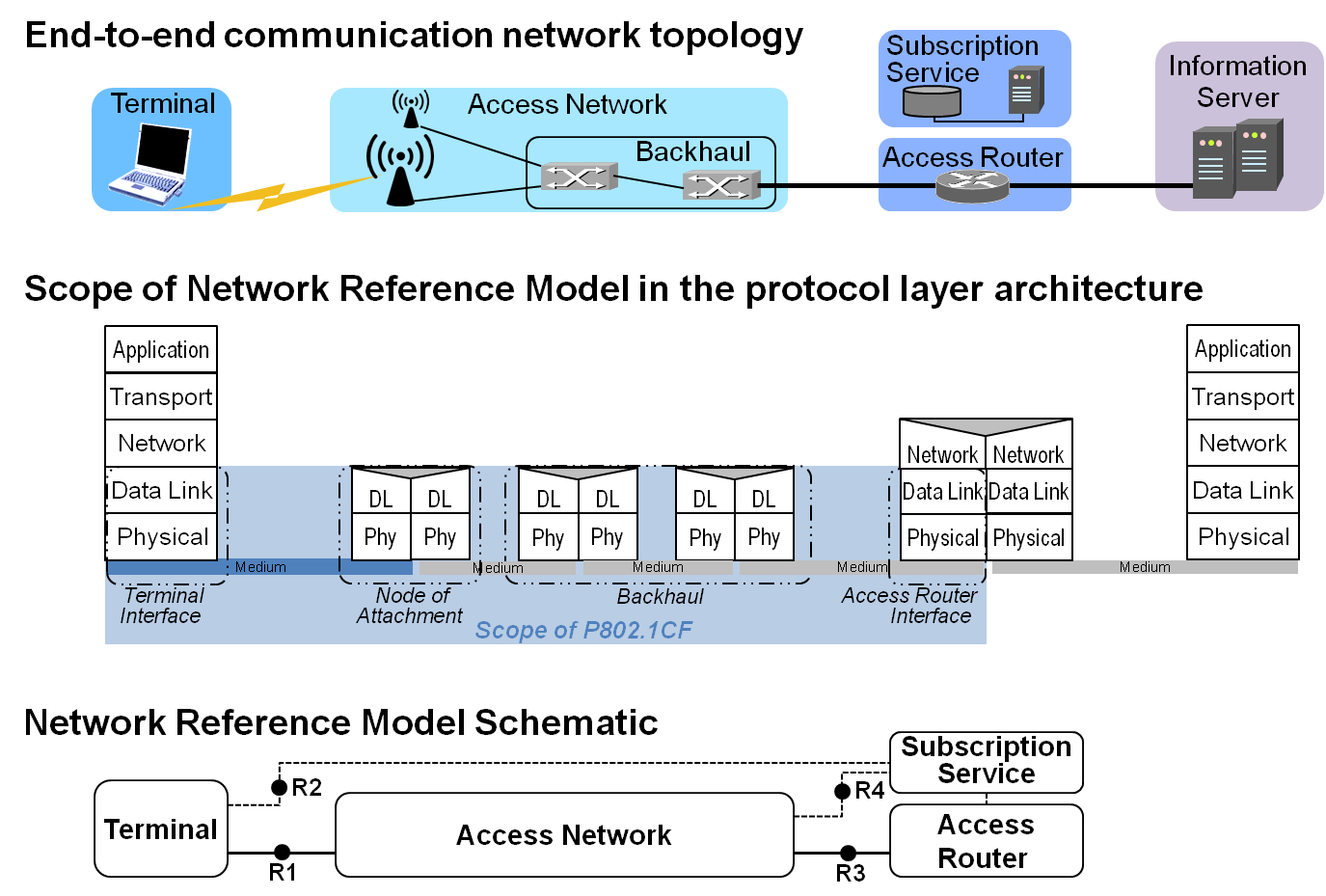


Figure 5—NRM overview

At the top of the figure the end-to-end communication network topology shows the main elements of providing network services to terminals. The terminal is connected by wired or wireless links to a node of attachment or base station of the access network. To serve a wider coverage area, a number of node attachments or base stations can be deployed within an access network, which are interconnected with each other. Traffic in the access network is aggregated and forwarded to the access router by the backhaul. The access router terminates the layer 2 link to the terminal and forwards user traffic towards information servers according to IP addresses carried in the payload of the layer 2 data frames. A subscription service is required authenticate the terminals requesting access to the network and to provide authorization to the access network to provide connectivity to services for particular terminals.

As indicated by the scope of the NRM in the protocol layer architecture, IEEE 802 access networks forward the user data according to the destination MAC address in the Ethernet frames, which represent the endpoints of the link in the access network. Avoiding a functional separation of the user plane from the transport plane, the specification provides an integrated model for backhaul connectivity combined with subscriber-specific connectivity functions as facilitated by modern IEEE 802.1 bridging technologies.

The bottom of the figure shows at first glance, that the NRM for an IEEE 802 access network consists of the terminal, the access network, the access router, and the subscription service. The subscription service provides authentication, authorization, and accounting, as well as policy functions specific for particular user accounts and terminals. Beyond the access router and out of scope of this specification is the infrastructure providing IP-based information services to the terminals.

FIG 6 illustrates the network reference mode schematic for network management system and protocol layer for network function virtualization.



FIG 6 Network function virtualization of NRM

FIG 6 (A) shows the NRM schematic for network management system. The network management system can include functions to manage the entire network, such as terminal, access network, access router and other network entities. The network management system for the access network includes the management for nodes of attachment and backhaul networks through the access network controller. The network management for the TE is through the access network. The network management for the access router is beyond of the scope of omniRAN.

FIG 6 (B) shows protocol layer for virtualized network functions of network reference model. The virtualized network functions include terminal subscription service management function (SSM-F), network provisioning management function (NPM-F), fault and diagnosis management function (FDM-F), The virtualized network management functions are distributed through the interfaces between Virtualized Network Function (VNF) layer and Network Function Virtualization Infrastructure layer.

The NFV management and Orchestration provides a common platform for virtualized network management.

### Reference Point Types

Communication interfaces between the entities are denoted by R1 for the interface between the terminal and the node of attachment, by R2 for the authentication procedures between terminal and subscription service, by R3 for the interface between access network and the access router, and by R4 for the authentication, authorization, accounting, and policy functions between the access network and the subscription service.

There are two kinds of reference points used in the Network Reference Model.

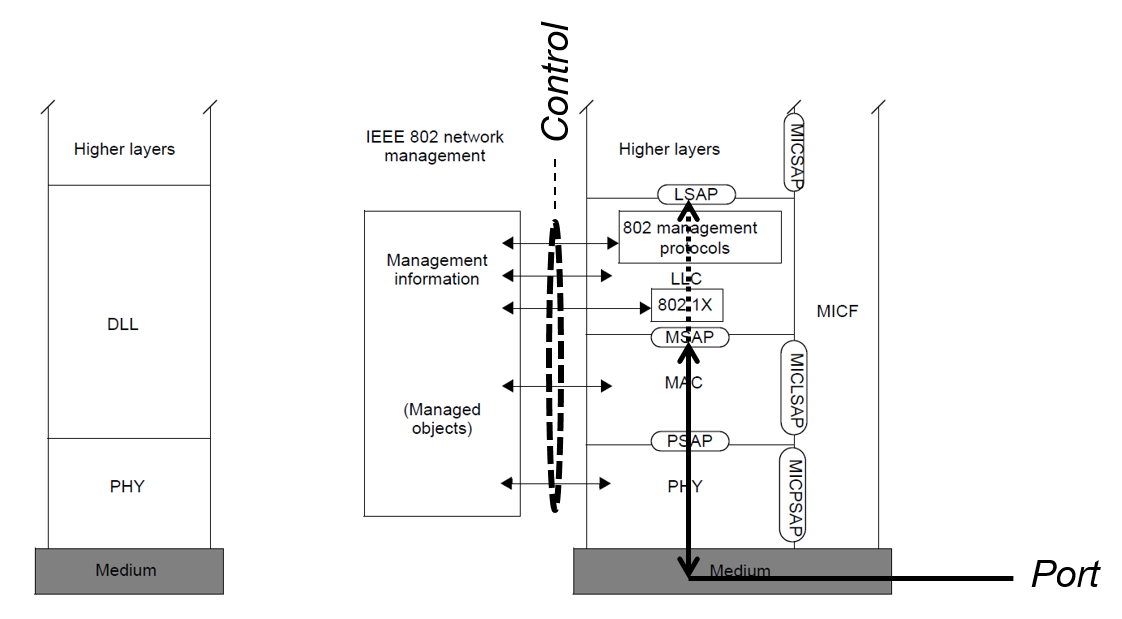


Figure 7: Reference Point types

According to the IEEE 802 basic architectural concepts and terms summarized in the previous section 6.1, information out of an IEEE 802 communication element is exchanged with another entity either over the port through the communication medium or as management information as payload over an unspecified kind of control protocol.

A control interface conveys IEEE 802 layer management information to another entity and is represented in the NRM by a dotted line. Usually IP based protocols like SNMP or RADIUS will be used for the transport of the layer management information.

In the network function virtualization, the IEEE802 PHY and MAC functions can be encapsulated as virtualized network functions to be controlled by the IEEE 802 network management system.

A port carries the user data and can convey as well IEEE 802 control protocol information to the peer entity encoded in layer 2 frames. It is represented in the NRM by a solid line.

## Basic Network Reference Model

The Network Reference Modeland management

The subscription service provides authentication, authorization, and accounting services (as well as user-specific policies) to the terminal, the access network, and the access router. The subscription service usually contains a database containing all the subscription-specific information. Multiple subscription services may be interlinked with each other for roaming users, i.e. for subscribers, who make use of network resources not belonging to their own business.

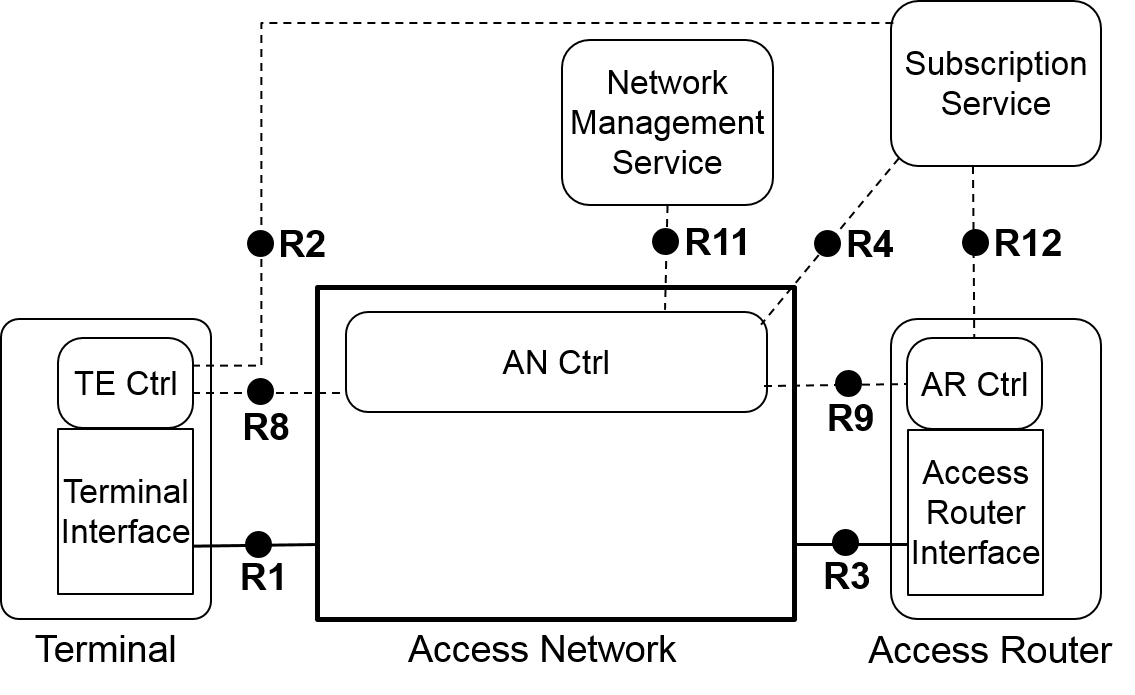


Figure 8—Basic Network Reference Model

Figure 8 presents the Basic Network Reference Model. Solid lines represent the interfaces representing the data plane and connecting ports, while dotted lines show the flow of control and management information. This NRM is the foundation for further refinements and includes the basic differentiation between functional entities and the reference points for their communication. The Basic NRM is composed of five main elements: i) the Terminal (TE), ii) the Access Network (AN), iii) the Access Router (AR), iv) the Subscription Service (SS), and v) the Network Management Service (NMS).

The NMS comprises the services for operation, administration and maintenance of the access network. As depicted in Figure8, the TE, AN, and AR each contain a control entity, which is denoted by Ctrl. Each of the three elements has its own specific control.

Note - The access router is a logical functional unit with various options for implementation depending of the design and architecture of the access router control.

Note - Please note that no assumptions are made regarding the ownership of the functional units. Access Net­work, Subscription Service, and Access Router may belong to the same operator, or may be distributed among three dis­tinct operators.

### Functional entities

#### Terminal

The terminal is a mobile device that seeks connectivity to a communication infrastructure to get access to communication services. The terminal contains a terminal interface providing the physical port for network connectivity, and eventually deploys a terminal control for dealing with particular parameters and configurations conveyed by the control and management interface.

#### Access Network

The access network consists of the nodes of attachment providing the physical ports toward the terminals and the backhaul for connecting the nodes of attachment toward the access router. The access network may deploy a dedicated access network control for configuration and management of the elements inside the access network as well as exchange of control and management information with both the terminal and access router. As a central controller, ANC acts as an element manager providing functions of management on network elements that connect to it, namely access network elements, terminal, and access router.

#### Access Router

The access router terminates the layer 2 connectivity to the terminal by realizing the anchor for network layer communication toward the terminal side. The access router contains an access router interface that establishes the physical port of the connectivity toward the access network, and may eventually include a dedicated access router control that handles and exchanges layer management information and configurations. With a dedicated access router control, the access router becomes a logical functional unit with various implementation options for the control and the packet forwarding engine attached to the access router interface.

#### Subscription Service

The subscription service provides authentication, authorization, and accounting services as well as user-specific policies to the terminal, the access network, and the access router. The subscription service usually contains a database containing all the subscription-specific information. Multiple subscription services may be interlinked with each other for roaming users, i.e. for subscribers, who make use of resources of networks not belonging to their own business.

#### Network Management Service

The Network Management Service consists of the functions, which allows the operator of an access network to configure the access network infrastructure, manage functions related to the interaction between multiple network elements, monitor the usage and correct operation of the access network and to perform tests for detection, determination and correction of faults. A NMS exists in every access network, however the kind of implementation and sophistication widely varies and depends of the size of the network and particular operational requirements. To simplify and unify the network and service management, the network functions are virtualized to represent as the resources of the physical entities in the virtualized network management system.

### Reference Points

**R1** represents the reference point for the PHY and MAC layer functions establishing the physical port, as specified in numerous IEEE 802 standards, between terminal and access network.

**R2** represents a logical control interface between terminal and the subscription service, e.g., for authentication. Information elements of the logical interface are tunneled over R1 and R4 between terminal and subscription service.

**R3** represents the physical port for the communication between the access network and the access router.

**R4** represents a control interface communicating subscription-specific information elements between the access network control and the subscription service.

**R8** represents a logical control and management interface between the AN and the TE, which terminates in access network control and the terminal control, respectively. The functionalities of this reference point are related to the management of the terminal and the control of the data flows in the terminal. In addition, the reference point may include some additional configuration parameters to influence the behavior and configuration of the terminal. Information elements of the logical interface are conveyed over R1 between terminal controller and access network.

**R9** represents a logical control and management interface between the access network control and access router control. This reference point supports the functionalities related to the management of the access router and the control of the data flows in the access router. In addition, the reference point may carry some additional configuration parameters to influence the behavior and configuration of the access router. Information elements of the logical interface are conveyed over R3 between access network controller and access router controller.

**R11** represents a control and management interface for conveying network management information between the NMS and network element management functions located in the access network control. It includes information elements for functions of management of the NEs, such as planning, organization, supervision, control, protection, and security of communications resources. Through R11, the network management functions of ANC could be virtualized as manageable resources in the NMS.

**R12** represents a control interface communicating subscription-specific information between the subscription service and the access router control.

## NRM with Coordination and Information Service

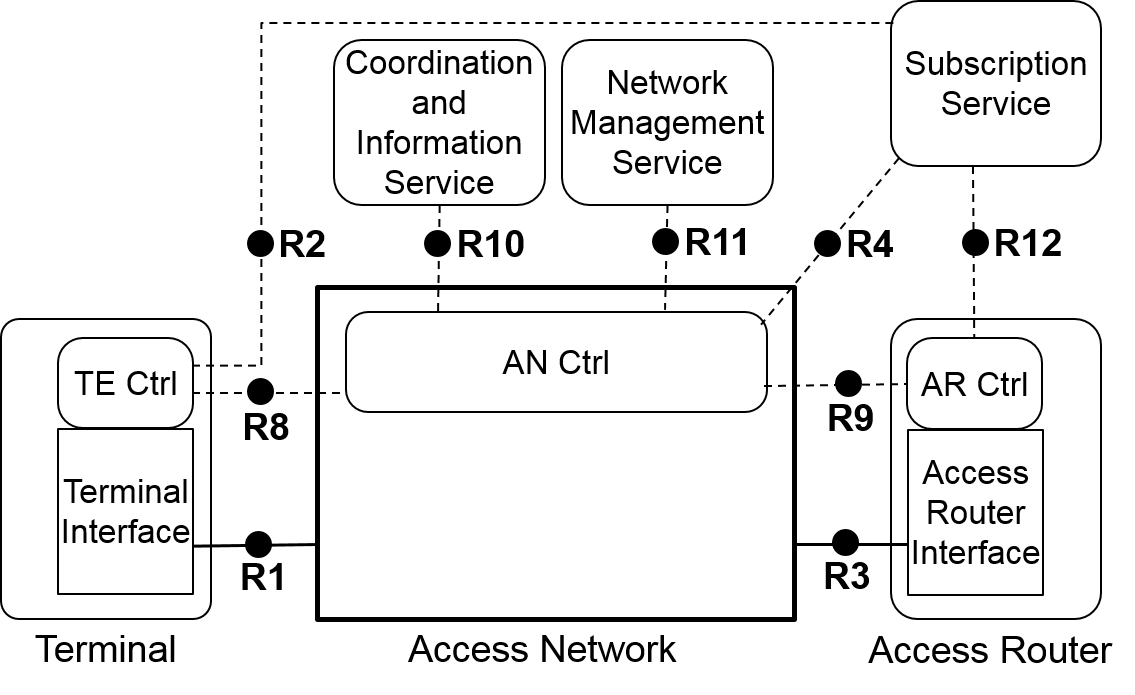


Figure 9—NRM with Coordination and Information Service

Some deployments include a Coordination and Information Service (CIS) to provide advanced services such as spectrum management, coexistence, and information services for mobility. The reference model includes the option for CIS by providing a reference point to communicate the information between CIS and the AN Ctrl, possibly propagated further by the AN Ctrl to the TE Ctrl and AR Ctrl over the R8 and R9 interfaces, respectively.

### Additional functional entities

#### Coordination and Information Service

The Coordination and Information Service is an entity that coordinates the use of common resources and exchange of operational parameters among multiple access networks. A CIS is usually only present when an external entity dynamically provides resources for the operation of the access network, or when multiple access networks coordinate their operation among each other’s by the help of an third party entity.

### Additional reference points

R10 represents a control and management interface between the access network control and the CIS.R10may be present between the access network control of different access networks when no third party entity is involved for the coordination of the operation between multiple access networks. In this case, the coordination and information service is provided in a distributed manner. Centralized and distributed CIS may coexist for different purposes in the same AN arrangement.

## Comprehensive Network Reference Model

The comprehensive Network Reference Model provides further details of functional entities and their interfaces inside the access network. The model decomposes the access network into the node of attachment and backhaul in addition to the AN control. The connections between NA, backhaul, and AN control are described by reference points R5, R6, and R7.

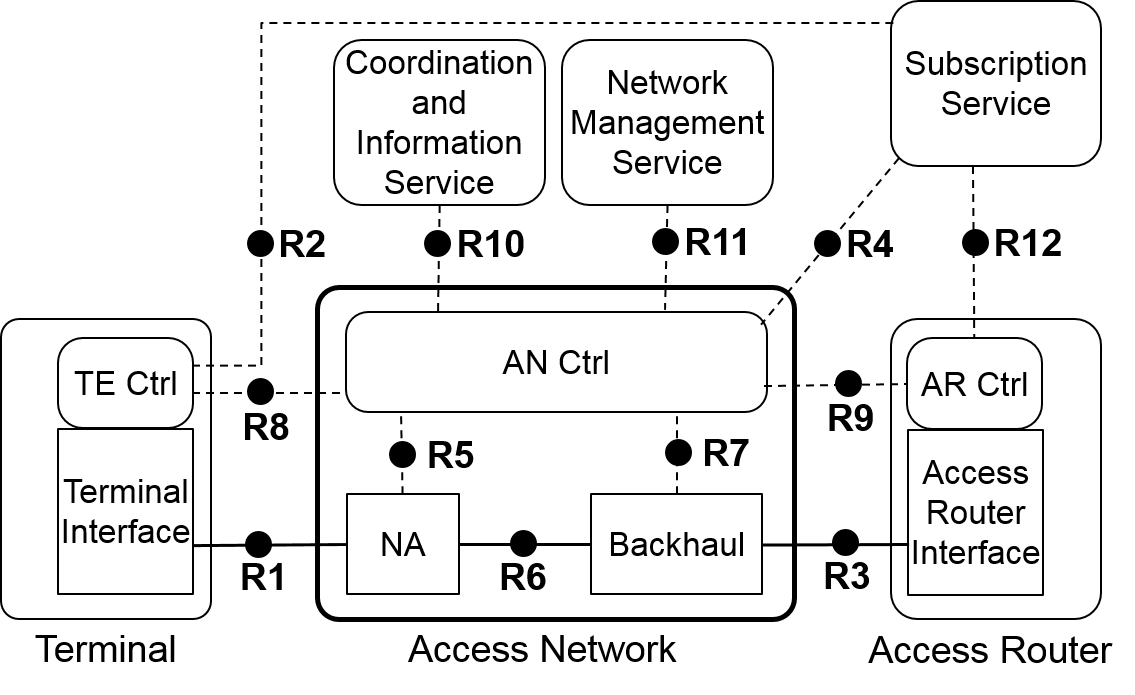


Figure 10—Network Reference Model exposing Access Network details

In Figure 8 the access network is decomposed into a node of attachment (NA) and the backhaul (BH). The NA represents the entity providing the link to the terminal, the interface to the backhaul, and the data for­warding function between these two. The connections between NA, backhaul, and AN control are described by reference points R5, R6, and R7.

### Additional functional entities

#### Node of Attachment

The node of attachment represents the access network entity that provides the physical link to the terminal. It forwards user data to a network side port inside the access network and is connected with the AN control for configuration and management.

#### Backhaul

The backhaul represents the aggregation and forwarding infrastructure inside the access network providing the link between the network side port of the NA and the AR interface.

### Additional reference points

**R5** represents a control-only interface for the configuration and operation of the node of attachment. It includes information elements for the configuration of the R6 port toward the backhaul, the R1 port toward the terminal, and the data-forwarding functions inside the node of attachment.

**R6** represents a reference point for the physical ports between the node of attachment and the backhaul.

**R7** represents an interface used to control and configure the user plane within the backhaul. The backhaul interconnects the NAs with the access router.

### Representation with abbreviations

For schematic use cases and when less space is available for reproducing the NRM with all terms spelled out, a representation of the NRM with abbreviations can be used.

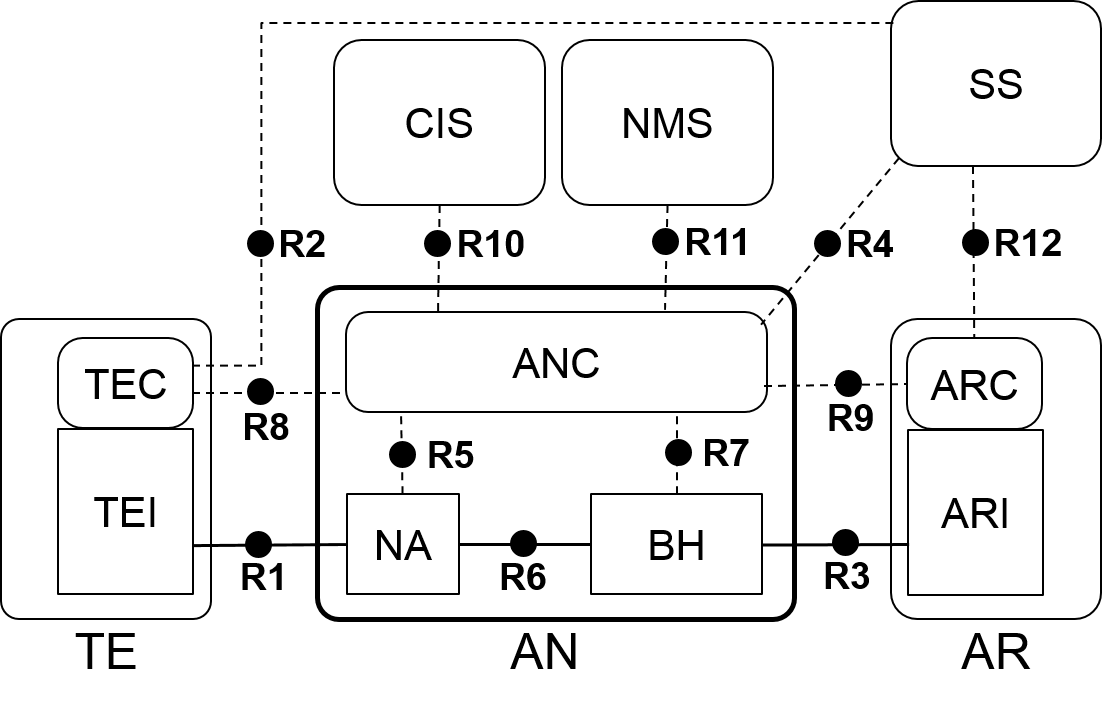


Figure 11 NRM with acronyms

## Network Virtualization

Network virtualization, often also called network slicing, allows for cost-effective installations of multiple dedicated access networks for different applications, for particular security requirements, or for isolated operational domains at the same area. To enable virtualization, network elements are designed the way, that a common hardware can realize multiple logical instances of such network element. However, due to common usage of the same hardware resources, some limitations regarding the configuration of the hardware dependent parameters may exist, e.g. the operation channel of a radio interface has to be the same for all of the virtual interfaces operating on the same device, or the PHY speed of a wired Ethernet interface is the same for all virtual connections going over a common LAN cable.

IEEE 802 technologies support the capabilities to realize multiple virtual instances of network elements under the potential restrictions mentioned above, e.g. IEEE 802.1Q defines the methods to share a common Ethernet infrastructure for the establishment of multiple virtual LANs (VLANs), and IEEE 802.11 describes the implementation of multiple virtual APs each exposing its own SSID and defining its own security environment on a single radio interface.

### Basic assumptions

The NRM represents a single instance of a virtual IEEE 802 access network. The virtual access network follows all the functional descriptions and exposes the same functional behavior at the reference points.

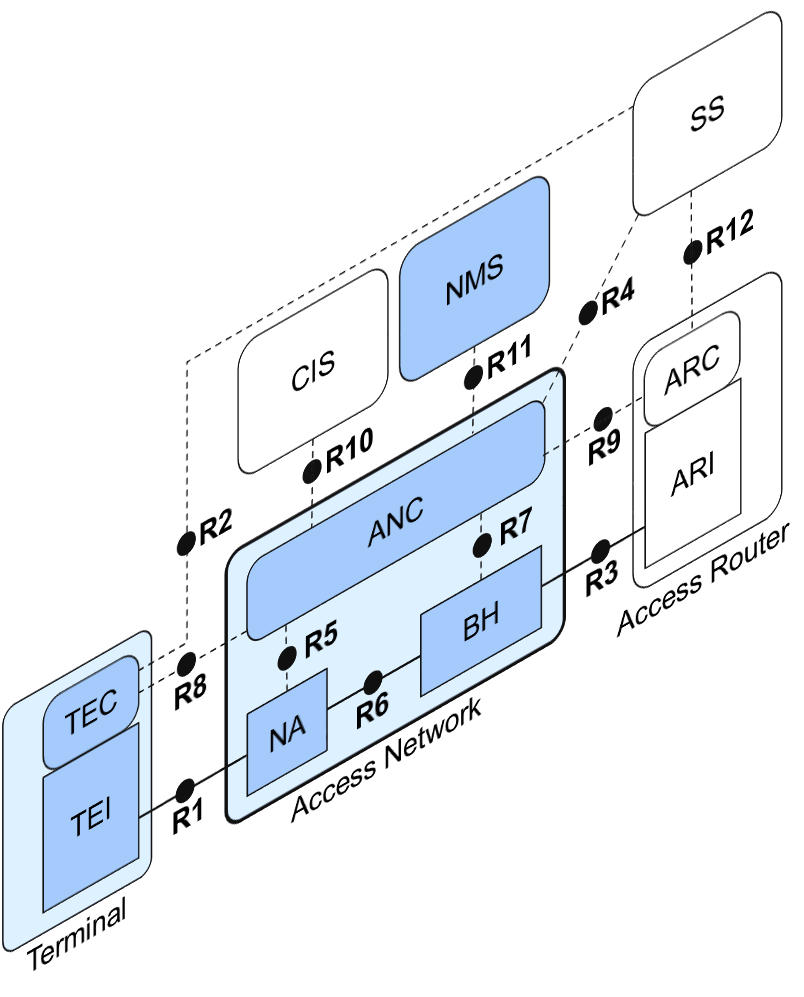


Figure 12: Single instance of IEEE 802 access network

In the case of a single instance of a virtualized access network the NRM completely covers the functional behavior however does not show the particularities of a virtualized infrastructure.

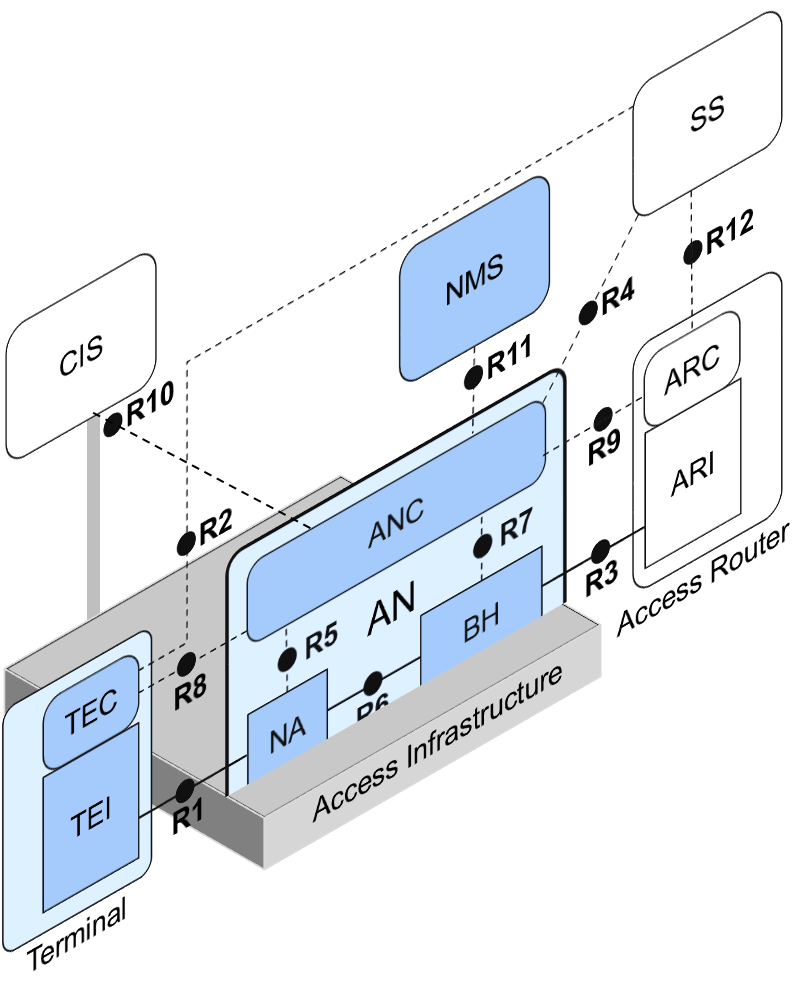


Figure 13: Virtualized access network resides on access infrastructure

Virtualization of the access network leads to a separation of the physical infrastructure from the functional behavior. As shown in the figure 13 above, the physical layer components of the Node of Attachment requiring dedicated hardware as well as the physical layer of the backhaul realized through hardware are becoming part of the access infrastructure layer, which consist of all the hardware components and computing resources, which provide all the necessary resources of the virtualized access network in the NFV.

The virtualized network functions in ANC receive the provisioning information from the NMS and provide the lower PHY layer configurations of NA as well as of BH, however the information is provided by the way of CIS and the parameters are mostly ‘read-only’, as the configuration of the access infrastructure predefines the configuration parameters of the lower PHY layer.

### Multi-instance Design and Issues

The full capabilities of network virtualization become visible in the following figure, which depicts 3 different AN instances on a common access infrastructure. All three ANs have an R10 reference point towards the common CIS, which allows for each of the virtualized access network to get access to the lower PHY layer parameters, which are common for all three networks, and to request modifications to the networking and computing resource parameters. As far as the requests do not collide with requests from the other virtualized ANs, the access infrastructure can dynamically adjust parameters according to requests.

For clarity of the visualization, the R2 reference point and signal flow is not shown in the figure below.

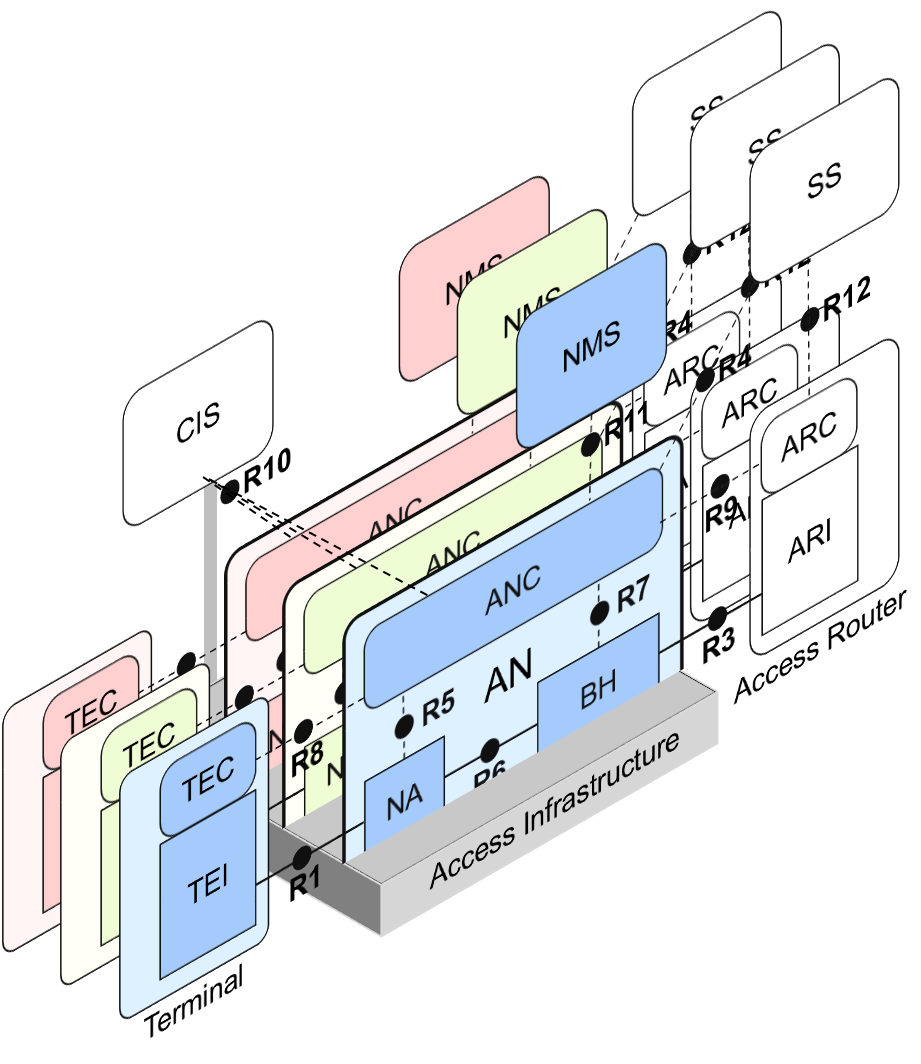


Figure 14: Multi-instance virtualization

Each of the three virtualized networks (network slices) fully realize the complete NRM including virtualized network function of NMS, SSs as well as ARs. Each of the slices can have its completely own arrangements through the virtualized networks, which are completely independent to each other’s over access infrastructure resources shared among the ANs with some limitations, as the sum of used resources can’t exceed the total available resources.

The virtualized network management functions of MNS provide the complete set of network management functions through the interface R11, which is virtually independent to the access network operator. Therefore each access network operator can manage and operate the shared access networks as its own private networks.

R10 interfaces of all virtualized access networks to a common CIS, which is tight to the physical access infrastructure, provides access to the infrastructure parameters and allows for dynamic allocation of resources. As the access infrastructure is shared among multiple AN instances, an AN can request modifications to the lower PHY layer parameters through the CIS, and it becomes possible, that the resources are dynamically allocated by the virtualized network provisioning function of ANC depending on load conditions and service requirements.

## **Identifiers of functional entities**

>>> content not modified <<<

## Deployment Scenarios

The following section present a variety of deployment scenarios of the IEEE 802 NRM. The listing begins with simple scenarios with only one or a few operational domains involved, and ends with very versatile deployments, where operational responsibilities are widely distributed and a bigger number of operational domains are involved in network operation.

### Residential network (Wi-Fi router)

In the case of a residential network all the entities of the NRM including terminal belong to the same operational domain. Such deployment allows for a number of simplifications, mainly in the area of network security.

### Integrated service provider

The integrated service provider operates all the network functional entities in a single operational domain. It owns the access network as well as the subscription service and the access router. Only customers of the integrated service provider are allowed to access the infrastructure.

### Wholesale access network

In the wholesale access network case, the access network operator has contractual agreements with one or more subscription service providers, which either operate their own access routers, or have relationship with some access router operators for providing the access router.

The wholesale access network is the most versatile deployment case, which requires that multiple different entities can be handled by each of the reference points.