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Abstract

Revision 02 introduces a number of minor clarifications due to feedback on the revision 01.

Revision 01 introduces further amendments to the omniran-14-0083-00-00TG documents to accommodate the results of the discussion on this document and to adopt ideas and views raised by the contributions omniran-15-0024-00-CF00-nrm-amendment and omniran-15-0026-00-CF00-nrm-discussions.

**Abstract of first revision of this document:**This document proposes a further revision of the text on the P802.1CF network reference model incorporating the agreed edits in omniran-15-0005-01-CF00. The revision mainly addresses the issues explained in the omniran-15-0008-02-00CF-nrm-refinements presentation.

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# P802.1CF Network Reference Model

## Nomenclature:

AN: Access Network

ANC: Access Network Control

AR: Access Router

ARC: Access Router Control

ARI: Access Router Interface

BH: Backhaul

CIS: Coordination and Information Service

NA: Node of Attachment

NRM: Network Reference Model

SS: Subscription Service

TE: Terminal

TEC: Terminal Control

TEI: Terminal Interface

## Basic architectural concepts and terms

Note: This section is essentially adopted from IEEE 802.1AC Capter 7 with some figures added from IEEE 802 for illustration.

The architectural concepts used in this and other IEEE 802.1 standards are based on the layered protocol model introduced by the OSI Reference Model (ISO/IEC 7498-1) and used in the MAC Service Definition (IEEE Std 802.1AC), in IEEE Std 802, in other IEEE 802 standards, and (with varying degrees of fidelity) in networking in general. IEEE 802.1 standards in particular have developed terms and distinctions useful in describing the MAC Service and its support by protocol entities within the MAC Sublayer.

### Protocol entities, peers, layers, services, and clients

The fundamental notion of the model is that each protocol entity within a system exists or is instantiated at one of a number of strictly ordered layers, and communicates with peer entities (operating the same or an interoperable protocol within the same layer) in other systems by using the service provided by interoperable protocol entities within the layer immediately below, and thus provides service to protocol entities in the layer above. The implied repetitive stacking of protocol entities is bounded at the highest level by an application supported by peer systems, and essentially unbounded at the lowest level. In descriptions of the model, the relative layer positions of protocol entities and services is conventionally referred to by N, designating a numeric level. The N-service is provided by an N-entity that uses the (N–1) service provided by the (N–1) entity, while the N-service user is an (N+1) entity.



Figure 1‑1: IEEE 802 Reference Model for end stations

Figure 1‑1 illustrates these concepts with reference to the layered protocol model and service access points of IEEE 802 end stations.

### Service interface primitives, parameters, and frames

Each N-service is described in terms of service primitives and their parameters, each primitive corresponding to an atomic interaction between the N-service user and the N-service provider, with each invocation of a primitive by a service user resulting in the service issuing corresponding primitives to peer service users. The purpose of the model is to provide a framework and requirements for the design of protocols while not unnecessarily constraining the internal design of systems: primitives and their parameters are limited to, but include all of the information elements conveyed to corresponding peer protocol entities or required by other systems (and not supplied by protocols in lower layers) to identify (address) those entities and deliver the information. The parameters of service primitives do not include information that is used only locally, i.e., within the same system, to identify entities or organize resources for example.[[1]](#footnote-1)



Figure 1‑2: MAC entities, the MAC service and MAC service users (clients)

Figure 1‑2 illustrates these concepts with reference to the MAC Sublayer, which contains MAC entities that provide the MAC Service at MAC Service Access Points (MSAPs), to MAC Service users.

The primitives of the MAC Service comprise a data request and a corresponding data indication; each with MAC destination address, MAC source address, a MAC service data unit comprising one or more octets of data, and priority parameters. Taken together these parameters are conveniently referred to as a frame, although this does not imply that they are physically encoded by a continuous signal on a communication medium, that no other fields are added or inserted by other protocol entities prior to transmission, or that the priority is always encoded with the other parameters transmitted.

### Layer management interfaces

A given N-entity can have many associated management controls, counters, and status parameters that are not communicated to its user’s peers, and whose values are either not determined by its user or not required to change synchronously with the occurrence of individual N-service primitives to ensure successful (N+1)- protocol operation. Communication of the values of these parameters to and from local entities, i.e., within the same system, is modeled as occurring not through service primitives[[2]](#footnote-2) but through a layer management interface (LMI). One protocol entity, for example an SNMP entity, can be used to establish the operational parameters of another. Communication of the results of authentication protocol exchanges to entities responsible for controlling and securing access is one of the uses of LMIs in this standard.



Figure 1‑3: IEEE 802 reference model with end-station management

Figure 1‑3 illustrates the layer management interfaces allowing access to controls, counters and status parameters inside a protocol entity.

### Service access points, interface stacks, and ports

Each service is provided to a single protocol entity at a service access point (SAP) within a system. A given N-entity can support a number of N-SAPs and use one or more (N-1)-SAPs. The service access point serves to delineate the boundary between protocol specifications and to specify the externally observable relationship between entities operating those protocols. A service access point is an abstraction, and does not necessarily correspond to any concrete realization within a system, but an N-entity often associates management counters with the SAP and provides status parameters that can be used by the (N+1)-entity using the SAP. Examples include the MAC\_Operational and operPointToPointMAC status parameters provide by MAC entities.

The network and link layers[[3]](#footnote-3) of the reference model accommodate many different real networks, subnetworks, and links with the requirements for bandwidth, multiplexing, security, and other aspects of communication differing from network to network. A given service, e.g. the MAC Service, is often provided by a number of protocols, layered to achieve the desired result. Together the entities that support a particular service access point compose an interface stack.



Figure 1‑4: An interface stack

Figure 1‑4 provides an example, showing the use of Link Aggregation (IEEE Std 802.1AX).

The term *port* is used to refer to the interface stack for a given service access point. Often the interface stack comprises a single protocol entity attached to a single LAN, and port can be conveniently used to refer to several aspects of the interface stack, including the physical interface connector for example. In more complex situations—such as that illustrated in Figure 1‑4, where the parts of the interface stack provided by the IEEE 802.3 MAC entities effectively compose two ports that are then used by link aggregation to provide a single port to its user—the port has to be clearly specified in terms of the particular service access point supported. Port-based network access control secures communication through that service access point.

### Media independent protocols and shims

Some protocols, such as those specified in IEEE Std 802.3, IEEE Std 802.11, and other IEEE 802 standards, are specific to their LAN media or to the way access to that media is controlled. Other protocols and functions within the MAC sublayer, such as link aggregation and bridging, are media independent—thus providing consistent management and interoperability across a range of media.

IEEE 802.1 standards use the term “shim” to refer to a protocol entity that provides the same service to its user as it uses from its provider (see 3.168 of IEEE Std 802.1Q-2011). Shims can be inserted into an interface stack to provide functions such as aggregation (e.g., IEEE Std 802.1AX), security (e.g., IEEE Std 802.1AE), or multiplexing.

### MAC Service clients

The protocol entity that uses the service provided at a MAC Service access point (MSAP) is commonly

referred to as the *client* of the MAC Service or of the entity providing the service. Within a Bridge, the MAC Relay Entity is a client of the Internal Sublayer Service (ISS), and the Logical Link Control (LLC) Entity is a client of the MAC Service. The LLC Entity is described in IEEE Std 802 and provides protocol identification, multiplexing, and demultiplexing to and from a number of clients that use a common MSAP. The clients of LLC are also often referred to as *clients of the MAC*.

### Stations and systems

A LAN station comprises a single media access method specific entity, operating the MAC procedures specified in the applicable IEEE 802 standard, together with other protocol entities mandated by those standards (e.g., an LLC Entity) or commonly used in conjunction with that entity.

A system is a collection of hardware and software components whose intercommunication is not directly externally observable and outside the scope of the IEEE 802 standards that specify the system behavior as a whole. Management of a system, when supported, is typically provided through a single management entity. A system (such as a bridge) can contain many media access method specific entities, of the same or a variety of types, attached to different LANs. A system can therefore be said to include one or more LAN stations.

### Connectionless connectivity and connectivity associations

The MAC Service supported by an IEEE 802 LAN provides connectionless connectivity, i.e., communication between attached stations occurs without explicit prior agreement between service users. The potential connectivity offered by a connectionless service composes a connectivity association that is established prior to the exchange of service primitives between service users (see RFC 787). The way in which such a connectivity association is established depends on the particular protocols and resources that support it, and can be as simple as making a physical attachment to a wire. However simple or complex, the establishment of a connectivity association for connectionless data transfer involves only a two-party interaction between the service user and the service provider (though it can result in exchanges between service providing entities in several systems) and not a three-party user-service-user interaction as is the case for connection-oriented communication. With the continual increase in the number of ways that IEEE 802 LAN connectivity can be supported, it is no longer useful to regard a LAN as a definite set of physical equipment. Instead, a LAN is defined by the connectivity association that exists between a set of MSAPs.[[4]](#footnote-4)

## Overview of IEEE 802 Network Reference Model

The network reference model defines a generic foundation for the description of IEEE 802 access network, which may include multiple network interfaces, multiple network access technologies, and multiple network subscriptions, aimed to unify the support of different interface technologies, enabling shared network control and use of software defined networking (SDN) principles.

It adopts the generic concepts of SDN by splitting the network model into a data plane and a control and management layer with well defined semantics for interfacing with higher layer management, orchestration and analytics functions. Additionally the model deploys a clear separation of functional roles in the operation of access networks to support various deployment models including leveraging wholesale network services for backhaul, network sharing and roaming.



Figure 1‑5: NRM 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 host in the terminal and the access router in the core network as depicted in Figure 1‑5.

For IEEE 802 access network the user data is forwarded 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. At a first glance, the network model for IEEE 802 access network consists of the terminal, the access network comprising the node of attachment and the backhaul, the access router and the subscription service, which provides authentication, authorization, 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.

 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.

## Functional Entities

### Terminal

The terminal is a mobile device which seeks connectivity to a communication infrastructure to get access to communication services. The terminal comprises a terminal interface building the physical port for connectivity and eventually deploys a terminal controller for dealing with particular parameters and configurations conveyed by the control and management interface.

### Access Network

The access network consists of the Node of Attachments providing the physical ports towards the terminals and the Backhaul for connecting the Node of Attachments towards the access router. The access network may deploy a dedicated access network controller for configuration and management of the elements inside the access network as well as exchange of control and management information with both the terminal as well as the access router.

### Access Router

The access router terminates the layer 2 connectivity to the terminal by realizing the anchor for network layer communication towards the terminal side. The access router comprises an access router interface that establishes the physical port of the connectivity towards the access network, and may eventually comprise a dedicated access router controller, that handles and exchanges layer management information and configurations. With a dedicated access router controller the access router becomes a logical functional unit with various implementation options for the controller 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 comprises 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.

### Coordination and Information Service

The coordination and information service in an entity which coordinates the use of common resources and exchange of operational parameters among multiple access networks.

## Basic Network Reference Model



Figure 1‑6: Basic Network Reference Model

Figure 1‑6 presents the Basic Network Reference Model (NRM). 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 four main elements; i) the Terminal (TE), ii) the Access Network (AN) and iii) the Access Router (AR), and iv) the Subscription Service (SS).

As depicted inFigure 1‑6, the TE, the AN, and the AR each comprise a control entity, which is denoted Controller (Ctrl). Each of the three elements has its specific Controller.

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

Note: s are maderegarding 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.

### 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 control interface between terminal and the subscription service, e.g. for authentication.
* **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 controller and the subscription service.
* **R8**: represents the control and management interface between the AN and the TE, which terminates in Access Network Controller and the Terminal Controller, respectively. The functionalities of this reference point are related to the configuration of the physical port in 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.
* **R9:** represents a control and management interface between the access network controller and access router controller.
* **R11:** represents a control interface communicating subscription-specific information between the subscription service and the access router controller.

## Network Reference Model including Coordination and Information Service



Figure 1‑7: 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.

### Reference Points

* **R10**: represents a control and management interface between the Access Network Controller and the CIS.

## Comprehensive Network Reference Model

The Network Reference Model comprises further details of interfaces inside the Access Network.



Figure 1‑8: Network Reference Model

Figure 4: Network Reference Model exposing Access Network details

In Figure 1‑8 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.

### Reference Points

* **R5**: Control-only interface for the configuration and operation of the node of attachment. It includes information elements for the configuration of the R6 port towards the backhaul, the R1 port towards the terminal, and the data forwarding functions inside of the Node of Attachment.
* **R6**: Reference point representing the physical ports between the node of attachment and the backhaul.
* **R7:** This interface is used to control and configure the user plane within the backhaul. The backhaul interconnects the NAs with the Access Router.
1. These points are frequently misunderstood by those unfamiliar with the reference model, who take it as simply restating common sense principles of modular engineering. Early variants of the MAC Service, for example, omitted the source MAC address parameter on the grounds that it was a fixed property of the transmitting station and should be supplied by the MAC entity itself, despite the fact that communicating peer service users (and the protocols they operate) required that information. The introduction of MAC Bridges necessitated the development of a MAC Internal Sublayer Service with the required parameter, and has led to a restatement of the service definition included in a number of standards. However the source address parameter would still have been required even if MAC Bridges did not exist. Similarly versions of the MAC Service have included local acknowledgment primitives or status return codes for primitives issued. These play no part in defining the peer to peer communication and do not conform to the reference model. The scope of some IEEE 802 standards does include the definition of interfaces, particularly electrical interfaces, within systems. These play a valuable role in defining components used to build those systems, but should not be confused with OSI service interfaces. [↑](#footnote-ref-1)
2. This would require considerable enlargement and continuous modification of service interfaces, obscuring their original purpose, not

to mention the creation of many additional interfaces and the addition of “pass-through” functions to others. [↑](#footnote-ref-2)
3. The data link layer, as originally envisaged in the OSI reference model, contained no addressing and caused some involved in its

development to reject the idea of LANs at the link layer. There is a sound argument for regarding LANs as simply subnetworks within

the network layer, and in practice this is how they are treated. However this would have been unpalatable to many more people at a time

when correspondence between LLC (ISO/IEC 8802-2:1998 [B7]) and high-level data link control (HDLC) was sought, together with

the adoption of a unique network layer protocol [ITU-T X.25 (1996)]. Continuing to regard the MAC Sublayer as part of the OSI Data

Link Layer does relatively little harm (except when duplication of network layer functionality is proposed) and is convenient given the

mass of historic documentation. [↑](#footnote-ref-3)
4. A LAN is thus defined in terms of its external observable behavior, not by an abstraction of its internal operation. [↑](#footnote-ref-4)